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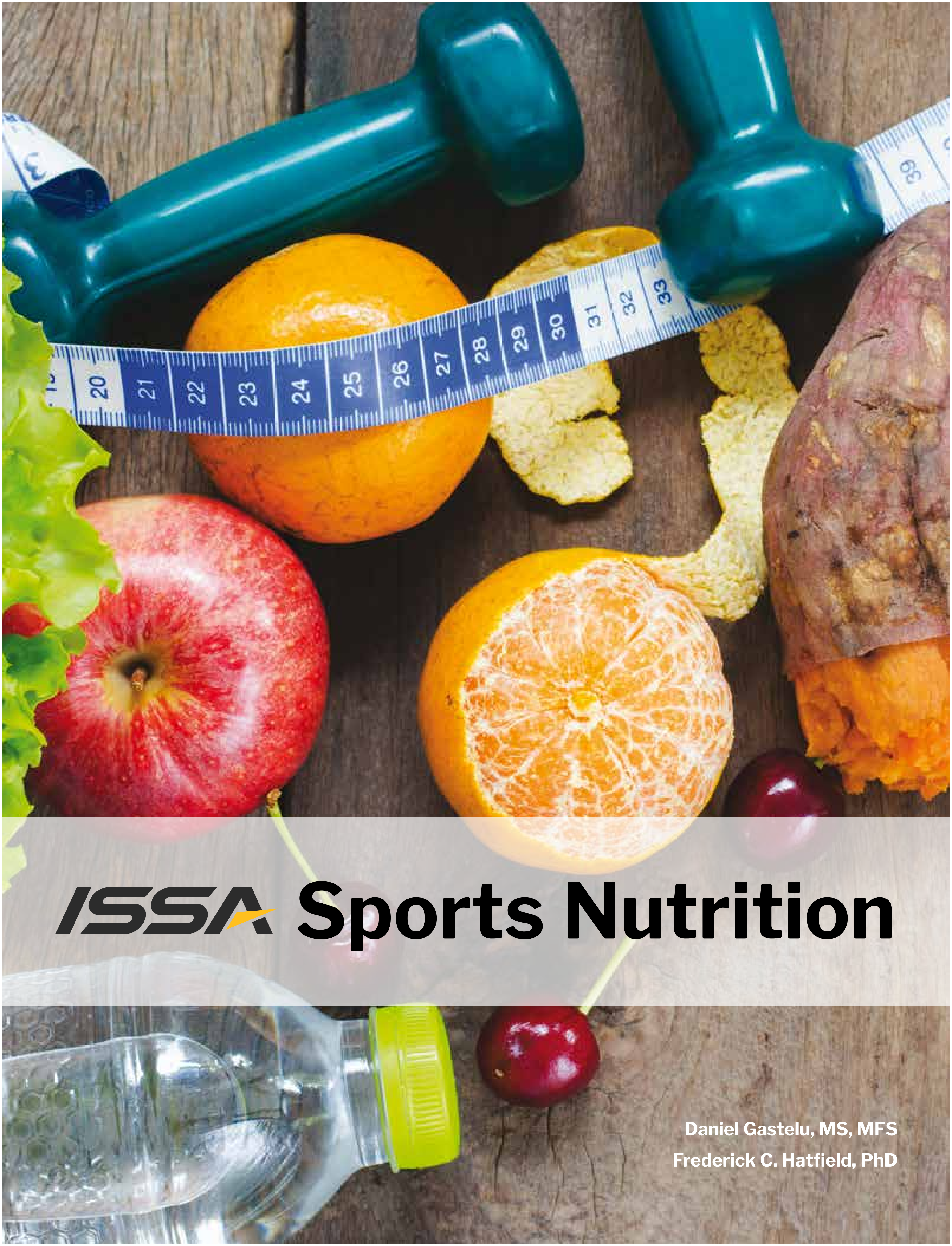
INTERNATIONAL SPORTS SCIENCES ASSOCIATION

Sports Nutrition

Daniel Gastelu, MS, MFS
Frederick C. Hatfield, PhD

Fifth Edition

Course Textbook for **SPECIALIST IN SPORTS NUTRITION**



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Sports Nutrition (Edition 5)

Official course text for: International Sports Sciences Association's Specialist in Sports Nutrition Program

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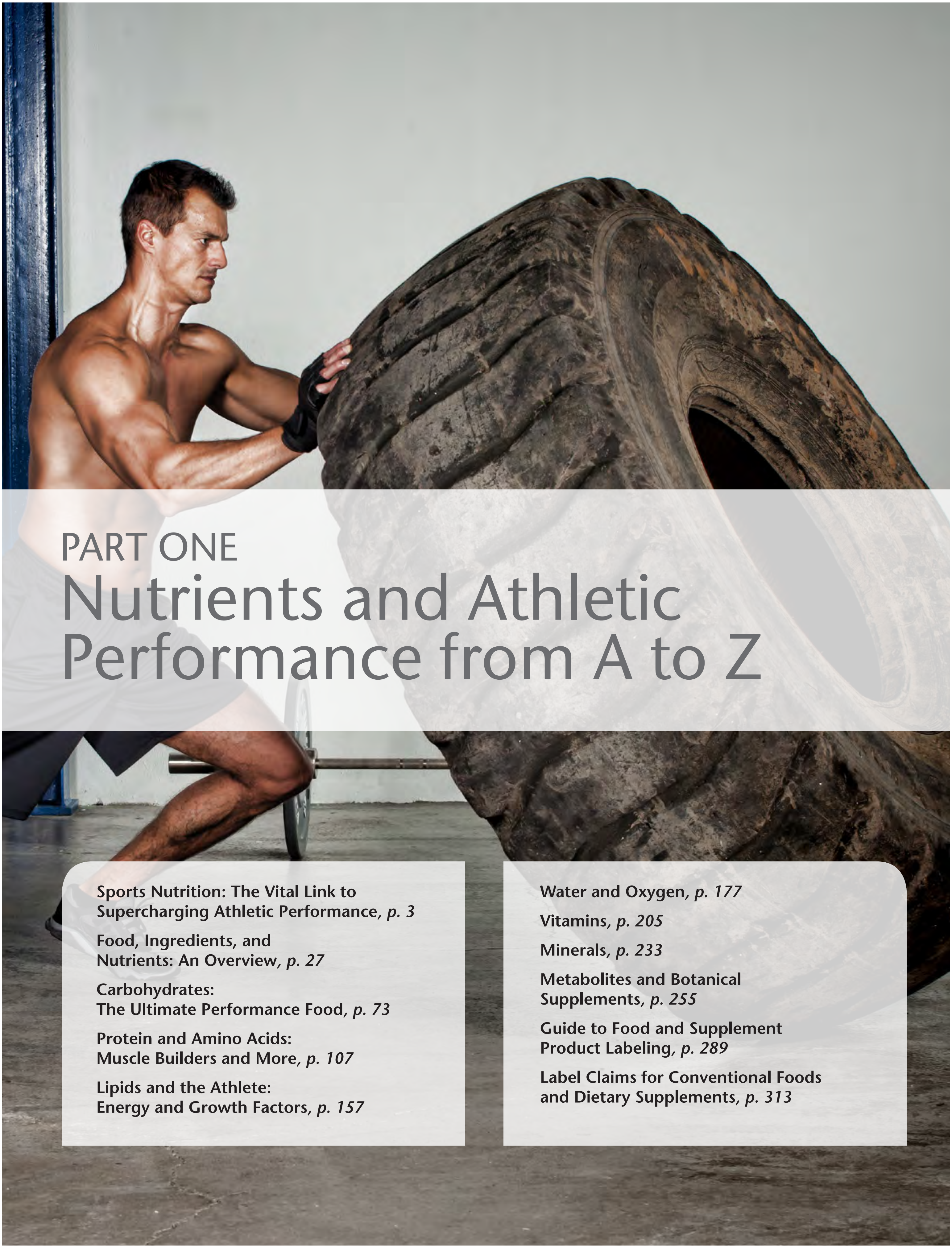

PART ONE
Nutrients and Athletic Performance from A to Z

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Topics Covered In This Unit

UNIT 1

SPORTS NUTRITION: THE VITAL LINK TO SUPERCHARGING ATHLETIC PERFORMANCE

Unit Outline

Learning Objectives

After completing this Unit, you will be able to:

- Understand the basic distinctions between nutrition for survival and nutrition for athletic performance (sports nutrition).
- Determine the pros and cons of the dietary reference value approach.
- Discuss the 3 Es of nutrition.
- Define the essential nutrients.

Introduction

Although it was once thought that nutrition was merely required to survive and be healthy, the most recent research makes it is clear that nutrition can also make people thrive in many ways, including improving athletic performance.

During the recent years of nutrition research, a diversity of information has continued to grow about how nutrients affect the structure and function of the human body, improve health and athletic performance, and even prevent a large

number of nutrition-based diseases—in addition to nutrition's traditional role. Early nutrition research solely focused on identifying which nutrients the human body required to prevent nutrient deficiency diseases, such as scurvy and promote general health. While this remains a central focus of nutrition research, the scope continues to widen to include determining how nutrients can make the human body work better, live longer, and attain peak athletic performance.

With all this new research at hand, and marvelous new discoveries, this updated course book edition has been expanded to include nutrition information focused on athletic performance, but it can also apply for general health and fitness goals, as a feature to his updated edition includes information about the *2015–2020 Dietary Guidelines for Americans,* Eighth Edition. Therefore, this most recent dietary guidelines-based information will add additional insights about how nutrition can help prevent certain diseases along with research-based sports nutrition findings for reaching peak physical performance found in the growing body of sports science research. For example, prevention of diseases such as cardiovascular diseases can be accomplished from eating certain foods every day. The research about how the right nutrition can help prevent cardiovascular diseases, and even certain cancers, is so compelling that the Food and Drug Administration (FDA) approved the use of certain individual and groups of foods for these disease-prevention purposes. Preventing cardiovascular diseases and certain cancers is certainly a goal in anybody's athletic performance and fitness nutrition programs. Learning what foods and dietary supplements are associated with disease prevention (reduced risk) will help focus on which foods to eat more of, versus consumption of the empty calorie or disease-causing unhealthy foods (disease-causing foods to avoid or reduce consumption of). This is especially vital when you consider that athletes typically consume a few to several thousand calories of food per day during the pre-competition and competition seasons.

Innovative Sports Nutrition Course

It is interesting to note that the introduction of this ISSA course during the 1990s was unique in many ways, including being among the first sports nutrition courses to be based in clinical research findings and experience—and a first-of-its-kind comprehensive scientific model, years ahead of what was even being taught in the top universities.

Some of the noteworthy innovative sports nutrition course features include:

- A comprehensive evidence-based model
- Bio-energetic based protein, carbohydrate, and lipid requirements.
- The performance daily intake approach for essential nutrients
- Use of novel ergogenic dietary supplement ingredients such as creatine, carnitine, and coenzyme Q10, to name a few
- Meal timing
- Carbohydrate loading options
- Focus on healthy lipids, such as omega-3 fatty acids
- Use of clinically research based botanicals and other ingredients
- Pre-, during, and post-training nutrition
- Healing and recovery nutrition
- Nutrition for improving mental focus/arousal
- Nutrition for improving tissue healing
- Nutrition for reducing pain/inflammation
- Nutrition for improving **aerobic** and **anaerobic** energy
- Nutrients for getting stronger
- Nutrients for building muscle mass
- Targeted fat loss for athletes
- Use of various sports supplements with clinical evidence

Aerobic: With oxygen.

Anaerobic: Without oxygen.

One of the processes of the scientific process is duplication of research studies to reconfirm the results of other research studies. As the body of sports nutrition science has grown tremendously during the past few decades and continues to grow, this sports nutrition course, and scientific model, continues being refined when new discoveries warrant. Additionally, new research findings often reconfirm old scientific discoveries. For example, the use of sugar- and salt-containing sports drinks, caffeine-containing drinks and supplements, and creatine supplements; and old discoveries but still effective athletic performance sports nutritionals.

Confirmation of what works can even be found in position papers of other organizations. Position papers typically are a works in progress of gathering and reviewing the scientific research evidence, one of the processes first established through this ISSA course and decades of independent work by the authors. For example, here are some of the sports nutrition issues collaborated by independent research reviews:

- Individual athlete energy requirements and body composition analysis
- Diet high in carbohydrates, in relation to protein and lipids
- Types of carbohydrates
- Nutrition practices for daily needs and pre-competition / competition / post-competition
- Meal timing, composition, calories, and frequency
- Protein needs for different types of athletes, all above the dietary guidelines for non-athletes.
- Types of proteins
- The right lipids/fats, and lower calories from lipids/fats
- Hydration guidelines
- Achieving adequate glycogen stores
- Use of certain essential nutrient dietary supplements to prevent nutrient deficiencies
- Use of certain sports foods, such as drinks, bars, gels, electrolytes, protein, meal replacements
- Ergogenic supplements with best scientific evidence, such as, creatine, caffeine, sodium bicarbonate, beta-alanine, nitrate sources (beet root), beta-hydroxy-beta-methylbutyrate (HMB)
- Special concerns regarding weight loss and management for athletes
- Knowledge about the Female Athlete Triad

A Word about Sports Nutrition Supplements and Other Sports Nutrition Products

Students should be aware that including information about sports supplements and other sports nutrition type products is based on what the scientific evidence shows can be useful for athletic performance and health. However, also be aware that it is not a mandate or obligation that you use any particular types of sports nutrition products or ingredients or recommend their use to your clients.

This course is for educational purposes, and each individual must be involved in the ultimate decisions of his or her nutrition program, the food and supplements he or she wishes to consume, from working with a personal expert support team—one ideally supervised by the team and/or personal physician, in addition to other health professionals such as fitness trainers. This will help provide some assurances as to the suitability of individualized sports nutrition programs and also help check for substances

that may be of concern from a sports governing organization rules standpoint, concerning avoiding banned substances and practices. This point is made at the onset of your course work due to occasionally having some students make comments about the evidence-based sports nutrition type products or ingredients contained herein. To clarify, the authors and ISSA remain neutral regarding your use of the information contained in the course materials.

United States and Canada

As you will soon be learning in a following section of this unit regarding dietary reference intakes, the United States and Canada worked closely in this major undertaking to update essential nutrition science and national guidelines. Additionally, regarding food and dietary supplement heath products, the United States and Canada also work closely. While the conventional food laws of the two countries are similar, the dietary supplement laws have some differences that will be elaborated on in subsequent units. But at this point in your reading, you may be interested to know that with the Canadian process, dietary supplements, including most sports nutrition supplements ingredients and claims, are reviewed, approved, and licensed before being allowed to enter the Canadian market. Also of interest is that Health Canada develops, approves, and maintains ingredient monographs for many of the ingredients used in supplement type products, referred to as Natural Health Products in Canada.

The point? With the Canadian process, controversy is eliminated through product licensing, with the highest level of credibility being attained. Most of the same ingredients that are used in Canada's natural health products are also being used in US dietary supplement products, including sports supplements. These Canadian-approved ingredients and claims will be noted in subsequent units. Therefore, while a level of nonsense (non-science) is encountered in the United States over these issues by the non-experts (typically in the uninformed media), paradoxically, the same ingredients and claims are approved in Canada and in other countries.

Dietary Reference Values

There has been much progress in the United States and other countries to determine nutrition requirements for promoting health and disease prevention/reduction related to nutrition. The limitations of the approached used are acknowledged by the groups of experts involved in creating the massive research reports. For example, the **Dietary Reference Intake** series of reports, by the IOM (Institutes of Medicine) is several thousand pages, published in several volumes, noted in a following section of this unit. These and other similar publications typically state that the nutrient amounts, such as the RDA, are not intended individual intakes—that for each person, a goal of planning nutrient intakes for individuals is to achieve nutrition intakes that work best for them but are safe and do not exceed upper limit amounts that could cause adverse health effects. So ranges of intakes for nutrients sets lower and upper limit boundaries, in which a particular person's requirements may fall within. Noting that a person's nutrient requirements can be changing, based on physical activity, state of health, special requirements, and life stage.

Dietary Reference Intakes (DRIs): DRIs are dietary reference values for the intake of nutrients and food components by Americans and Canadians.

For students who are new to the IOM's Dietary Reference Intake report series, a good one to start with is the *Dietary Reference Intakes: The Essential Guide to Nutrient Requirements (2006)*. This is an overview of the previous thousands of pages of DRI reports and consolidates the various macronutrient and micronutrient topics in one publication. Electronic copies are available online free, and on the National Academy of Sciences website, and may be located for download at the USDA's website. A list of these reports is presented in a following section of this unit.

Athletic Perfection from Imperfection

Something to be aware of is that one distinction of sports nutrition versus general nutrition is that nutrition programs for athletes become highly customized and quantified. This takes plenty of work, typically a team effort, and constant fine-tuning during the various athletic periods of the year, relating nutrition intake to athletic performance outcomes; the best types of foods and supplements; body composition goals; and measures of health. Therefore, while striving for athletic performance perfection, a challenge is dealing with dietary, body composition, caloric intake, and other measurements that are not perfect. For example, nutrient and caloric content of foods can be plus or minus 10 to 20 percent, or more, especially when dealing with whole foods. The nutrient content of food reference tables and databases also has a wide margin of variability. In addition, the methods for determining body composition and caloric intake requirements are also variable. Then, there is also variability in the dietary reference intakes and other reference values to contend with. Dealing with this variability is similar to dealing with the athletes' variable response to physical training approaches. But once the nutrition and training variability is mastered, athlete's will gain a major sports performance advantage compared to athletes that are not undergoing the same levels of nutrition and training program sophistication.

Dealing with nutrition variability also provides insights why particular athletes or teams may seem to have a characteristic selection of foods and supplements, usually not that diversified. Typically, this is due to a combination of factors such as being more reliable sources of the nutrients and calories with less variation, affordability, preparation, availability, and good athlete compatibility in terms of digestibility, utilization, and good tolerance.

The Dynamic Nutrition Approach

Because the authors' personal athletic quests have always been to attain peak athletic performance to excel in sports, nutrition became a point of focus early in our lives when aspiring to be champion athletes. During this quest for athletic training and nutrition knowledge, we reviewed almost every textbook and research study on nutrition that was available, the meager chapters about nutrition for athletes usually found in athletic training guides and books, and a variety of directed research studies and case studies.

During this research and development episode, it became apparent that on the surface there were seemingly many ways to achieve the same result. In fact, until the first edition of this course book, there were no texts dedicated to sports nutrition that had a scientific basis, which is the point we would like to underscore. Our pioneering spirits and determination led us to applying the scientific approach to sports nutrition. The Dynamic Nutrition Approach (coined by coauthor Daniel Gastelu) is therefore a comprehensive scientific approach that was based on the intricacies of how the essential nutrients and other beneficial substances cause the human body to work best overall and under conditions of exercise, athletic training, and athletic competition.

As you will soon discover, the Dynamic Nutrition Approach model to sports nutrition has stood the test of time. Subsequent independent scientific research continues to confirm what this model already includes. For example, while scientists debated whether athletes in general needed more protein then nonathletes did, the Dynamic Nutrition Approach model not only acknowledged that athletes need more protein than nonathletes, it also noted that different types of athletes require different amounts of protein. Turning attention to fat loss and weight maintenance, it was coauthor Dr. Hatfield who developed the

ZIGZAG diet approach in the 1970s, which has become part of this course. Since then, the ZIGZAG approach had been written about in numerous publications. Independent researchers and authors have even claimed that it as a medical breakthrough of the 21st century.

The Dynamic Nutrition Approach to sports nutrition also focuses on providing health-promoting guidelines in addition to athletic performance enhancing guidelines. It is also dynamic regarding the evolving flow of information, retaining the time tested and reconfirmed nutrition sciences, with room for allowing in new discoveries and sometimes replacing old effective technologies with new, more effective ones.

Origins of Sports Nutrition

When we look through human history, the search for performance enhancing foods is clearly evident and dates back several thousand years before even the earliest civilizations had risen. It is thought that in these primitive times the early humans searched for foods that increased strength and performance to be better hunters and win wars, not races. History is filled with tales of warriors who ate and drank various foods to boost their combat prowess. There are even gruesome accounts of victors eating the hearts of their opponents to capture the spirit of their strength.

What these early competitors realized in their own crude way was that nutrition is an important factor of physical performance. Just as most cultures have a variety of potions to boost sexual performance, they also have their traditional foods and rituals for increasing athletic performance. Nevertheless, aside from these many anecdotal accounts of ancient nutrition practices, it is in the home of the Olympics that we find the first legitimate documented attempt to improve sports performance through nutrition. Historians estimate the time and place around 450 BC in Greece. It was here that Dromeus of Stymphalus is credited with adopting special nutrition practices for the improvement of athletic performance. Most noteworthy of these practices was the consumption of large amounts of meat to improve muscular strength. Many athletes continue to eat high-protein diets for increased performance in various sports.

Keeping with the tradition of emulating what athletes do to be their best has shaped the way we approach fitness nutrition, too. When you eat correctly for peak physical performance, peak fitness will result as well. It is just a matter of extent. A person engaged in a competitive sport will follow a more precise and demanding nutrition and supplement program than will the individual who exercises for general health and fitness reasons. Historically, people also sought to be the healthiest (fittest) they could be through nutrition for some important reasons. First, ancient humans needed a fit body to survive the primitive times. If you were not strong and fit, you probably were not going to survive. Then there was the matter of not getting sick or developing degenerative diseases. “Let food be your medicine, let medicine be your food” was the health mantra of the day. It is interesting to note that the most ancient texts include food laws and eating guidelines. More interesting is that modern science has confirmed that this ancient whole-food eating approach is also a healthy way to eat even in modern times. The nutrition-disease connection is increasingly apparent. As such, it makes perfect sense to eat foods every day that make you healthy and prevent disease and to avoid eating foods that may lead to causing disease and to eschew a poor diet that makes the body weak and malfunction—making you more susceptible to contracting infectious diseases or developing degenerative diseases.

Modern Science Discovers How Nutrition Improves Human Athletic Performance

We now know much more about how nutrition affects athletic performance, and we reserve higher than normal protein diets for special times and fine-tuned for certain groups of athletic individuals, such as strength athletes versus endurance athletes. Furthermore, athletic individuals must be using all aspects of nutrition correctly. There is no single food solution that will increase athletic performance and health. The misconception of the "magic food solution" is the reason there are so many nutrition myths and such tremendous controversy within the field of sports and fitness nutrition. Nutrition for athletics and health is an involved science, and many factors must be considered to achieve optimum results.

When you think of the high-tech society we live in today, it is hard to believe that it was only a few decades ago that the practice of carbohydrate loading and intake of carbohydrates during athletic events began. Many of you may still remember the days when marathon runners experienced the phenomena of "hitting the wall" at the end of the race when they depleted their body's store of carbohydrates and were running primarily on stored body fat. By simply ingesting a carbohydrate drink during the race, marathoners could increase their speed and avoid hitting the wall.

We know much more today about improving athletic performance and fitness with nutrition than our predecessors could have ever imagined. The past decades have yielded thousands of studies about how nutrients and nutrition practices can improve athletic performance, fitness, and health. Still, people succumb to misguided information spread around the locker room, in magazines and the internet. Usually younger do-it-yourself athletes are at greatest risk for misinformation. Performance athletes require nutrition and training programs specific to excel in their sport.

Additionally, surprising recent scientific surveys reveal that the majority of athletes, coaches, trainers, and other professionals tending to the sports person do not have a working knowledge of what constitutes a good sports/fitness nutrition program. This is why many people continually resort to ridiculous nutrition practices and may end up turning to snake oils or even illegal drugs in an attempt to compensate for poor nutrition and training approaches. This ignorance is not only dangerous but also counterproductive.

Also, every athletic person has experienced directly or indirectly the need to lose weight for sports like wrestling, football, and gymnastics or to be healthier and look their best. In fact, losing weight has grown into multibillion-dollar-a-year industry. However, do you think that the common methods for losing weight like starving, taking laxatives, engaging in nutritionally unbalanced fad diets, and spitting or sweating off the weight are healthy or effective methods? Of course not!

The New Age of Sports Nutrition

Now is the time to exit the dark ages of hit-or-miss performance nutrition and enter into the scientifically based renaissance of high-tech performance nutrition for athletes. This text is written for every fitness trainer, strength coach, athletic trainer, other health professionals, athletes, and even athletic exercisers. The rest of this unit will provide some general background information about the evolution of nutrition, building up to sports nutrition.

Nutrition Defined

Defining nutrition seems to be an appropriate starting point, so here we go. **Nutrition** is the process of eating and converting food into structural and functional body compounds like skin, muscle, and hair. Nutrition is required for energy production, growth, maintenance of bodily functions, repair of body tissues, physical performance, and promotion of good health. Different parts of the body need special nutrients to function properly. For example, your nervous system has different nutritional needs than your muscles have. These differences must be considered to make the whole body perform at its best.

Nutrition: the process of the body using food to sustain life.

On the surface, getting the nutrition you need seems easy enough. After all, everyone eats something every day. But recent government reports have concluded that the vast majority of Americans eat too much of the wrong things (such as saturated fats, sodium and sugar) and not enough of the good stuff (like whole-food complex carbohydrates, lean meats, vegetables. and fruits). It is unbelievable how many athletic people eat frequently at fast food restaurants, consume large amounts of snack foods, and believe that they are on health sports nutrition diets. In truth, they are on high-fat, high-sodium diets that are low in essential nutrients.

Nonessential Doesn’t Mean Unimportant

Traditionally, the term “essential nutrient” refers to a nutrient that the body cannot make at all or cannot make in sufficient amounts to maintain good health. Scientists have discovered over 40 nutrients that fit into this category. They include the carbohydrate glucose, certain amino acids from protein, certain fatty acids (linolenic acid), thirteen vitamins, and seventeen minerals.

The term “non-essential” nutrient is terribly misleading and includes all the other nutrients that are not considered essential. When you are eating for maximum performance and health, the non-essential nutrients can be just as important as the essentials. For example, by eating a full profile protein that contains both non-essential and essential amino acids, your body will get the amino acids it needs more quickly, as it will not have to spend time making the non-essentials from the essentials. For maximum performance and health, eating the right proportions and amounts of both essential and non-essential nutrients is important. Plus, there are other performance factors like herbs, metabolites (creatine, choline, inosine, L-carnitine), and phytochemicals that are not essential for survival, but are essential for improved performance. In fact, the FDA recently declared that Choline is an essential nutrient, and established intake standards. Also recently, the benefits of carnitine were acknowledged by the federal government, and carnitine is now begin referred to as a semi-essential or conditionally essential nutrient.

The problems of poor nutrition are highly complex but originate from the simple fact that most people and the people preparing our meals learned about nutrition way back in grade school, years ago. What was taught then and even today has nothing to do with nutrition for athletes, and barely provides a good nutrition program for the non-athlete to follow. The basic guidelines that you remember probably use the food group approach to good nutrition. This includes eating a balanced diet consisting of foods from the following groups:

1. Fruits and Vegetables
2. Meat, Poultry, Fish
3. Dairy
4. Breads and Cereals

In theory, this food group approach should work. In practice, we are a nation suffering from fatal diseases due to poor nutrition. A qualitative approach to nutrition does not deal in exact amounts of nutrients for each individual; nor does it compensate for the special needs of athletes. It only recommends eating several servings of different foods each day. Additionally, you cannot be certain that the food you eat will provide reliable nutrition. Scientists have determined that the nutrition content of most foods will vary greatly depending upon where it is grown. This means that the potato you buy from Maine may have different amounts of vitamins and minerals then the one grown in Idaho. Many studies report about how athletic people are deficient in important minerals and vitamins; they are simply not eating right.

Nutrition, especially sports nutrition, is has become a quantitative science. While the nonathlete may survive day to day by following general guidelines, the athletic persons needs a more sophisticated and precise approach to nutrition to achieve performance and fitness excellence. This means a 150-pound female swimmer eats differently from a 250-pound shot-putter, for example.

Billions of people eat and live every day. The food supply is quite varied all over the world, and so is health. Most of us associate a well-fed person with a healthy person. However, millions of people die each year from diet-borne diseases caused by eating too much of the wrong fats and not enough of the essential nutrients. Athletic persons must do more than just eat and live. They must operate at an optimum level of performance and fitness. For this reason, the athletic persons must always maintain a special performance nutrition program. The average athlete's diet consists of two to three or more times the amount of daily caloric intake than that of a nonathlete. Typically, a competitive athlete consumes a few to several thousand calories per day. At these high levels of food intake, an athlete had better make sure to eat the right foods. The same is true for fitness individuals. While their total nutrition intake will be less than that of a competitive athlete, what they eat needs to be both performance enhancing and healthy.

The Three Es of Nutrition

The following will present a picture of the different levels of nutrition commonly practiced and will shed new light on the reasons someone's nutrition program may be incomplete. There are three general categories of nutrition approached practiced today, excluding clinical nutrition for disease treatment:

- Essential Nutrition for Survival and Basic Health
- Essential Nutrition for Optimum Health
- Essential Nutrition for Athletic Performance

Essential Nutrition for Survival and Basic Health

Most of the diets eaten by the general population fit into the "Essential Nutrition for Survival and Basic Health" category. This category is based on the United States government standard you have heard so much about; the RDA (recommended dietary allowances). The RDAs were first established in 1943 to serve as a goal for good nutrition. It was recognized that nutrition goals must be established and met to propagate good health on a national basis. Every several years, the National Research Council publishes a new, updated edition of the RDAs to reflect the best scientific judgment on nutrient allowances for good health. The RDAs also serve as the basis for evaluating the adequacy of diets for specific groups of people. This data baseline is a particularly useful reference point for health practitioners.

However, many progressive health practitioners claim that the RDAs are not adequate for the best health. New and evolving research is demonstrating how eating more of certain nutrients can help improve and protect health. For example, research shows that taking certain nutrients in amounts more than the RDA recommends can reduce the risk of certain diseases. This recent shift away from the strict RDA approach to nutrition is founded on a health-driven philosophy of achieving optimum nutrition. The RDAs, and other similar government nutrition standards found worldwide, are primarily concerned with preventing diseases that result from essential nutrient deficiencies like scurvy from the lack of vitamin C.

These government-based guidelines are not aimed at achieving optimum health. In fact, most of the RDA values are based on the average nutrient intakes of our entire population. For this approach to be valid, it must be assumed that everyone is eating a healthy diet and that everyone's nutrition requirements are the same. But, as mentioned earlier, the National Research Council has determined that the majority of people are eating poor diets. In fact, the typical American diet is responsible for causing diseases and the deaths of millions of people each year. Thus you see right from the start that the RDA system is not meant to promote optimum health. A short run through the RDA story will demonstrate this point.

To begin with, the following nine nutrients were the only ones with RDAs first established by 1963.

1. Protein
2. Vitamin A
3. Vitamin D
4. Vitamin C
5. Thiamin
6. Riboflavin
7. Niacin
8. Calcium
9. Iron

The Essential Nutrients: Nutrients that the body cannot make at all or in insufficient amounts to maintain good health			
Carbohydrate: As a source of Glucose			
Fat: As a source of Linoleic Acid and Linolenic Acid			
Protein: As sources of essential amino acids			
Histidine	Isoleucine	Leucine	Lysine
Methionine plus Cystine	Phenyalanine	Tyrosine	Threonine
Tryptophan	Valine		
Minerals:			
Calcium	Phosphorus	Sodium	Potassium
Chloride	Magnesium	Sulfur	Iron
Iodide	Zinc	Copper	Manganese
Cobalt	Fluoride	Selenium	Chromium
Molybdenum			
Vitamins:			
Vitamin A	Vitamin D	Vitamin E	Vitamin K
Thiamin (B1)	Riboflavin (B2)	Niacin (B3)	Pyridoxine (B6)
Cobalamin (B12)	Ascorbic Acid (C)	Folic Acid	Biotin
Pantothenic Acid (B6)	Choline	Inositol	
Other essential nutrients to be discovered?			

Now turn your attention to the list of more than two dozen nutrients that has grown to be essential enough to have values: Protein, Vitamin A, Vitamin D, Vitamin E, Vitamin K, Vitamin C, Thiamin, Riboflavin, Niacin, Vitamin B6, Folate, Vitamin B12, Calcium, Phosphorus, Magnesium, Iron, Zinc, Iodine and Selenium, Biotin, Choline, Pantothenic Acid, Copper, Manganese, Fluoride, Chromium and Molybdenum, and macronutrients too.

Dietary Reference Intakes

Since the writing of the previous editions of this course book, another set of standards was introduced called DRI's (Dietary Reference Intakes). However, this system provides no reliable assurance that people are getting the nutrition needed for optimum health and certainly has limitations for athletes. This is why essential nutrient dietary supplements can be important to include as part of an athlete's sports nutrition program in addition to other dietary supplements for special athletic performance uses. In the new DRI system, it was recognized more than ever that although nutrient requirement data on the population level are important, better determining the nutrition requirements of the individual is even more important, including how nutrition requirements change during the different stages of life.

As noted in one of the DRI reports, the DRI values replace the former Recommended Dietary Allowances (RDAs) for the United States and Recommended Nutrient Intakes (RNIs) for

Canada. In the past, RDAs and RNIs were the primary values available to US and Canadian health professionals for planning and assessing the diets of individuals and groups. The DRIs represent a more complete set of values. They were developed in recognition of the growing and diverse uses of quantitative reference values and the availability of more sophisticated approaches for dietary planning and assessment purposes. However, as with the previous RDA system, it is noted, "The Dietary Reference Intakes (DRIs) are developed and published by the Institute of Medicine (IOM). The DRIs represent the most current scientific knowledge on nutrient needs of healthy populations. Please note that individual requirements may be higher or lower than the DRIs."

Dietary Reference Intakes Reports by the Food and Nutrition Board, Institute of Medicine, National Academy of Sciences
Dietary Reference Intakes for Vitamin D and Calcium (2011).
Dietary Reference Intakes: The Essential Guide to Nutrient Requirements (2006).
Dietary Reference Intakes for Energy, Carbohydrate, Fiber, Fat, Fatty Acids, Cholesterol, Protein, and Amino Acids (Macronutrients) (2005).
Dietary Reference Intakes for Water, Potassium, Sodium, Chloride, and Sulfate (2004).
Dietary Reference Intakes for Vitamin A, Vitamin K, Arsenic, Boron, Chromium, Copper, Iodine, Iron, Manganese, Molybdenum, Nickel, Silicon, Vanadium, and Zinc (2001).
Dietary Reference Intakes for Vitamin C, Vitamin E, Selenium, and Carotenoids (2000).
Dietary Reference Intakes for Thiamin, Riboflavin, Niacin, Vitamin B6, Folate, Vitamin B12, Pantothenic Acid, Biotin, and Choline (1998).
Dietary Reference Intakes for Calcium, Phosphorus, Magnesium, Vitamin D, and Fluoride (1997).
Meeting Summary: IOM DRI Chronic Disease Indicators Planning Meeting (2009).
Background Paper: Framework for DRI Development (2008).
The Development of DRIs, 1994–2004: Lessons Learned and New Challenges. Workshop Summary (2007).
Dietary Reference Intakes: A Risk Assessment Model for Establishing Upper Intake Levels for Nutrients (1998).
How Should the Recommended Dietary Allowances be Revised? (1994).
[Source: http://fnic.nal.usda.gov/dietary-guidance/dietary-reference-intakes/dri-nutrient-reports]

Dietary Reference Intake terminology

Here is some of the terminology used in relationship to the Dietary Reference Intakes and reports:

- **Dietary Reference Intakes (DRIs):** are dietary reference values for the intake of nutrients and food components by Americans and Canadians.
- **Estimated Average Requirement (EAR):** The average daily nutrient intake level that is estimated to meet the requirements of half of the healthy individuals in a particular life stage and gender group.
- **Recommended Dietary Allowance (RDA):** The average daily dietary nutrient intake level that is sufficient to meet the nutrient requirements of nearly all (97–98 percent) healthy individuals in a particular life stage and gender group.
- **Adequate Intake (AI):** The recommended average daily intake level based on observed or experimentally determined approximations or estimates of nutrient intake by a group (or groups) of apparently healthy people that are assumed to be adequate; used when an RDA cannot be determined.
- **Tolerable Upper Intake Level (UL):** The highest average daily nutrient intake level that is likely to pose no risk of adverse health effects to almost all individuals in the general population. As intake increases above the UL, the potential risk of adverse effects may increase.
- **Acceptable Macronutrient Distribution Range (AMDR):** An AMDR is the range of intakes of an energy source that is associated with a reduced risk of chronic disease, yet can provide adequate amounts of essential nutrients. The AMDR is expressed as a percentage of total energy intake. A principal feature of each AMDR is that it has a lower and upper boundary. For example, the AMDR for carbohydrates ranges from 45 to 65 percent of total energy intake. Intakes that fall below or above this range increase the potential for an elevated risk of chronic diseases. Intakes outside of the range also raise the risk of inadequate consumption of essential nutrients.

Subsequent units will elaborate about the Dietary Reference Intakes as they pertain to the unit's specific topics. But also note that there is additional terminology for food and supplement labeling, presented in Unit 10. This related labeling terminology includes:

- Daily Reference Value (DRV)
- Reference Daily Intake (RDI)
- Daily Value (DV)

Essential Nutrition for Optimum Health (The ODAs)

As discussed above, the early focus of the government and many nutrition professionals who follow the government's nutrient intake standards is providing nutrition that provides a minimum amount of the essential nutrients to prevent nutrient deficiencies. The focus is not necessarily to achieve optimum nutrition. Furthermore, there is no emphasis put on the "non-essential" nutrients. Thanks to the developing health industry, however, the past few decades have fostered a nutrition revolution that promotes a diet that is rich in all nutrients, in greater amounts than previously recommended. Finally, we are looking at an integrated nutrition approach.

Progressive nutritionists like Shari Lieberman, PhD, author of *The Real Vitamin & Mineral Book*, tells us that the body needs more nutrients in higher amounts for optimum health than the RDAs recommend for optimum health. Dr. Lieberman is one of the nutritional pioneers who coined the term ODA (Optimum Daily Allowance) to indicate that we require higher amounts of vitamins and minerals than those identified in the RDAs and more of the nonessential nutrients and herbal factors as well.

There are many reasons for this greater need, including that our bodies are faced with warding off a host of environmental stresses, such as air pollution, poor quality or contaminated drinking water, pesticides, additives, and other non-nutritive toxins. Furthermore, our food supply does not provide the proper amounts of nutrients for optimum health. Research is finding new uses for nutrients besides their role in basic survival. For example, a group of vitamin and mineral nutrients called the antioxidants has been found to protect the body from the wear and tear caused by free radicals.

Free radicals are formed naturally in the body, and higher amounts of free radicals are caused by increased physical activity, exposure sunlight, and exposure to everyday chemicals. This means that athletic people need to reduce the amount of free radical damage to their bodies by taking nutrients with antioxidant activity. This will stimulate quicker recovery and more rapid movements in performance. As it turns out, although some of the essential nutrients, like vitamins E and C are important antioxidants, the most recent research has determined that it is groups of chemicals from plants that are turning out to be even more potent and important antioxidants. In recent DRI Reports, it seems that the ODA approach is now being acknowledged, in particular when presenting information related to individual nutrition programs, with essential nutrient intake being between the lower limit and below the ULs.

Essential Nutrition for Athletic Performance

Essential nutrition for athletic performance is the most recent advancement in the field of nutrition. Sports and fitness scientists make new discoveries daily, uncovering the intimate connection between nutrition, athletic performance, and fitness. Eating for maximum athletic performance includes eating foods for maintenance of optimum health plus extra nutrients to achieve peak athletic performance and to compensate for the increased caloric and essential nutrient requirements associated with athletic training and competition. Peak athletic performance includes being your best 24 hours a day. This means having the energy to sustain workouts or competitions along with the proper nutrition for recovery and rest and superior health.

Performance Daily Intakes (The PDIs™)

The PDIs provide a set of guidelines based on the science of nutrition, sports nutrition, and fitness nutrition. These guidelines provide safe and efficacious nutrition information based on research and a vast review of the reference publications on nutrition. (Note that the original edition of this course book used the term "Performance Daily Allowance," and this has been changed to keep in pace with the new recent RDI terminology.)

The PDIs for each nutrient should be obtained from a total nutrition plan, consisting of both food and supplement sources taken together. In most cases, the lower limit of the PDI range is equal to or higher than the RDA/RDI/DRI values are. Therefore you can expect that food sources alone will not provide or will just barely provide the lower amount of the PDI range. To ensure that adequate levels of nutrients are maintained each day, you may need to use dietary supplements.

The PDI ranges for each nutrient reflect the different needs of individuals based on their size and activity level. Smaller or less active individuals therefore target their nutrient intake at the lower end of the range, whereas larger and more active individuals follow intake levels on the upper end of the range. Always consult the specific detailed sections on each nutrient for comprehensive guidelines and information about each nutrient. Also note that supervision of a physician is always required, and testing the athlete's blood levels of the essential nutrients, and other biomarkers would be the ideal approach to fine-tune food and supplement intake.

The PDI summary chart for vitamins and minerals is presented in Units 7 and 8, which also contain other reference values for comparison. Note that too often individuals take too much of a few supplements and not enough of many of the essential vitamins and minerals. Remember, all are important, and there is no magic pill.

When using the PDI guidelines, keep in mind that they:

- are intended for athletes and healthy, physically active adults;
- are dynamic and consider a wide range of needs, activity levels, and size of athletic individuals;
- are for both men and women;
- compensate for the higher nutrition requirements that athletes and physically active people have when compared with nonathletes;
- are for working with physician and other applicable health professional supervision.

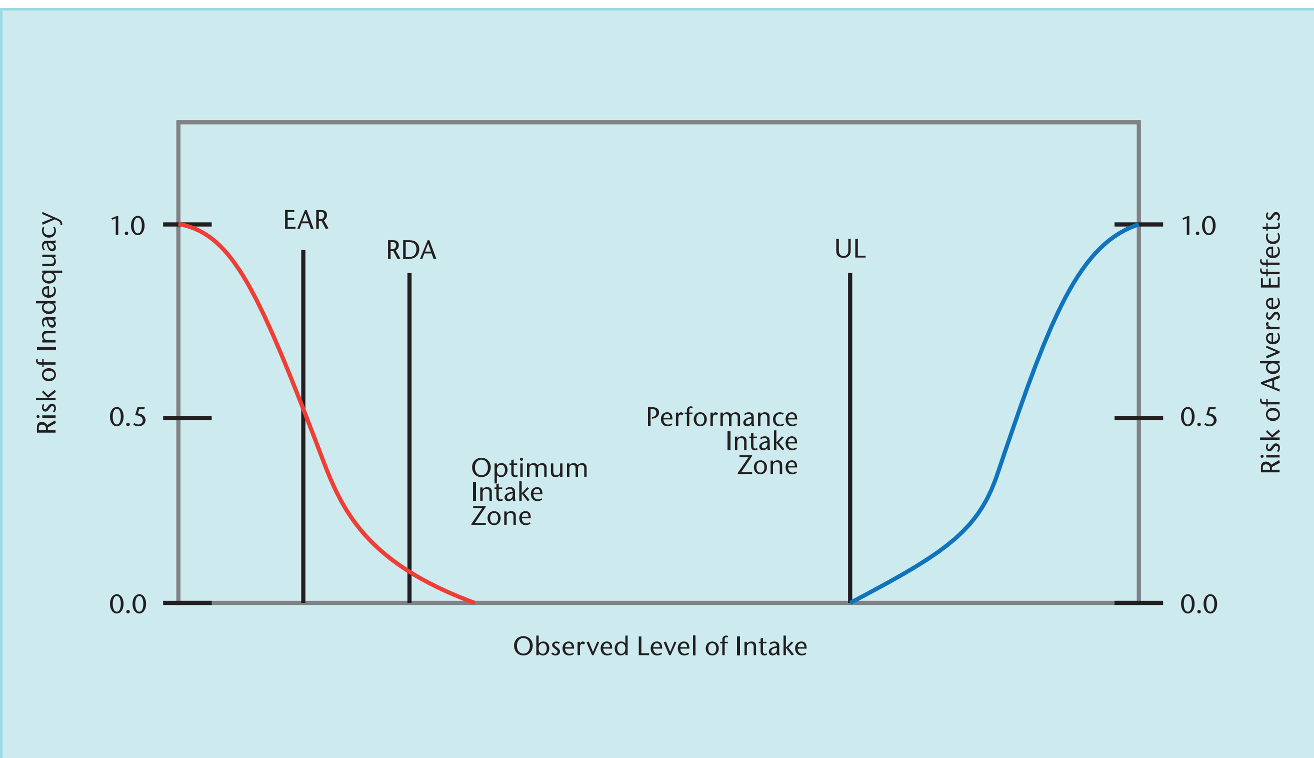
We now know that for peak performance and fitness, you must consume certain foods before and after exercise to yield optimum results. Breakfast will be different from dinner. Meals will vary from day to day depending on your activity level. The powerlifter will eat differently than the basketball player does. The proportions of carbohydrates, protein, fat, and cofactors must match the metabolic needs all day long to achieve peak performance. This requires knowledge about unique individual metabolic demands. Body type, type of sport or fitness program, training, activity level, and body composition all determine what custom fuel mix is required. Meal timing and nutrient composition is also important to achieve optimum performance and fitness nutrition.

Effectiveness and Safety

Regarding the nutrients themselves found in food and supplements, there are dietary intake issues based on both sides of the dietary intake equation; inadequate consumption (not enough) and overconsumption (too much). In general, foods and supplements have an excellent safety record. When you review effectiveness and safety issues, the point is to establish a performance-enhancing range of effective intake for nutrients and related substances so that you will ingest enough to make a positive difference, but not excessive amounts that might not provide any extra benefits or may possibly develop rare, but unwanted side effects from this overconsumption.

This phenomenon may be new to some people, one in which an essential nutrient is vital to life, but can potentially cause adverse side effects if consumed in excessive amounts or inadequate amounts. As the following reference chart below illustrates, when nutrient intake levels are low (to the left), nutrient deficiency diseases or conditions can develop. When nutrient intake is too high (to the right), the risk of potential nutrient overconsumption-related side effects may occur.

Theoretically, the nutrient intake zone between the lowest level and the highest level is the optimum health zone and athletic performance intake zone. However, for whatever reason, the "authorities" establish nutrient intake standards at the lowest level of intake—even below the level at which inadequate nutrient intake is estimated to occur, the EAR and RDA values are actually in the risk of inadequacy area, as seen in the illustration.



Technically, the UL is an estimated upper value of intake representing the point at which is the highest level of daily nutrient intake that is likely to pose no risk of adverse health effects to almost all individuals in the general population. At intakes above the UL, the risk of adverse effects may increase. This is because these are general guidelines are used for health planning at the national level. It is recognized that individuals, or groups of individuals with special dietary needs, such as athletes, will have different nutrient intake needs and sensitivities. The activity level of an individual, his or her size, and the nutrient status will all factor in when determining the optimum range of intake for nutrients. It is also interesting to note that just in 1997, the UL began to be published, and for some of the essential nutrients, no ULs could be established because there was no research that supported any adverse effects.

Thus while the “authority” adopted system is useful for general nutrition intake purposes, the DRI guidelines and nutrient intakes may be too low, or inadequate for athletes, especially for larger and more active athletes and particularly during training and competition periods. Additionally, dietary intake surveys conducted among athletes consistently report about how most athletes’ diets are deficient in one or more of the essential vitamins and minerals. When a person is deficient in a nutrient, he or she sometimes must ingest amounts of the nutrient in large amounts to overcome and correct the nutrient deficiency. This underscores the importance of working under the supervision of a health professional—to determine the exact needs of an individual and to monitor his or her health when self-prescribed nutrition and training programs are being used.

Healthy Adults

Note that any nutrition examples contained in the units and other course materials could apply to healthy adults, based on their individual requirements, as determined by their physicians and or qualified health professionals. This information does not apply to everybody the same way, or it does not apply to children or teenagers or to older adults. The information contained in the units therefore is intended to provide an understanding of the various nutrients and other dietary substances and to provide a framework for reference purposes. Creating personalized sports nutrition programs for athletes will depend on many factors, including legal aspects, such as any professional health practitioner licensing requirements; years of experience, training, education, and other required skills; and working as part of a heath professional team, including physicians.

Nutrition Intake Approaches

Ways of determining nutrition intake approaches are also evolving. For example, for some nutrients, an approach may be to establish one fixed value per day, such as 60 milligrams per day for adult males; or on a gram per kilogram of body weight per day, such as 0.66 grams of protein per kilogram of body weight per day; or on a percentage of total daily calories (energy intake), such as 65% of energy intake for carbohydrates. In reality, when dealing on an individual basis, a combination of these approaches can be useful, in particular percentage of energy intake and on a per-kilogram-of-body-weight basis, keeping in mind that there are pros and cons for each individual approach. When applicable in subsequent units, more details about these approaches will be reviewed. For example, when dealing with grams per kilograms of body weight per day, people with different amounts of lean body mass and body fat will get different dosages based on a lean body mass basis. Also, if one is using this g/kg body weight / day approach, total daily energy expenditure may not be accurately accounted for, such as 3,000-calorie days or 6,000-calorie days.

Conclusion

This introductory chapter has presented a new perspective on nutrition that many people never consider. From this point on in your study program, the road to understanding sports nutrition will be made simpler each step along the way as you progress from unit to unit, which will ultimately lead you to a comprehensive understanding of the Dynamic Nutrition Approach to Sports Nutrition.

Key Words

Aerobic

Anaerobic

Dietary Reference Intakes (DRIs)

Estimated Average Requirement (EAR)

Recommended Dietary Allowance (RDA)

Adequate Intake (AI)

Tolerable Upper Intake Level (UL)

Acceptable Macronutrient Distribution Range (AMDR)

Topics Covered In This Unit

UNIT 2

FOOD, INGREDIENTS, AND NUTRIENTS: AN OVERVIEW

Unit Outline

I. Introduction

II. Food

III. Ingredients

a. Ingredients and Dietary Labeling

IV. Dietary Supplement Definitions

V. Macronutrients: Meeting Energy and Growth Requirements

a. Macronutrient Manipulation/Modulation

b. Water and Electrolytes

VI. Micronutrients: Metabolic Cofactors

a. Nutrient Density

b. Bioavailability

c. The Limiting Nutrient Concept

VII. Ergogenic Aids

a. Nutraceutal

VIII. Research on Nutrients

a. Food Safety

b. GRAS

IX. New Dietary Ingredients

X. Special Topics

a. Adultertation

b. Misbranding

c. Food and Allergy Intolerance

d. BSE (Bovine Spongiform Encephalopathy)

e. Genetically Engineered (GE) Foods

f. Gluten

g. Foodborne Pathogens

XI. Conclusion

Learning Objectives

After completing this Unit, you will be able to:

- Define and describe terms related to ingredients and nutrients.
- Discuss food additives the FDA approves and regulates.
- Macronutrients and micronutrients.
- Compare US and Canadian definitions for dietary supplements and natural health products.
- Discuss various food and supplement topics, nutraceuticals, food safety, food-borne illness, GRAS, adulteration, and misbranding.

Introduction

Every day the human body requires many nutrients for energy, growth, structure, function, performance, and health. Scientists, nutritionists, and health professionals developed special terminology to categorize and represent many nutrition concepts. There are several main categories of nutrients that you need be concerned with to increase athletic performance and fitness. Most of the **essential nutrients** are lumped into two main categories: **macronutrients** and **micronutrients**. This chapter will provide an overview of the basic food and ingredient basis jargon, which will include substances that occur in food, in addition to the essential nutrients.

Going beyond pure science, the regulatory agencies such as the Food and Drug Administration (FDA) and lawmakers have created terminology related to food and ingredients, noting that dietary supplements are a special category of food in the United States. Presentation of some of this regulatory/legal terminology is also included, as this is what appears on food labeling and is encountered when dealing with FDA-regulated products.

This unit contains a new section under the heading "Special Topics." This section was added in response to student inquiries about these food-, ingredient-, and nutrient-related topics. The Special Topics section includes information about subjects such as Adulteration, Misbranded, BSE (Bovine Spongiform Encephalopathy), Genetically Engineered Foods, Food Allergies and Intolerances, Gluten, and Foodborne Illness.

Essential Nutrient: a nutrient that the body cannot produce itself or that it cannot produce in sufficient amounts to maintain good health.

Macronutrient: a macronutrient is any nutrient that the body uses in relatively large amounts. Macronutrients include carbohydrates, fat, and proteins. Macronutrients are different from micronutrients, such as vitamins and minerals, which the body needs in smaller amounts.

Micronutrients: nutrients present in the diet and body in small amounts

Food

According to the legal definition from the Federal Food, Drug and Cosmetic Act:

"The term "food" means (1) articles used for food or drink for man or other animals, (2) chewing gum, and (3) articles used for components of any such article."

The term "processed foodwd includes any raw agricultural commodity that has been subject to processing, such as canning, cooking, freezing, dehydration, or milling.

The FDA's terminology related to defining food includes "means a raw, cooked, or processed edible substance; ice, beverage, or ingredient used or intended for use or for sale in whole or in part for human consumption; or chewing gum."

Aside from definitions, the important issue to consider related to sports nutrition is that foods are the source of essential nutrients and water and other health and performance-promoting substances. However, as presented in the following information, food often contains "other ingredients" not essential to health or athletic performance. As athletes are training strenuously to attain peak sports performance while maintaining good health, reducing dietary intake of the non-nutritive substances added to foods for technical purposes and extra effort to avoid foodborne pathogens becomes an important strategy. Consuming higher amounts of healthy, fresh whole foods and fresh prepared foods, organic when possible, is a good starting point for a "cleaner" or "purer" sports nutrition program to reduce the body's burden of processing the "other ingredients" and avoiding any metabolic disruption or unwanted health issues that may occur.

INGREDIENTS

From a scientific research perspective, ingredients related to foods usually focuses on nutritive aspects and substances, like macronutrients, micronutrients, the growing list of plant bioactive substances, water, and metabolite substances such as **creatine** and Beta-alanine. From an FDA regulation standpoint, food ingredients go beyond the required nutritive substances to include technical ingredients like preservatives, flavors, sweeteners, and colors for example. The following summary from the FDA lists the types of common food ingredients, why they are used, and some examples of the names that can be found on product labels.

Creatine (also, phosphocreatine): a compound produced in the body, stored in the muscle fibers, and broken down by enzymes to quickly replenish the adenosine-triphosphate stores. Also a supplement ingredient.

Antioxidant: a nutrient that has been found to seek out and neutralize free radicals in the body and to stimulate the body to recover more quickly from free-radical damage.

Ingredients and Dietary Ingredients Labeling

Although the topic of food labeling is presented in detail in another unit, it is appropriate to review some information related to the topic of ingredients. Regarding packaged foods, such as frozen vegetables, and of processed foods, like pasta, a list of ingredients is located next to the Nutrition Facts panel. For conventional foods bearing a Nutrition Facts

Ingredients			
TYPES OF INGREDIENTS	**WHAT THEY DO**	**EXAMPLES OF USES**	**NAMES FOUND ON PRODUCT LABELS**
Preservatives	Prevent food spoilage from bacteria, molds, fungi, or yeast (antimicrobials); slow or prevent changes in color, flavor, or texture and delay rancidity (**antioxidants**); maintain freshness	Fruit sauces and jellies, beverages, baked goods, cured meats, oils and margarines, cereals, dressings, snack foods, fruits and vegetables	Ascorbic acid, citric acid, sodium benzoate, calcium propionate, sodium erythorbate, sodium nitrite, calcium sorbate, potassium sorbate, BHA, BHT, EDTA, tocopherols (Vitamin E)
Sweeteners	Add sweetness with or without the extra calories	Beverages, baked goods, confections, table-top sugar, substitutes, many processed foods	Sucrose (sugar), glucose, fructose, sorbitol, mannitol, corn syrup, high fructose corn syrup, saccharin, aspartame, sucralose, acesulfame potassium (acesulfame-K), neotame
Color Additives	Offset color loss due to exposure to light, air, temperature extremes, moisture and storage conditions; correct natural variations in color; enhance colors that occur naturally; provide color to colorless and "fun" foods	Many processed foods, (candies, snack foods margarine, cheese, soft drinks, jams/jellies, gelatins, pudding and pie fillings)	FD&C Blue Nos. 1 and 2, FD&C Green No. 3, FD&C Red Nos. 3 and 40, FD&C Yellow Nos. 5 and 6, Orange B, Citrus Red No. 2, annatto extract, beta-carotene, grape skin extract, cochineal extract or carmine, paprika oleoresin, caramel color, fruit and vegetable juices, saffron (Note: Exempt color additives are not required to be declared by name on labels but may be declared simply as colorings or color added)
Flavors and Spices	Add specific flavors (natural and synthetic)	Pudding and pie fillings, gelatin dessert mixes, cake mixes, salad dressings, candies, soft drinks, ice cream, BBQ sauce	Natural flavoring, artificial flavor, and spices
Flavor Enhancers	Enhance flavors already present in foods (without providing their own separate flavor)	Many processed foods	Monosodium glutamate (MSG), hydrolyzed soy protein, autolyzed yeast extract, disodium guanylate or inosinate
Fat Replacers (and components of formulations used to replace fats)	Provide expected texture and a creamy "mouth-feel" in reduced-fat foods	Baked goods, dressings, frozen desserts, confections, cake and dessert mixes, dairy products	Olestra, cellulose gel, carrageenan, polydextrose, modified food starch, microparticulated egg white protein, guar gum, xanthan gum, whey protein concentrate

Ingredients continued			
TYPES OF INGREDIENTS	**WHAT THEY DO**	**EXAMPLES OF USES**	**NAMES FOUND ON PRODUCT LABELS**
Nutrients	Replace vitamins and minerals lost in processing (**enrichment**), add nutrients that may be lacking in the diet (**fortification**)	Flour, breads, cereals, rice, macaroni, margarine, salt, milk, fruit beverages, energy bars, instant breakfast drinks	Thiamine hydrochloride, riboflavin (Vitamin B2), niacin, niacinamide, folate or folic acid, beta carotene, potassium iodide, iron or ferrous sulfate, alpha tocopherols, ascorbic acid, Vitamin D, amino acids (L-tryptophan, L-lysine, L-leucine, L-methionine)
Emulsifiers	**Emulsifiers** allow smooth mixing of ingredients, prevent separation Keep emulsified products stable, reduce stickiness, control crystallization, keep ingredients dispersed, and help products dissolve more easily	Salad dressings, peanut butter, chocolate, margarine, frozen desserts	Soy lecithin, mono- and diglycerides, egg yolks, polysorbates, sorbitan monostearate
Stabilizers and Thickeners, Binders, Texturizers	Produce uniform texture, improve "mouth-feel"	Frozen desserts, dairy products, cakes, pudding and gelatin mixes, dressings, jams and jellies, sauces	Gelatin, pectin, guar gum, carrageenan, xanthan gum, whey
pH Control Agents and acidulants	Control acidity and alkalinity, prevent spoilage	Beverages, frozen desserts, chocolate, low acid canned foods, baking powder	Lactic acid, citric acid, ammonium hydroxide, Sodium carbonate
Leavening Agents	Promote rising of baked goods	Breads and other baked goods	Baking soda, monocalcium phosphate, calcium carbonate
Anti-caking agents	Keep powdered foods free-flowing, prevent moisture absorption	Salt, baking powder, confectioner's sugar	Calcium silicate, iron ammonium citrate, silicon dioxide
Humectants	Retain moisture	Shredded coconut, marshmallows, soft candies, confections	Glycerin, sorbitol
Yeast Nutrients	Promote growth of yeast	Breads and other baked goods	Calcium sulfate, ammonium phosphate
Dough Strengtheners and Conditioners	Produce more stable dough	Breads and other baked goods	Ammonium sulfate, azodicarbonamide, L-cysteine
Firming Agents	Maintain crispness and firmness	Processed fruits and vegetables	Calcium chloride, calcium lactate
Enzyme Preparations	Modify proteins, polysaccharides and fats	Cheese, dairy products, meat	Enzymes, lactase, papain, rennet, chymosin
Gases	Serve as propellant, aerate, or create carbonation	Oil cooking spray, whipped cream, carbonated beverages	Carbon dioxide, nitrous oxide

panel, all of the ingredients, food, nutrients, or technical ingredients must be included in ingredient list, usually in descending order of weight. Then the Nutrition Facts panel contains information about the nutrition / nutrients provided by these ingredients.

When it comes to the special category of foods referred to as dietary supplements, the underlying principles are similar to Nutrition Facts panel bearing foods, with some minor difference and overlap in the food labeling regulations. The actual nutritionally active ingredients used to make dietary supplements are referred to as dietary ingredients. A short definition of a dietary ingredient is as follows: a vitamin; a mineral; an herb or other botanical; an amino acid; a dietary substance for use by human to supplement the diet by increasing total dietary intake; or a concentrate, metabolite, constituent, extract, or combination of any of the above dietary ingredients.

The listing of ingredients for dietary supplements can use two approaches. The first ingredient list approach is to list all the ingredients together the same as for Nutrition Facts bearing foods. The second ingredient list approach is to list the sources of the dietary ingredients in the Supplement Facts panel and just list the other non-dietary ingredient ingredients under the heading "Other Ingredients" next to the Supplement Facts Panel. Therefore, for example, a dietary supplement product containing vitamin C, the Supplement Facts Panel can list Vitamin C, or Vitamin C (as ascorbic acid). If Vitamin C is only listed in the Supplement Facts Panel, and then all the ingredients must be listed under the ingredient heading. If vitamin C (as ascorbic acid) is used, then all the other ingredients contained in the product would be listed under the heading "Other Ingredients," excluding ascorbic acid that was already declared in the Supplement Facts Panel. Many more rules and requirements related to food labeling will be covered in a subsequent unit.

Enrichment: the addition of specific nutrients (i.e., iron, thiamin, riboflavin, and niacin) to refined grain products to replace losses of the nutrients that occur during processing. Enrichment of refined grains is not mandatory; however, those that are labeled as enriched (e.g., enriched flour) must meet the standard of identity for enrichment set by the FDA. When cereal grains are labeled enriched, it is mandatory that they be fortified with folic acid. (The addition of specific nutrients to whole-grain products is referred to as fortification; see Fortification.)

Fortification: as defined by the US Food and Drug Administration (FDA), the deliberate addition of one or more essential nutrients to a food, whether or not it is normally contained in the food. Fortification may be used to prevent or correct a demonstrated deficiency in the population or specific population groups; restore naturally occurring nutrients lost during processing, storage, or handling; or to add a nutrient to a food at the level found in a comparable traditional food. When cereal grains are labeled as enriched, it is mandatory that they be fortified with folic acid.

Emulsifier: a substance that, during digestion, helps disperse fats in water mediums.

Dietary Supplement Definition (and Dietary Ingredient, Too)

For reference purposes, here is the official definition of dietary supplements in the United States, which includes defining a dietary ingredient, as dietary supplements must contain dietary ingredients, along with other considerations regarding their use:

The term "dietary supplement"—

(1) means a product (other than tobacco) intended to supplement the diet that bears or contains one or more of the following dietary ingredients:

(A) a vitamin;

(B) a mineral;

(C) an herb or other botanical;

(D) an amino acid;

(E) a dietary substance for use by man to supplement the diet by increasing the total dietary intake; or

(F) a concentrate, metabolite, constituent, extract, or combination of any ingredient described in clause (A), (B), (C), (D), or (E);

(2) means a product that—

(A)(i) is intended for ingestion in a form described in section 411(c)(1)(B)(i); or (ii) complies with section 411(c)(1)(B)(ii);

(B) is not represented for use as a conventional food or as a sole item of a meal or the diet; and

(C) is labeled as a dietary supplement; and

(3) does—

(A) include an article that is approved as a new drug under section 505 or licensed as a biologic under section 351 of the Public Health Service Act (42 U.S.C. 262) and was, prior to such approval, certification, or license, marketed as a dietary supplement or as a food unless the Secretary has issued a regulation, after notice and comment, finding that the article, when used as or in a dietary supplement under the conditions of use and dosages set forth in the labeling for such dietary supplement, is unlawful under section 402(f); and

(B) does not include—

(i) an article that is approved as a new drug under section 505, certified as an antibiotic under section 507 1, or licensed as a biologic under section 351 of the Public Health Service Act (42 U.S.C. 262), or

(ii) an article authorized for investigation as a new drug, antibiotic, or biological for which substantial clinical investigations have been instituted and for which the existence of such investigations has been made public, which was not before such approval, certification, licensing, or authorization marketed as a dietary supplement or as a food unless the Secretary, in the Secretary's discretion, has issued a regulation, after notice and comment, finding that the article would be lawful under this Act.

Except for purposes of sections 201(g) and 417, a dietary supplement shall be deemed to be a food within the meaning of this Act.

For comparison to the definition of dietary supplements in the United States, here is the definition related to Natural Health Products in Canada, which includes dietary supplement-type products and ingredients and also includes natural drug products, primarily nonprescription (over the counter). The Natural Health Product category includes both topical and ingestible health products. The active ingredients are referred to as medicinal ingredients. The following list is referred to as Schedule 1: List of Included Substances:

1. A plant or a plant material, an alga, a bacterium, a fungus or a non-human animal material.

A plant is a member of the biological Kingdom Plantae and is either the whole plant or parts thereof. A plant consists of complex multicellular eukaryotes that have a cell wall composed primarily of cellulose. A plant usually produces its own food by photosynthesis using chlorophylls a and b. Example of plants are Allium sativum and Cassia angustifolia. Examples of plant parts are bark, wood, leaves, stems, roots, flowers, fruits, seeds and berries, or parts thereof.

A plant material is material obtained from a plant, including pollens, nucleic materials, mitochondria, chlorophyll and exudates such as resin.

An alga is a member of one of the protist biological Kingdoms. It consists of unicellular, colonial. or relatively simple multicellular eukaryotes and has a cell wall containing cellulose or silica. Algae usually produce their own food by photosynthesis and are mostly aquatic. Examples of algae are Chlorella pyrenoidosa and Laminaria digitata.

A bacterium is a member of one of the biological Kingdoms of the Domains Bacteria or Archaea. It consists of usually unicellular (sometimes aggregated, colonial or simple multicellular) prokaryotes whose cells lack nuclei or other internal compartmentalization but that have a cell wall external to the plasma membrane in most species. An example is Spirulina (cyanobacteria).

A fungus is a member of the biological Kingdom Fungi. A fungus consists mainly of complex multicellular eukaryotes that have a cell wall composed primarily of chitin. Fungi are heterotrophs that absorb nutrients from their surroundings by decomposing organic materials. Examples are Lentinus edodes (Shiitake mushroom) and Grifolia frondosa (Maitake mushroom).

An animal is a member of the biological Kingdom Animalia. An animal consists of complex multicellular eukaryotes whose cells have a membrane but no wall. Most members have muscles and nervous tissues. They are heterotrophs that mostly ingest food into a specialized cavity, where it is digested. Examples are Squalus acanthias (shark) and Gadus morhua (cod).

A non-human animal material is a body part or secretion obtained from an animal other than a human and is used in the preparation of a natural health product. Examples are elk antler velvet, bovine colostrums, shark cartilage, and attenuation prepared from canine milk (Lac caninum).

To be acceptable as homeopathic medicines under the Natural Health Products Regulations, a non-human animal material must be listed in one of the following: the Homeopathic Pharmacopoeia of the United States, the Homöopathische Arzneimittel, the Pharmacopée française, or the European Pharmacopeia.

2. An extract or isolate of a substance described in item 1, the primary molecular structure of which is identical to that which it had prior to its extraction or isolation.

An extract is a substance prepared by treating a plant or a plant material, an alga, a bacterium, a fungus or a non-human animal material with solvents to obtain the desired compounds. Examples are Echinacea angustifolia solid extract, Panax ginseng tincture and St. John's Wort fluid extract.

An isolate is a purified constituent of a defined molecular structure obtained from a plant or a plant material, an alga, a bacterium, a fungus or a non-human animal material.

Examples are glutathione and capsaicin.

3. Any of the following vitamins:

1. Biotin
2. Folate
3. Niacin
4. Pantothenic acid
5. Riboflavin
6. Thiamin
7. Vitamin A
8. Vitamin B6
9. Vitamin B12
10. Vitamin C
11. Vitamin D
12. Vitamin E

Vitamins are naturally occurring organic substances required by the body to maintain health. Dietary Reference Intakes (DRIs) are the standards for referencing upper levels of vitamins. More information on DRIs can be found at http://www.hc-sc.gc.ca/hpfbdgpsa/onpp-bppn/diet_ref_e.html. In some cases, Health Canada's Therapeutic Products Directorate has established lower levels for vitamins; in other words, the amount of vitamin in a natural health product cannot be lower than this level.

Recognizing that the natural health product definition excludes substances that require a prescription, and that vitamin K is currently listed on Schedule F to the Food and Drug Regulations without specifying parameters, NHPD has removed vitamin K from Schedule 1 until the parameters for vitamin K have been determined.

4. An amino acid.

An amino acid is a class of organic molecule that contains amino and carboxyl groups. Amino acids form the main constituents of proteins that are found in a plant or a plant material, an alga, a fungus, a bacterium or a non-human animal material. The following are acceptable amino acids:. NHPD acknowledges that there are other amino acids not captured under this definition. These amino acids will be captured under the isolate category:

1. L-alanine
2. L-arginine
3. L-asparagine
4. L-aspartic acid
5. L-cysteine
6. L-glutamine
7. L-glutamic acid
8. L-glycine
9. L-histidine
10. L-isoleucine
11. L-leucine
12. L-lysine
13. L-methionine
14. L-phenylalanine
15. L-proline
16. L-serine
17. L-threonine
18. L-tryptophan
19. L-tyrosine
20. L-valine

5. An Essential Fatty Acid

An essential fatty acid cannot be synthesized in the body; hence, it must be supplied through the diet or a supplement. Linoleic acid and alpha linolenic acid are essential fatty acids. All other fatty acids (such as oleic acid, conjugated linoleic acid, gamma-linoleic acid, arachidonic acid, eicosapentaenoic acid and docosahexaenoic acid) are considered extracts or isolates (see item 2, above). For more information, see the Evidence for Quality of Finished Natural Health Products Guidance Document.

6. A synthetic duplicate of a substance described in any of items 2 to 5

A synthetic duplicate is a substance that shares an identical chemical structure and pharmacological properties with its natural counterpart. Examples are vitamin E - DL alpha-tocopherol.

A semi-synthetic substance may also be acceptable as a natural health product provided it shares an identical chemical structure and pharmacological properties with its natural counterpart. A semi-synthetic substance is produced by a process that chemically changes a related starting material that has been extracted or isolated from a plant or a plant material, an alga, a fungus or a non-human animal material. An example is ginsenosides (the starting compound used is betulafolienetriol).

7. A Mineral

A mineral is a naturally occurring solid, inorganic substance with a definite and predictable chemical composition and physical properties.

8. A probiotic

The Natural Health Products Regulations define a probiotic as a monoculture or mixed culture of live micro-organisms that benefit the microbiota indigenous to humans. A probiotic is limited to non-pathogenic microorganisms. An example is Lactobacillus acidophilus.

[Source: Natural Health Products Directorate, Overview of the Natural Health Products Regulations Guidance Documents, 2003.]

It is interesting to make a direct comparison to the US and Canadian "definitions" related to dietary supplement type products. Note that in practice, both approaches have strong points and weaknesses, with room to evolve via interpretation and or updating the laws and regulations. In either case, this brings the highest level of credibility to the various ingredients used in dietary supplements, including sports supplements. Since the Natural Health Product was established in 2004, over 50,000 products have been licensed, using hundreds of ingredients and associated claims, including the same ingredients used in sports nutrition supplements in the United States.

Protein: one of the nutrients that provides calories to the body. Protein is an essential nutrient that helps build many parts of the body, including blood, bone, muscle, and skin. Protein provides 4 calories per gram and is found in foods like beans, dairy products, eggs, fish, meat, nuts, poultry, and tofu. Proteins are composed of amino acids, nine of which are indispensable (essential), meaning they cannot be synthesized by humans and therefore must be obtained from the diet. The quality of dietary protein is determined by its amino acid profile relative to human requirements as determined by the body's requirements for growth, maintenance, and repair. Protein quality is determined by two factors: digestibility and amino acid composition.

Fat: a major source of energy in the diet, fat helps the body absorb fat-soluble vitamins, such as vitamins A, D, E, and K. Some kinds of fats, especially saturated fats and trans fatty acids, may raise blood cholesterol and increase the risk for heart disease. Other fats, such as unsaturated fats, do not raise blood cholesterol. Fats that are in foods are combinations of monounsaturated, polyunsaturated, and saturated fatty acids.

Energy Expenditure: The amount of energy that you use measured in calories. You use calories to breathe, send blood through your blood vessels, digest food, maintain posture, and be physically active.

Macronutrients: Meeting Energy and Growth Requirements

Macronutrients are nutrients that are required daily in large amounts and are thought of in quantities of ounces and grams. They include carbohydrates, **protein**, lipids, and water. Macronutrients are important for providing the body with a supply of energy and serving as the building blocks the body needs for growth and repair. Macronutrients occur in all foods but vary in amount and proportion. For example, meats can be high in protein and **fat**, with almost no carbohydrate content. Pasta however is very high in carbohydrates, with moderate amounts of protein and a low fat content.

Carbohydrates and lipids are the macronutrients primarily used to provide the body with energy. Proper energy substrate intake is important to balance **energy expenditure** and maintain desired body composition and performance. Your energy requirements will vary with age, activity, and foods eaten. Adult daily energy requirements may range from a low of 1,800 (or even lower) to more than 6,000 calories per day. Although alcohol is not an essential nutrient, for those who choose to consume alcoholic beverages, you may be interested to know that daily alcohol consumption can contribute large amounts of "empty" calories to your diet.

The approximate caloric content of the macronutrients and alcohol are as follows:

Caloric Content of Macronutrients and Alcohol

	Calories per Gram	Calories per Ounce
Carbohydrate	4	113.6
Protein	4	113.6
Fat	9	255.6
Alcohol	7	198.8
Water	0	0.0

As you can see, on a weight basis, fat has the most calories followed by alcohol, carbohydrates, and protein. In the past, it was assumed that all calories supplied by nutrients were metabolized the same way and that their total caloric content was equally used for energy. However, in recent years, scientists have determined that the energy content of different macronutrients may vary slightly in the body depending upon the relative proportions of the other macronutrients present in the diet, the type of macronutrient, the presence of vitamin and mineral cofactors, the level of hydration, and the physical conditioning of the individual. For example, protein is considered a protected nutrient because the body reserves its use for the synthesis of tissues and molecules instead of energy use. Therefore, the body has a tendency to use carbohydrates, including glycogen stores and lipids (fats), for energy instead of using ingested protein and the protein that makes up muscle tissue. In fact, a **thermogenic response** has been detected in response to eating diets high in protein, indicating that more energy is used in the digestion and metabolism of proteins; see box on thermogenesis for details. Although, with increased athletic conditioning and training volume and energy expenditure, some protein and amino acids get used for energy, and minimizing this occurrence and compensating for it in a sports nutrition plan is a vital strategy—in addition to the preferred high-energy substrate intake.

Thermogenic Response: the rise in the metabolic rate. Also known as the thermogenic effect or specific dynamic action (sda).

Thermogenesis: the process by which the body generates heat, or energy, by increasing the metabolic rate above normal.

Metabolic Rate: the body's total daily caloric expenditure.

Thermogenesis

Thermogenesis is a term generally used to describe metabolic heat production by the body. Some different terms maybe used to describe different aspects of thermogenesis. For example, related to nutrition, there is a thermic effect of food (TEF), also referred to as diet-induced thermogenesis (DIT). This is due to the energy it takes to digest, process, and use or store food by the body. This is sometimes also referred to as the thermogenic effect of food. This is usually in relationship to an increase of the rate of energy expenditure above the basal metabolic rate. The food related raise in **metabolic rate** is also referred to as specific dynamic action (SDA).

After a meal, the metabolic rate and energy expenditure increases. It is estimated this increase may be about 10 percent per day from food consumed. The type of macronutrients seems to have different effects on the thermogenic response. When food is ingested the metabolic rate (energy used) increases above the fasting level. In the case of proteins, it is thought that this occurs because the body must use energy to process the proteins, which are then used as building blocks for tissue growth and repair. On the other hand, carbohydrates and fats function primarily as fuel, and the metabolism can more efficiently use them for energy without much energy input to process them, when compared to protein. They therefore have a lower thermogenic effect compared to protein. Some example DIT values reported in the research for separate nutrients include: 0 to 3% for fat, 5% to 10% for carbohydrate, and 20% to 30% for protein. [Westerterp K. Diet induced thermogenesis. Nutr Metab (Lond) 2004;1(1):5.]

A thermogenic effect is also experienced from physical activity and shivering in response to exposure to cold. Aside from conventional food consumption, some ingredients may have a thermogenic effect; caffeine for example may increase the metabolic rate in some people. Again, this is in relationship to the basal metabolic rate.

Glucose: a simple carbohydrate that is a monosaccharide. Also called dextrose or grape sugar.

Starch: a complex carbohydrate that occurs only in plants.

Several types of carbohydrates will affect your energy and performance depending on when you eat them and what kind of carbohydrate you eat. There are complex carbohydrates (starches) and simple carbohydrates, like **glucose** and fructose. **Starch** (which is composed of chains of glucose) may provide the body with a slow and steady supply of glucose, depending on the type of food. Generally, simple carbohydrates, like glucose, get into the bloodstream fast and serve as a quick supply of energy. Fructose gets into the bloodstream at a slower rate than glucose does and has a typically slower metabolic series of pathways. However, ingesting too much fructose must be avoided, as should restricting the consumption of other simple carbohydrates to certain nutrient timing opportunities, as reviewed in the corresponding unit.

Lipids are a technical term that refers to fats and other plant and animal nutrients that are insoluble in water. The fatty acids that make up fats and oils contain the highest energy of any macronutrient on a per weight basis. Other lipids, like cholesterol, are not important energy sources, but are major components of steroid hormones and bile acids. Your body is always using a mixture of carbohydrate and fat for energy, plus a little protein. This energy mixture will vary depending upon a person's program of training and level of fitness, the intensity and duration of physical activity and the composition of the diet. Endurance sports tend to cause the body to burn a higher proportion of fat, and condition the body to be better at using fats for energy. Compare this with power sports, like sprinting, which burn a greater amount of carbohydrates for energy during these types of physical activity. Thus, physical activity will dictate the proportion of macronutrients needed in your diet. For example, a marathon runner will generally need a diet high in carbohydrates and moderate in fat and protein. On the other hand, the power lifter needs a diet high in carbohydrates and protein with low amounts of fat. This is one of the several aspects of the Dynamic Nutrition Approach model.

Protein utilization during and after exercise is more complicated than is the use of carbohydrates and fats for energy. Protein provides the body with essential building blocks in the form of its subunits, called amino acids. The body therefore has a tendency to avoid using protein/amino acids for energy. However, during exercise, the body will use certain amino acids for energy and other metabolic functions. This cannot be prevented, but it can be compensated for by ingesting proteins with higher amounts of the certain amino acids used during exercise—the branched chain amino acids, for example. Research has also shown that even during rest, the athletes' highly trained muscles will still use certain amino acids for energy, even in the presence of carbohydrates and fat. Special nutrition supplements can be used to boost the efficiency and utilization of dietary proteins, along with certain vitamin and mineral cofactors to prevent muscle breakdown and encourage muscle repair, such as amino acid tablets and protein supplement drinks and nutrition bars.

Macronutrient Manipulation/Modulation

A constant intake of protein and the other macronutrients is needed all day long for optimum nutrition. However, the proportions of these macronutrients may vary around your training, meal and resting periods. This variation in macronutrient intake has been termed by sports nutritionists as "**macronutrient modulation**" or "macronutrient manipulation." This simply refers to the practice of varying the intake of macronutrients to meet your specific nutrition needs. For example, right before and during the time that a person exercises, intake of water, electrolytes, some amino acids, and simple carbohydrates will be desirable to maintain energy and spare glycogen stores and muscle tissue. Fat and large amounts of proteins are not desirable right before or during training or athletic events because they take longer to digest and will impair performance. During exercise bouts or athletic competition, intake of water and or hypotonic (carbohydrate - electrolyte) beverages is typically needed to prevent **glycogen depletion**. Of course, glycogen depletion causes fatigue and reduced exercise output, so athletic individuals want to avoid depletion of their glycogen (carbohydrate body stores). Finally, studies have shown that ingestion of carbohydrates, or a mixed meal about 60 minutes after exercise will result in significant glycogen repletion. Mastering meal timing and macronutrient modulation can help fine-tune the most sophisticated performance and fitness nutrition improvement programs.

Macronutrient Modulation: the practice of varying the ratio of the macronutrients in the diet to meet specific metabolic needs to enhance performance. Also called macronutrient manipulation.

Glycogen Depletion: the draining of the body's glycogen stores.

Water and Electrolytes

Water is the most essential macronutrient to life but provides no calories or nutrition. Water is the universal solvent that all life on earth depends on and is the medium for transporting the food materials to be used in the body. A person can survive several weeks without food but only several days without water. The importance of water has always been recognized, but recently, more and more research has shown that maintaining optimum levels of hydration is important in maintaining peak performance and recovery. In sports like soccer and basketball, the athletes can lose several pounds of water weight in just one game. This can adversely affect performance and, in the long run, cause peaks and valleys in the athlete's performance curve.

Electrolyte Balance: the ratio of chloride, potassium, sodium, and the other electrolytes in the body.

In addition to maintaining hydration, the body also needs to maintain its **electrolyte balance**. The major electrolytes found in body fluids include sodium, chloride, and potassium along with calcium, phosphate, and magnesium. Water constitutes a small or large part of every cell, depending on the function of the cell. Likewise, specific quantities of electrolytes are found in both cellular and extra cellular water. Water and electrolyte concentrations in the body are closely controlled, even under extreme temperature conditions. Like water, electrolytes can be lost through sweat and excretion. Replenishing water and electrolyte losses during exercise and throughout the day has become an increasingly complex task for athletic individuals as new discoveries about the dynamics of these critical nutrients are made, such as different rates of loss.

Micronutrients: Metabolic Cofactors

Even more diverse than the macronutrients is the group of nutrients called micronutrients. As the name implies, micronutrients are nutrients present in the diet and body in small amounts. They are measured in milligrams and micrograms. They do not provide significant amounts of calories to the body but act as cofactors in making biomolecules, have structural roles, function as electrolytes, and function as enzymes. Broadly speaking, the essential vitamins and minerals, the non-essential vitamins and minerals, vitamin-like substances, and other dietary biomolecules which are important in performance, fitness, and health fall into the micronutrient category.

Vitamins are organic compounds that are required by the body for maintenance of good health and growth. Vitamins are further classified as fat-soluble and water-soluble. By convention, the word vitamin has been reserved for certain nutrients that the body cannot manufacture and must get through eating food. The fat soluble vitamins include vitamins A, D, E, and K. Because they are soluble in fat (lipids), they tend to store themselves in the body's fat tissue, fat deposits, and liver. This storage capability makes it possible to take so much of the fat soluble vitamin that the effect on the body is toxic. Concern over the intake of fat-soluble vitamins should be exercised. Guidelines will be provided in subsequent Units regarding safe limits of intake.

The water soluble vitamins include the B vitamins and vitamin C. In contrast to the fat-soluble vitamins, the water-soluble vitamins are not easily stored by the body. More often, they are lost from foods during cooking or eliminated from the body. The B vitamins function mainly as coenzymes. Vitamin C has several important metabolic roles. Vitamins are not usually metabolized for energy, but some of them are essential for the production of energy from the macronutrients and act as cofactors. As with the macronutrients, vitamin research has only begun to illuminate how these nutrients benefit performance and health beyond nutritional deficiency prevention. However, current findings give us a good picture of how vitamins are important for health and performance. In fact, you may be aware of some multivitamin supplements designed for athletic people, typically containing higher amounts of the B vitamins.

The mineral nutrients are inorganic nutrients or inorganic-organic complexes that are found in the body; and, although they only comprise about 4 percent of the body's weight, they are essential structural components and necessary for many vital metabolic processes. Minerals such as calcium are required in large amounts every day, about 1,200 milligrams (mg) or more, whereas other minerals, such as chromium, are needed in microgram (mcg) amounts. A microgram is 1,000th of a milligram. Even though there is a relatively wide range of intake observed, the relative importance of each mineral is equal. Some minerals are found in the body in their inorganic form, such as calcium salts in the bone and sodium chloride in the blood. Other minerals are present in the body in organic combinations, such as iron in hemoglobin and iodine in thyroxin. Absorption of minerals into the body will vary greatly depending upon the type of mineral. Researchers are discovering that just because a food contains a mineral, or vitamin, does not mean that all of it will get into the body. This is another reason sports supplements are recommended. They ensure that the exact amount of nutrients will be supplied to the body. Additionally, you can get high-quality nutrients without the fat, salt, pesticides, and other junk that is found in many foods.

In addition to the essential vitamins and minerals, there exists a host of other micronutrients that the body can make on its own but can also benefit from by eating. These are sometimes referred to as "accessory nutrients" or "nonessential nutrients." When it comes to the athlete, many of these nutrients will actually improve performance. Sodium bicarbonate can improve performance in explosive power sports. L-Carnitine is essential for the oxidation of long-chain fatty acids into energy. While carnitine can be made from the amino acids lysine and methionine, research has shown that supplemental amounts can benefit fat metabolism and increase endurance. Another nutrient, creatine, is widely taken by athletes in supplement form and touted for its energy-enhancing effects and usefulness in strength sports.

In addition to the vitamins, minerals, and accessory nutrients, there is a growing awareness of other substances found in plants and animals that can improve health and performance. A group of naturally occurring plant compounds, the bioflavonoids, beneficially maintain the artery walls of the circulatory system and have other beneficial health effects. Furthermore, vitamins, minerals, and supplements like glucosamine and herbal curcumin can be important for optimizing healing and recovery of exercise-induced wear and tear. Then there are the probiotics, which are live microorganisms with beneficial health effects, such as promoting gastrointestinal wellness and some immune system function.

Nutrient Density

Foods contain macronutrients and micronutrients in a variety of combinations and amounts. A potato is high in complex carbohydrates, contains some protein and B vitamins, and is a good source of vitamin C, some minerals, (especially potassium and phosphorus), and a trace amount of fat. Meat, like steak for example, is high in protein and fat but has no carbohydrates. Steak also acts as a good source of vitamin A, some B vitamins, phosphorus, potassium, iron, and magnesium. Creatine is also found in steak but can get converted during the cooking process to the inactive creatinine. Just a brief look at these two foods demonstrates that although they contain some of the essential nutrients, they lack others. The nutrient content of food will also vary depending upon when and where it is grown.

In these modern times, a vast portion of food is processed. Most of these processed foods are very low in micronutrients. For example, white pasta, which is a good source of carbohydrates, has been stripped of most of its micronutrient content and its fiber from the external bran layer in processing its flour. In fact, most pasta is now vitamin fortified to compensate for this low nutrient content. Canned vegetables can also lose much of their vitamin content in the preparation process, including enzymes lost from the cooking process.

Eating whole foods and supplements is necessary for high-quality nutrition. This is the real solution. If you are eating a great many carbohydrates from sugar, for example, the essential vitamin cofactors will not be present in proper amounts to obtain the most efficient and highest level of energy out of this food. Too much sugar intake also can cause imbalances in your insulin levels. These factors have a direct effect on how you body uses nutrients for energy or for conversion to fat. Therefore, maintaining an intake of foods that are high in quality nutrients is important for reaching top performance. For the athlete, attaining a **nutrient dense** diet will include combining fresh healthy whole foods with the right supplements for your sport or fitness activity. For example, a long-distance runner can improve performance by taking co-enzyme Q-10 and carnitine supplements, whereas a power lifter will benefit from ingesting extra protein and taking a creatine monohydrate supplement, and a range of athletes and exercisers may benefit from Beta-alanine.

Bioavailability

It was once assumed that the presence of a nutrient in a particular food meant that the body would make full use of it. We now know that this assumption does not hold true for many nutrients. **Bioavailability** refers to the ability of an ingested nutrient to enter from the digestive tract, into the bloodstream, and on to the cells where it is utilized. A nutrient's bioavailability is affected in many ways. Certain nutrients compete with each other for intestinal absorption. Food preparation can affect bioavailability. Problems with your digestive system will interfere with nutrient absorption, and some nutrients are absorbed better in the presence of other nutrients–the intestinal absorption of phosphorus by vitamin D for example. When constructing a nutrition program, you need to pick foods and supplements that contain highly bioavailable nutrients to achieve maximum nutrition performance. Even the nutrients used in supplement formulation can vary. Thus choosing supplements with highly bioavailable nutrients is important.

Nutritional Revelations

The following list includes typical main nutritional problems in that can occur in people's diets. The basis of any healthy sports nutrition program should be structured to prevent and correct these nutritional inadequacies and imbalances.

Most American diets are:

Too high in total fat

Too high in saturated fats

Too high in cholesterol

Too high in sodium

Too high in sugar

Too high in processed foods

Too high in empty calorie foods

Too high in snack foods

Too high in junk foods

Too high in refined flours

Too high in total calories

Too low in potassium

Too low in calcium

Too low in magnesium

Too low in antioxidants

Too low in alpha linolenic acid

Too low in EPA and DHA

Too low in other essential vitamins and minerals

Too low in protein

Too low in fiber

Too low in fluid (water)

Nutrient Dense: a characteristic of foods and beverages that provide vitamins, minerals, and other substances that contribute to adequate nutrient intakes or may have positive health effects, with little or no solid fats and added sugars, refined starches, and sodium. Ideally, these foods and beverages also are in forms that retain naturally occurring components, such as dietary fiber. All vegetables, fruits, whole grains, seafood, eggs, beans and peas, unsalted nuts and seeds, fat-free and low-fat dairy products, and lean meats and poultry—when prepared with little or no added solid fats, sugars, refined starches, and sodium—are nutrient-dense foods. These foods contribute to meeting food group recommendations within calorie and sodium limits. The term "nutrient dense" indicates the nutrients and other beneficial substances in a food have not been "diluted" by the addition of calories from added solid fats, sugars, or refined starches or by the solid fats naturally present in the food.

Bioavailability: the ability of an ingested nutrient to cross from the digestive tract into the bloodstream and then from the bloodstream into the cells in which it will be utilized.

The Limiting Nutrient Concept

Assimilation: conversion of food into living tissue.

While more than 90 percent of the nutrients in food are usually absorbed into the body, the absence of even one nutrient can limit the utilization of other nutrients. For example, the mineral chromium is an essential cofactor for the proper functioning of the hormone insulin. When you eat a meal, insulin is secreted into the bloodstream and is required for the passage of glucose and amino acids from the bloodstream to the cells. Chromium is needed for insulin to function properly. Even if your body is making enough insulin, a shortage of chromium can prevent the complete **assimilation** of dietary glucose and amino acids. Researchers have determined that chromium is not present in optimal amounts in most diets, especially among athletes. When chromium is not present in optimal amounts, dietary glucose and amino acids in the bloodstream that cannot enter the cells will circulate back to the liver and may end up being converted to fat. Additionally, muscle cells will be deprived of amino acids for proper growth and recovery and of glucose for replenishment of glycogen stores. In this example, chromium is a limiting nutrient because its lack limits the cellular uptake of other nutrients.

Some of the same amino acids that build proteins can also become limiting nutrients for the athlete. As mentioned earlier, during exercise, some amino acids are used for energy. The amino acid leucine is one of these. Leucine is an essential amino acid. It is used to make other amino acids and is important in metabolic pathways and especially for muscle growth and maintenance. For the athlete, leucine can become a limiting nutrient and affect the utilization of the other amino acids when it is selectively used for energy and the other amino acids are not. Amino acids are used to build proteins, which are chains of amino acids. The result of an amino acid running out, is the inhibition and reduction of the rate of protein synthesis and a slowing down of the body's growth and repair. One way to compensate for the disproportionate use of leucine for energy is to eat supplemental amounts of leucine and other amino acids that are used for energy and can become potential limiting nutrients. It is equally important to ingest the right amount of the "nonessential" amino acids and other "nonessential" nutrients so the body does not need to waste time and energy making these nutrients.

You can begin to see how sports nutrition is different from just eating for survival or optimum health. First, determine which nutrients (both essential and nonessential) the athlete's body uses and how and when it uses them. Then supply them in the diet from foods and supplements. It's like formulating a super-charged fuel for a high-performance engine. But the engine in this case is the human body, and it is a dynamic one that can have different needs each day and changing needs over time from progressive athletic training and development.

Ergogenic Aids

"**Ergogenic aids**" is a catchall term to describe athletic performance-enhancing substances and training techniques. Ergogenic aids can be nutritional and non-nutritional and include special training techniques, blood doping, mental strategies, and drugs. Substances range from water to large dosages of vitamins. In the most fundamental sense of the definition, a nutritional ergogenic aid would cause some immediate observable benefit for athletic performance.

Ergogenic Aids: a catchall term that describes anything that can be used to enhance athletic performance. Ergogenic aids can be dietary or non-dietary and include dietary supplements, special training techniques, and mental strategies.

Although there are many viable ergogenic aids, as far as this course is concerned, your entire nutrition and training program should be approached as an ergogenic aid. Therefore, do not just focus on one or two magic nutritional bullets. While certain short-term performance-enhancing methods are employed as part of the Dynamic Nutrition Approach (like macronutrient modulation and carbohydrate loading), you must focus on perfecting your total nutrition and training programs to increase and maximize performance and fitness. If your baseline nutrition is not optimum to begin with, then use of a nutritional ergogenic aid will not allow you to derive the maximum benefits it may offer. For example, if athletes are given large amounts of vitamin B12 for energy and are not eating the proper amounts of carbohydrates, the potential performance-enhancing benefits of the B12 will not be realized. As you review the nutrients one by one in the units that follow, remember that it is the sum total nutrition approach that will far exceed any of the individual parts.

Nutraceutical

The term "nutraceutical," sometimes spelled "nutriceutical," was created from the words "nutrition" and "pharmaceutical" in the 1980s by Stephen DeFelice, MD, founder and chair of the Foundation for Innovation in Medicine in New Jersey. According to DeFelice, a nutraceutical is any substance that is a food or a part of a food, medical food, or dietary supplement and provides medical or health benefits, including the prevention and treatment of disease. This concept of nutraceutical goes beyond the simple notion of simply providing adequate nutrition to prevent nutrient deficiency diseases or health, as it widens the view to include prevention and treatment of all diseases.

Health Canada has taken the lead in publishing official definitions of nutraceutical and a related term, functional foods:

- A nutraceutical is a product isolated or purified from foods that is generally sold in medicinal forms not usually associated with food. A nutraceutical is demonstrated to have a physiological benefit or provide protection against chronic disease.
- A functional food is similar in appearance to, or may be, a conventional food, is consumed as part of a usual diet, and is demonstrated to have physiological benefits and/or reduce the risk of chronic disease beyond basic nutritional functions.

While the term nutraceutical is recent relative to medical history, the concept of preventing and treating diseases is thousands of years old. In fact, there is a famous quote from an ancient Greek doctor, Hippocrates, who is considered the founder of scientific medicine:

"Let food be thy medicine and medicine be thy food."

In addition to essential nutrients, some examples of foods and food substances that have been regarded as nutraceutical include whole-grain foods, fruits and vegetables, whey protein, soy protein, garlic, onions, fish oils, green tea, soy isoflavones, lutein, lycopene, curcumin, sphingolipids, resveratrol, isothiocynates, conjugated linoleic acid, quercetin, beta-carotene, capsaicin, lecithin, fiber, catechins and probiotics. Thus, in addition to eating the right foods and supplements to ensure optimum intake of the essential nutrients, eating foods with nutraceutical value will serve to make your diet even healthier.

Dr. DeFelices's pioneering vision of creating a new branch of medicine has caught on somewhat with the FDA. In fact, as you will learn more about in a subsequent unit, the US's FDA recognized the disease prevention importance of food. It created a health claim system in which foods/nutrients can obtain approvals for helping prevent diseases based on their review of the science. Under this system, foods and foods substances can also have health claims to avoid or reduce their intake of due to potential disease-causing effects. Since the health claim regulations were in effect, the FDA approved more than a dozen foods/nutrients that can help prevent diseases, ranging from cardiovascular diseases to cancer. Health claims are for conventional foods and dietary supplements.

Research on Nutrients

Historically, the majority of research on nutrition focused on nutrient deficiencies, nutritional care for metabolic disorders like diabetes, and clinical nutrition. Nutrition research on improving physical performance and optimum health was historically scanty. However, from the late 1970s to the present, more and more research is being conducted on the ways in which nutrition affects athletic performance and health. Researchers are breaking the confines of traditional dogma, delving into unexplored areas of nutrition, and looking at the relationships between human performance, fitness, and nutrition. In fact, there are scientific journals filled with new research on how food and supplements affect athletic performance, and as an example, *The International Journal of Sport Nutrition and Exercise Metabolism* is dedicated to this one subject and to a growing list of other journals.

There is still opportunity for new discoveries, and this area of research is rapidly growing. The good news is that many fundamental and even some quite sophisticated discoveries have been made concerning the effects that nutrition has on athletic performance and fitness. These important scientific findings will be included in the following units about the nutrients. It is important to note, however, that most studies conducted on the effects that different nutrition programs and supplements may have on performance or body composition are often short in duration, several weeks to a few months. Therefore, it is important to understand that he long-term safety of some of the sports supplements may only be determined for these short periods. As such, if you or your clients practice certain supplement loading or use techniques, they are best done under the supervision of a doctor or nutritionist as a safeguard. There are very few cases reported in the scientific literature on supplements' causing adverse effects on healthy individuals. But you know that many athletes do not follow balanced diets, and they may rely on certain supplements as a majority of their food intake. This type of inadequate nutrition can lead to problems. Remember, supplements are intended to do just that: supplement the diet. They are not intended to replace good eating habits, meals, or whole foods.

While on the topic of research, another consideration is regarding old and new, effective or not effective. Old research findings are still valid for sports nutrition and other nutrition science. The Dietary Reference Intake reports for example review and rely on research that is sometimes decades old. The use of sugary and salty **energy drinks** by athletes continues and recommended by most sports medical and nutrition experts, and this original research is decades old. Part of the scientific process is repeating research studies, so ingredients like creatine may have over 100 research studies, most just reconfirming the initial findings of strength athlete benefits reported in the 1990s. Using the creatine

Energy Drink: a beverage that contains caffeine as an ingredient, along with other ingredients, such as taurine, herbal supplements, vitamins, and added sugars or other carbohydrates. It is usually marketed as a product that can improve perceived energy, stamina, athletic performance, or concentration.

example again for another consideration is conducting experiments for different dosages, timing of ingestion and other types of athletes. As a result of diversified research studies, some using ineffective dosages or creatine for endurance athletes that rely on aerobic energy pathways versus the anaerobic energy pathway creatine is most involved with, this “other research” will often find no benefit. Diversified research therefore includes testing the limits of use and benefits, and is common with nutrition research. Therefore, carefully read the research findings in light of the entire body of research to better judge the big picture and reality.

One more point regarding old versus new research can be made with drugs. Most drugs being used are based on research that is more than a decade old, and older. For example, the generic drugs are decades old. One of the oldest synthetic drugs, aspirin (acetylsalicylic acid), is still in use and still effective for reducing fever, pain, and inflammation for 100 years, in addition to new uses.

Food Safety

Multiple factors can be related to food safety, including dietary supplements which tend to be the safest type of food. A primary factor is that the food, ingredients, and dietary ingredients are determined to be safe for human consumption to begin with. The next factor is that during the transportation, processing, manufacturing, packing, storage, and handling, quality practices are used to prevent contamination of injurious substances or pathogens. Finally, another major factor is in the store, restaurant, and at home storage and handling.

How do we know then whether the food we are eating is safe? How do scientists determine whether a nutrient is harmful? Two primary ways are used to detect whether a food or food constituent is harmful / injurious to health. The first is epidemiological evidence, which results from studying groups of people in various areas of the world. You periodically read articles or watch news reports about a group of people living in a particular region that develops fewer numbers of certain cancers because their diets are low in fat and high in fiber. Epidemiological evidence can also be examined for the same population or group from year to year. In this way, researchers try to correlate the changes in diet from year to year to see whether there are increases or decreases in diet-related diseases.

The next way to determine whether a food will cause a disease is through direct experimental evidence. Because it is unethical to experiment on people with harmful substances, laboratory animals are used. The experimental animals eat different amounts of the suspected food substance to see what happens. In the case of cancer, the researchers might have observed epidemiological evidence indicating a food component as the cause of breast cancer. Lab researchers would then isolate the suspected compound, test different concentrations on lab animals, and observe the incidence of cancer formation. Even when the government agencies and independent researchers do their best, it may not be until years after a food is being used by the population before any harmful effects are detected. Then there is the reality of individuality, when a particular food or ingredient may be safe for one person but may cause health problems for another person—food allergies for example.

It's interesting to note that even when a substance is proven harmful to human health, it may still be available for human consumption. Some artificial ingredients used in foods have shown some evidence to cause cancers in laboratory animals or other laboratory tests but remain available in foods. Sometimes they are permitted in foods, under the condition that their labels bear a warning that studies show the product causes cancer in laboratory animals. California has standards for the presence of known or potentially toxic substances, primarily focused on cancer and reproductive health. As a result, consumers will sometimes encounter a warning statement such as "This product may contain a chemical known to cause cancer or birth defects or other reproductive harm." Such warnings may be found occurring on a variety of consumer products, not just ingestible products. Regarding ingestible products, presence of heavy metals, such as lead, mercury, and arsenic, above certain minimum amounts can be what triggered the need for the warning statement. Keep in mind that under federal FDA regulations, harmful substances referred to as adulterants are not permitted in foods or supplements and other regulated heath products. When it comes to the heavy metals, which occur naturally in the soil and are present in food at usually very low levels, there are limits that are usually tested for, in particular with processed/manufactured foods that need to pass finished product testing. Mercury in some seafood is another example of a potentially toxic substance in foods, where levels may not be detectable or low and not of concern or may be found at a higher level raising a concern not to eat these foods or to minimize their consumption, as the case may be.

The same is true with high levels of highly saturated fat foods, which may cause health problems when consumed in excess. Most recently the department of Health and Humans Services (HHS) determined that recent studies that indicate that consumption of trans fatty acids (also called trans fats, formed from the hydrogenation of oils used in foods) contributes to increased blood LDL-cholesterol ("bad: cholesterol) levels, which increase the risk of coronary heart disease (CHD). Recent information from the American Heart Association indicates that CHD causes about 500,000 deaths annually, making it the number one cause of death in the United States. Trans fats (hydrogenated oils / fats), a common ingredient in many foods, have now been determined to be unhealthy at any level in the diet. In the United States, trans fats are being phased out as a food additive. However, be aware that trans fats do occur naturally, and keep checking the nutrition labels if you want to avoid trans fat-containing foods.

In light of many unanswered question regarding artificial ingredients in foods, you can follow a "purest" health food approach, as it is best to create the healthiest nutrition starting point. In practice, it may not be possible to avoid or minimize some of the more undesirable ingredients found in foods, as they are commonly used. You will most likely have to adopt a health food, or organic, way of eating. Start by making the best selections for the foods you most often eat. As you develop the habit of examining what's in the foods you eat, eventually your diet will consist of healthier foods. Do your best and keep your diet as healthy as possible.

Foodborne illness is another major concern because a major percentage of problems with foods are linked to pathogenic organisms, such as certain bacteria, fungi, protozoa, worms, viruses, prions, and natural toxins. Examples of top food pathogens is presented in the following Special Topics section. Some examples of natural toxin include: Ciguatoxin, Shellfish toxins (PSP, DSP, NSP, ASP, AZP), Scombrotoxin, Tetrodotoxin, Mushroom toxins, Aflatoxins, Gempylotoxin, Pyrrolizidine alkaloids, Venomous fish, Grayanotoxins, Phytohaemagglutinin.

Some foods can also cause devastating allergic responses (see below for information about food allergies). Food allergies can be tricky to determine and live with. There is even some evidence that certain foods eaten before exercise can cause a food allergic response during exercise due to exercise physiology related changes that occur during exercise. Then there the category of food intolerance, such as lactose intolerance. For athletes who want to perform their best, and for everybody how wants to be their healthiest, one option is to work with a medical professional trained in determining food allergies and intolerances. This typically involves following a medically supervised elimination diet. Elimination diets usually eliminate the top problem foods and may be followed for a few to several weeks. Then the trained medical expert will start to reintroduce different types of potentially problem foods one at a time, and determine how the body reacts. The process continues for weeks or months until all types of foods are rotated in the diet to determine food allergies or intolerances. The variety of food additives, pesticides and other chemicals that may be presence in the diet can certainly complicate the evaluation process. For competitive athletes, the elimination diet process would be ideally conducted in the off-season.

GRAS

According to the FDA "GRAS" is an abbreviation for the phrase Generally Recognized as Safe. Under sections 201(s) and 409 of the Federal Food, Drug, and Cosmetic Act (the Act), any substance that is intentionally added to food is a food additive, that is subject to premarket review and approval by FDA, unless the substance is generally recognized, among qualified experts, as having been adequately shown to be safe under the conditions of its intended use, or unless the use of the substance is otherwise excluded from the definition of a food additive. Using this GRAS approach:

- The use of a food substance may be GRAS either through scientific procedures or, for a substance used in food before 1958, through experience based on common use in food.
- General recognition of safety through scientific procedures requires the same quantity and quality of scientific evidence as is required to obtain approval of the substance as a food additive and ordinarily is based upon published studies, which may be corroborated by unpublished studies and other data and information.
- General recognition of safety through experience based on common use in foods requires a substantial history of consumption for food use by a significant number of consumers.

New Dietary Ingredients (Dietary Supplements)

When the Dietary Supplement Health and Education Act was enacted in 1994, and the special food category of dietary supplements was created, the law and subsequent regulations created a process to address new dietary ingredients based on the GRAS and infant formula approaches. One approach is that if an ingredient is determined to be GRAS and used in conventional foods, it can be used as a dietary ingredient, assuming it meets the definition of dietary ingredient. The other approach unique for dietary supplements is referred to as New Dietary Ingredients Notification Process.

According to the FDA, the Federal Food, Drug, and Cosmetic Act (the FD&C Act) requires manufacturers and distributors that wish to market dietary supplements that contain “new dietary ingredients” notify the FDA about these ingredients. Generally, the notification must include information that is the basis on which the manufacturer or distributor has concluded that a dietary supplement containing a new dietary ingredient will reasonably be expected to be safe under the conditions of use recommended or suggested in the labeling. The FDA has also created a lengthy guidance document and other publications to clarify the process and assist companies when they have a new dietary ingredient they want to start using in dietary supplements. In practice, the FDA can delay and prolong the notification process if after it receives the initial submission, it has additional questions or concerns. regarding “other ingredients,” the technical ingredients, as with other foods, dietary supplements have to use other ingredients that have GRAS status.

Special Topics

Adulteration

Historically speaking, a major focus of the history of FDA laws and regulations was on the prevention of adulteration of foods. In the simplest sense, adulteration is concerned with substances that are injurious to health. But as with most laws and regulations, the related issues are usually more complex. The best way to gain an understanding of the issues related to adulteration of foods, including dietary supplements, is to read the legal definition, as follows.

§342. Adulterated food

A food shall be deemed to be adulterated-

(a) Poisonous, Insanitary, Etc., Ingredients

> (1) If it bears or contains any poisonous or deleterious substance which may render it injurious to health; but in case the substance is not an added substance such food shall not be considered adulterated under this clause if the quantity of such substance in such food does not ordinarily render it injurious to health.[1] (2)(A) if it bears or contains any added poisonous or added deleterious substance (other than a substance that is a pesticide chemical residue in or on a raw agricultural commodity or processed food, a food additive, a color additive, or a new animal drug) that is unsafe within the meaning of section 346 of this title; or (B) if it bears or contains a pesticide chemical residue that is unsafe within the meaning of section 346a(a) of this title; or (C) if it is or if it bears or contains (i) any food additive that is unsafe within the meaning of section 348 of this title; or (ii) a new animal drug (or conversion product thereof) that is unsafe within the meaning of section 360b of this title; or (3) if it consists in whole or in part of any filthy, putrid, or decomposed substance, or if it is otherwise unfit for food; or (4) if it has been prepared, packed, or held under insanitary conditions whereby it may have become contaminated with filth, or whereby it may have been rendered injurious to health; or (5) if it is, in whole or in part, the product of a diseased animal or of an animal which has died otherwise than by slaughter; or (6) if its container is composed, in whole or in part, of any poisonous or deleterious substance which may render the contents injurious to health; or (7) if it has been intentionally subjected to radiation, unless the use of the radiation was in conformity with a regulation or exemption in effect pursuant to section 348 of this title.

(B) Absence, Substitution, or Addition of Constituents

(1) If any valuable constituent has been in whole or in part omitted or abstracted therefrom; or (2) if any substance has been substituted wholly or in part therefor; or (3) if damage or inferiority has been concealed in any manner; or (4) if any substance has been added thereto or mixed or packed therewith so as to increase its bulk or weight, or reduce its quality or strength, or make it appear better or of greater value than it is.

(C) Color Additives

If it is, or it bears or contains, a color additive which is unsafe within the meaning of section 379e(a) of this title.

(D) Confectionery Containing Alcohol or Nonnutritive Substance

If it is confectionery, and-

(1) has partially or completely imbedded therein any nonnutritive object, except that this subparagraph shall not apply in the case of any nonnutritive object if, in the judgment of the Secretary as provided by regulations, such object is of practical functional value to the confectionery product and would not render the product injurious or hazardous to health;

(2) bears or contains any alcohol other than alcohol not in excess of one-half of 1 per centum by volume derived solely from the use of flavoring extracts, except that this clause shall not apply to confectionery which is introduced or delivered for introduction into, or received or held for sale in, interstate commerce if the sale of such confectionery is permitted under the laws of the State in which such confectionery is intended to be offered for sale; or

(3) bears or contains any nonnutritive substance, except that this subparagraph shall not apply to a safe nonnutritive substance which is in or on confectionery by reason of its use for some practical functional purpose in the manufacture, packaging, or storage of such confectionery if the use of the substance does not promote deception of the consumer or otherwise result in adulteration or misbranding in violation of any provision of this chapter, except that the Secretary may, for the purpose of avoiding or resolving uncertainty as to the application of this subparagraph, issue regulations allowing or prohibiting the use of particular nonnutritive substances.

(E) Oleomargarine Containing Filthy, Putrid, Etc., Matter

If it is oleomargarine or margarine or butter and any of the raw material used therein consisted in whole or in part of any filthy, putrid, or decomposed substance, or such oleomargarine or margarine or butter is otherwise unfit for food.

(F) DIETARY SUPPLEMENT OR INGREDIENT: SAFETY

(1) If it is a dietary supplement or contains a dietary ingredient that-

(A) presents a significant or unreasonable risk of illness or injury under-

(i) conditions of use recommended or suggested in labeling, or

(ii) if no conditions of use are suggested or recommended in the labeling, under ordinary conditions of use;

(B) is a new dietary ingredient for which there is inadequate information to provide reasonable assurance that such ingredient does not present a significant or unreasonable risk of illness or injury;

(C) the Secretary declares to pose an imminent hazard to public health or safety, except that the authority to make such declaration shall not be delegated and the Secretary shall promptly after such a declaration initiate a proceeding in accordance with sections 554 and 556 of title 5 to affirm or withdraw the declaration; or

(D) is or contains a dietary ingredient that renders it adulterated under paragraph (a)(1) under the conditions of use recommended or suggested in the labeling of such dietary supplement.

In any proceeding under this subparagraph, the United States shall bear the burden of proof on each element to show that a dietary supplement is adulterated. The court shall decide any issue under this paragraph on a de novo basis.

(2) Before the Secretary may report to a United States attorney a violation of paragraph [2] (1)(A) for a civil proceeding, the person against whom such proceeding would be initiated shall be given appropriate notice and the opportunity to present views, orally and in writing, at least 10 days before such notice, with regard to such proceeding.

(G) DIETARY SUPPLEMENT: MANUFACTURING PRACTICES

(1) If it is a dietary supplement and it has been prepared, packed, or held under conditions that do not meet current good manufacturing practice regulations, including regulations requiring, when necessary, expiration date labeling, issued by the Secretary under subparagraph (2).

(2) The Secretary may by regulation prescribe good manufacturing practices for dietary supplements. Such regulations shall be modeled after current good manufacturing practice regulations for food and may not impose standards for which there is no current and generally available analytical methodology. No standard of current good manufacturing practice may be imposed unless such standard is included in a regulation promulgated after notice and opportunity for comment in accordance with chapter 5 of title 5.

(h) Reoffer of Food Previously Denied Admission

> If it is an article of food imported or offered for import into the United States and the article of food has previously been refused admission under section 381(a) of this title, unless the person reoffering the article affirmatively establishes, at the expense of the owner or consignee of the article, that the article complies with the applicable requirements of this chapter, as determined by the Secretary.

(i) Noncompliance with Sanitary Transportation Practices

> If it is transported or offered for transport by a shipper, carrier by motor vehicle or rail vehicle, receiver, or any other person engaged in the transportation of food under conditions that are not in compliance with regulations promulgated under section 350e of this title.

[Source: http://uscode.house.gov/browse.xhtml]

Misbranding

Misbranding on the surface is a simple concept: The information on product labels has to be correct, but because of the numerous ways information mistakes can occur, combined with the numerous labeling laws and regulations, misbranding is more complex than adulteration is. Note that labeling of foods and dietary supplements will be reviewed in detail in another unit. But for now, an FDA-regulated food or dietary supplement product can be declared misbranded if there are mistakes in the information, such as not listing an ingredient that is contained in a product, listing an ingredient that is not contained in a product, omitting information required by FDA's labeling regulations, or including information that is not truthful or is misleading. Depending on the specific misbranding circumstance, the FDA may require products to be recalled, or it may choose to warn the offending company and demand corrections as soon as possible on new product inventory. Recalls are typically requested when the misbranding can result in adverse health outcomes, such as not listing an ingredient that is a known allergen, or if an unauthorized new ingredient is in a product with potential health concerns.

Food Allergy and Intolerance

According to the FDA, food allergies can range from merely irritating to life-threatening. Each year, millions of Americans experience food allergies, some cases resulting in hospitalization or, in some cases, even death. A food allergy is a specific type of adverse food reaction involving the immune system. The body produces what is called an allergic, or immunoglobulin E (IgE), antibody to a food. Once a specific food is ingested and binds with the IgE antibody, an allergic response occurs. Although note that some experts claim there may be additional mechanisms to an allergic response, the IgE appears to be the most prevalent one.

A food allergy should not be confused with a food intolerance or other nonallergic food reactions. Food intolerance refers to an abnormal response to a food or additive, but it differs from an allergy in that it does not involve the immune system. For example, people who have recurring gastrointestinal problems when they drink milk may say they have a milk allergy. But they really may be lactose intolerant. One of the main differences between food allergies and food intolerances is that food allergies can result in an immediate life-threatening response. Thus, typically compared with food intolerances, food allergic reactions pose a much greater health risk; however, both types of food reactions are health concerns that should be identified and treated by expert health professionals.

Blood Pressure: the pressure of the blood against the walls of the arteries.

Food Groups: a method of grouping similar foods for descriptive and guidance purposes. Food groups in the USDA Food Patterns are defined as vegetables, fruits, grains, dairy, and protein foods. Some of these groups are divided into subgroups, such as dark-green vegetables or whole grains, which may have intake goals or limits. Foods are grouped within food groups based on their similarity in nutritional composition and other dietary benefits. For assignment to food groups, mixed dishes are disaggregated into their major component parts.

Symptoms of a food allergy usually develop within about an hour after eating the offending food. The most common signs and symptoms of a food allergy include:

- Hives, itching, or skin rash
- Swelling of the lips, face, tongue and throat, or other parts of the body
- Wheezing, nasal congestion, or trouble breathing
- Abdominal pain, diarrhea, nausea, or vomiting
- Dizziness, lightheadedness, or fainting

In a severe allergic reaction to food—called anaphylaxis—you may have more extreme versions of the above reactions. Or you may experience life-threatening signs and symptoms such as:

- Swelling of the throat and air passages that make it difficult to breathe
- Shock, with a severe drop in **blood pressure**
- Rapid, irregular pulse
- Loss of consciousness

Food labels are required to state clearly whether the food contains a major food allergen. A major food allergen is defined as one of the following foods or **food groups** or is an ingredient that contains protein derived from one of the following foods or food groups:

- Milk
- Eggs
- Peanuts
- Tree nuts such as almonds, walnuts, and pecans
- Soybeans
- Wheat
- Fish
- Shellfish such as crab, lobster, and shrimp

An important point to consider regarding this situation is that these foods or food groups account for about 90 percent of all food allergies in the United States, with focuses on IgE-related food allergies. Therefore, this required food allergy labeling does not protect everyone with a food allergy but should likely protect the majority of people who may have severe allergic responses to foods.

If you have food allergies, you must be prepared for unintentional exposures. The National Institute of Allergies and Infectious Diseases (NIAID) recommends that people with food allergies do the following:

- Wear a medical alert bracelet or necklace stating that you have a food allergy and are subject to severe reactions.
- Carry an auto-injector device containing epinephrine (adrenaline) that you can get by prescription and give to yourself if you think you are experiencing a food allergic reaction.
- Seek medical help immediately if you experience a food allergic reaction, even if you have already given yourself epinephrine, either by calling 911 or getting transportation to an emergency room.

BSE (Bovine Spongiform Encephalopathy)

According to the FDA, BSE is thought to arise due to disease causing prions. Prions (pronounced "PREE – ons") aren't living things but may cause a certain type of rare, deadly disease if infected cattle are eaten. Prion disease in cattle isn't common (there have been only three known cattle cases in the United States) and affects the brain, some nerves, the spinal cord, eyes, tonsils, and bowel.

Since 1996, when it first appeared in humans, only 217 people in the world are known to have contracted the disease, whose medical name is "variant Creutzfeldt-Jakob disease," shortened to vCJD. It's thought that the meat these people ate was contaminated because the cattle had been given feed that contained parts of other dead cattle (as a protein source) that were contaminated with disease-causing prions. Since that kind of cattle feed has been banned, the number of new cases has dropped even lower.

In both humans and cattle, disease-causing prions are a protein that has taken on the wrong shape. Normally, the correctly shaped prion protein helps the brain and nerves work properly, but when it takes on the wrong shape, it can result in vCJD in humans. Once meat from diseased cattle is eaten and diseased prions enter a person's system, they turn the normal prions into disease-causing prions, and the brain and nerves no longer work properly, leading to death. It's thought that symptoms don't appear until about 10 years after the infectious meat is eaten. The illness may begin with depression or other psychiatric problems and develop into neurologic symptoms, such as unpleasant feelings in the face, arms, and legs and trouble understanding, remembering, talking, and walking, which becomes extreme.

Note that the FDA also works with the US Department of Agriculture (USDA) to keep cows in the United States healthy and free of BSE. The USDA prevents high-risk cows and cow products from entering the United States from other countries. The USDA also makes sure that high-risk cow parts, such as the brains and spinal cords, and cows that are unable to walk or that show other signs of disease are not used to make food for people. The steps the FDA and USDA have taken to prevent cows in the United States from contracting BSE are working very well. Only four cows with BSE have been found in the United States. Three of these cows were born in the United States, and the fourth was born in Canada. According to information published by the FDA, the last cow with BSE in the United States was found in 2012.

[http://www.fda.gov/AnimalVeterinary/ResourcesforYou/AnimalHealthLiteracy/ucm136222.htm]

Genetically Engineered (GE) Foods

Foods from genetically engineered plants is a topic that can fill volumes of course books. The FDA is involved in regulating GE plants and notes: "We regulate human and animal food from genetically engineered (GE) plants like we regulate all food. The existing FDA safety requirements impose a clear legal duty on everyone in the farm to table continuum to market safe foods to consumers, regardless of the process by which such foods are created. It is unlawful to produce, process, store, ship or sell to consumers unsafe foods. FDA's role is to ensure that everyone in the farm to table continuum is meeting this obligation. We encourage producers of new foods and food ingredients to consult with FDA when there is a question about an ingredient's regulatory status. This general practice extends to foods produced using genetic engineering techniques." The following information from the FDA addresses some of the common questions asked by health professionals and consumers.

Consumer Info about Food from Genetically Engineered Plants

FDA regulates the safety of food for humans and animals, including foods produced from genetically engineered (GE) plants. Foods from GE plants must meet the same food safety requirements as foods derived from traditionally bred plants.

While genetic engineering is sometimes referred to as "genetic modification" producing "genetically modified organisms (GMOs)," FDA considers "genetic engineering" to be the more precise term.

Crop improvement happens all the time, and genetic engineering is just one form of it. We use the term "genetic engineering" to refer to genetic modification practices that utilize modern biotechnology. In this process, scientists make targeted changes to a plant's genetic makeup to give the plant a new desirable trait. For example, two new apple varieties have been genetically engineered to resist browning associated with cuts and bruises by reducing levels of enzymes that can cause browning.

Humans have been modifying crops for thousands of years through selective breeding. Early farmers developed cross breeding methods to grow numerous corn varieties with a range of colors, sizes, and uses. For example, the garden strawberries that consumers buy today resulted from a cross between a strawberry species native to North America and a strawberry species native to South America.

Why genetically engineer plants?

Developers genetically engineer plants for many of the same reasons that traditional breeding is used. They may want to create plants with better flavor, higher crop yield (output), greater resistance to insect damage, and immunity to plant diseases.

Traditional breeding involves repeatedly cross-pollinating plants until the breeder identifies offspring with the desired combination of traits. The breeding process introduces a number of genes into the plant. These genes may include the gene responsible for the desired trait, as well as genes responsible for unwanted characteristics.

Genetic engineering isolates the gene for the desired trait, adds it to a single plant cell in a laboratory, and generates a new plant from that cell. By narrowing the introduction to only one desired gene from the donor organism, scientists can eliminate unwanted characteristics from the donor's other genes.

Genetic engineering is often used in conjunction with traditional breeding to produce the genetically engineered plant varieties on the market today.

Am I eating food from genetically engineered plants?

Consumer Info about Food from Genetically Engineered Plants, continued

Foods from GE plants were introduced into our food supply in the 1990s. Cotton, corn and soybeans are the most common GE crops grown in the U.S. In 2012, GE soybeans accounted for 93 percent of all soybeans planted, and GE corn accounted for 88 percent of corn planted.

The majority of GE plants are used to make ingredients that are then used in other food products. Such ingredients include:

- Corn starch in soups and sauces
- Corn syrup used as a sweetener
- Corn oil, canola oil and soybean oil in mayonnaise, salad dressings, breads, and snack foods
- Sugar from sugar beets in various foods

Other major crops with GE varieties include potatoes, squash, apples, and papayas.

Are foods from GE plants safe to eat?

Yes. Credible evidence has demonstrated that foods from the GE plant varieties marketed to date are as safe as comparable, non-GE foods.

Are Foods from GE plants regulated?

Yes. FDA regulates foods from GE crops in conjunction with the U.S. Department of Agriculture (USDA) and the Environmental Protection Agency (EPA).

FDA enforces the U.S. food safety laws that prohibit unsafe food. GE plants must meet the same legal requirements that apply to all food. To help ensure that firms are meeting their obligation to market only safe and lawful foods, FDA encourages developers of GE plants to consult with the agency before marketing their products. For more information about the Plant Biotechnology Consultation Program, see How FDA regulates food from GE plants.

The mission of USDA's Animal and Plant Health Inspection Service APHIS is to safeguard the health, welfare and value of American agriculture and natural resources, including regulating the introduction of certain genetically engineered organisms that may pose a risk to plant health. To learn more about APHIS regulation of genetically engineered organisms, visit their website.

EPA regulates pesticides, including those genetically engineered into food crops, to make sure that pesticides are safe for human and animal consumption and won't harm the environment. For additional information, see the EPA's Regulating Biopesticides web page.

How Does FDA Evaluate the Safety of GE Plants?

During the FDA consultation process, the food developer conducts a safety assessment. This safety assessment identifies the distinguishing attributes of the new traits in the plant and assesses whether any new material in food made from the GE plant is safe when eaten by humans or animals. As part of this assessment, the developer compares the levels of nutrients and other components in the food to those in food from traditionally bred plants or other comparable foods.

The developer submits a summary of its safety assessment to FDA for FDA's evaluation. When the safety assessment is received by FDA, our scientists carefully evaluate the data and information. FDA considers the consultation to be complete only when its team of scientists is satisfied that the developer's safety assessment has adequately addressed all safety and other regulatory issues. To learn more about the consultation process, see How FDA regulates food from GE plants.

[http://www.fda.gov/Food/FoodScienceResearch/GEPlants/ucm461805.htm]

Gluten

Gluten is a term that refers to a mixture of proteins that occur in some grains, such as wheat. Gluten exhibits viscoelastic properties, providing elasticity to dough and structure and chewy texture to bread and other gluten-containing food products. Gluten's characteristics are also useful for other types of processed foods, imitation meats for example. Health concerns about gluten were generated from its association with a disorder called celiac disease along with non-celiac gluten sensitivity and wheat allergy. The following FDA article provides additional information about gluten and the label referred to as "Gluten-Free"

'Gluten-Free' Now Means What It Says

In August 2013, the Food and Drug Administration issued a final rule that defined what characteristics a food has to have to bear a label that proclaims it "gluten-free." The rule also holds foods labeled "without gluten," "free of gluten," and "no gluten" to the same standard.

Manufacturers had one year to bring their labels into compliance. As of August 5, 2014, any food product bearing a gluten-free claim labeled on or after this date must meet the rule's requirements.

This rule was welcomed by advocates for people with celiac disease, who face potentially life-threatening illnesses if they eat the gluten found in breads, cakes, cereals, pastas and many other foods.

Andrea Levario, executive director of the American Celiac Disease Alliance, notes that there is no cure for celiac disease and the only way to manage the disease is dietary—not eating gluten. Without a standardized definition of "gluten-free," these consumers could never really be sure if their body would tolerate a food with that label, she adds.

As one of the criteria for using the claim "gluten-free," FDA set a gluten limit of less than 20 ppm (parts per million) in foods that carry this label. This is the lowest level that can be consistently detected in foods using valid scientific analytical tools. Also, most people with celiac disease can tolerate foods with very small amounts of gluten. This level is consistent with those set by other countries and international bodies that set food safety standards.

"This standard 'gluten-free' definition eliminates uncertainty about how food producers label their products. People with celiac disease can rest assured that foods labeled 'gluten-free' meet a clear standard established and enforced by FDA," says Felicia Billingslea, director of FDA's division of food labeling and standards.

What Is Gluten? Gluten is a mixture of proteins that occur naturally in wheat, rye, barley and crossbreeds of these grains.

As many as 3 million people in the United States have celiac disease. It occurs when the body's natural defense system reacts to gluten by attacking the lining of the small intestine. Without a healthy intestinal lining, the body cannot absorb the nutrients it needs. Delayed growth and nutrient deficiencies can result and may lead to conditions such as **anemia** (a lower than normal number of red blood cells) and osteoporosis, a disease in which bones become fragile and more likely to break. Other serious health problems may include diabetes, autoimmune thyroid disease and intestinal cancers.

Before the rule, there were no federal standards or definitions for the food industry to use in labeling products "gluten-free." An estimated 5 percent of foods formerly labeled "gluten-free" contained 20 ppm or more of gluten.

Anemia: a condition in which the oxygen-carrying capacity of the blood is reduced. It is the most common symptom of iron deficiency.

Gluten-Free' Now Means What It Says, continued

How Does FDA Define 'Gluten-Free'? In addition to limiting the unavoidable presence of gluten to less than 20 ppm, FDA now allows manufacturers to label a food "gluten-free" if the food does not contain any of the following:

- an ingredient that is any type of wheat, rye, barley, or crossbreeds of these grains
- an ingredient derived from these grains and that has not been processed to remove gluten
- an ingredient derived from these grains and that has been processed to remove gluten, if it results in the food containing 20 or more parts per million (ppm) gluten

Foods such as bottled spring water, fruits and vegetables, and eggs can also be labeled "gluten-free" if they inherently don't have any gluten.

Under the final rule, a food label that bears the claim "gluten-free," as well as the claims "free of gluten," "without gluten," and "no gluten," but fails to meet the requirements of the rule is considered misbranded and subject to regulatory action by FDA.

According to Felicia Billingslea, director of FDA's division of food labeling and standards, consumers should know that some foods labeled "gluten free" that are in the marketplace may have been labeled before the rule's compliance date of August 5.

Some of these foods, like pasta, have a longer shelf life and may legally remain on the shelves a little bit longer. Therefore, it is possible that stores may still be selling some foods that are labeled "gluten-free" produced before the compliance date of the final rule.

If consumers have any doubts about a product's ingredients and whether or not the product is gluten-free, they should contact the manufacturer or check its website for more information.

What About in Restaurants? Some restaurants use the term "gluten-free" in their menus. The gluten-free final rule applies to packaged foods, which may be sold in some retail and food-service establishments such as some carry-out restaurants. However, given the public health significance of "gluten-free" labeling, restaurants making a gluten-free claim on their menus should be consistent with FDA's definition.

State and local governments play an important role in oversight of restaurants. FDA will work with partners in state and local governments with respect to gluten-free labeling in restaurants.

Billingslea suggests that consumers who are concerned about gluten-free claims in restaurants ask the following questions when ordering foods described as gluten-free:

- •What does the restaurant mean by the term "gluten free?"
- •What ingredients are used in this item?
- •How is the item prepared?

"With the new FDA gluten-free regulations now being enforced, restaurants will be well-served to ensure they are meeting the FDA-defined claim," said Joy Dubost, Ph.D., R.D., Senior Director of Nutrition, National Restaurant Association. "We will continue to work with restaurant operators and chefs to assist and ensure a favorable dining experience for consumers."

This article appears on FDA's Consumer Updates page, which features the latest on all FDA-regulated products.

August 5, 2014 http://www.fda.gov/ForConsumers/ConsumerUpdates/ucm363069.htm

Foodborne Pathogens

The Centers for Disease Control and Prevention (CDC) estimates that each year roughly 48 million people become sick from a foodborne illness, 128,000 are hospitalized, and 3,000 die. The 2011 estimates provide the most accurate picture of which foodborne bacteria, viruses, microbes (pathogens) are causing the most illnesses in the United States. According to the 2011 estimates, the most common foodborne illnesses are caused by norovirus and by the bacteria salmonella, Clostridium perfringens, and Campylobacter. Foodborne pathogen infection is certainly a major impediment for athletes in training and during competition. In addition to your taking food safety steps, reviewed in another Unit, insights as to the sources and reasons of top foodborne pathogens will provide information to assist you with preventative actions and to also recognize common symptoms to be alert to for seeking medical treatment.

The chart on the following page, from the FDA, includes foodborne disease-causing organisms that frequently bring about illness in the United States. As the chart shows, the threats are numerous and varied, with symptoms ranging from relatively mild discomfort to extremely serious and even life-threatening illness. Although the very young, the elderly, and persons with weakened immune systems are at greatest risk of serious consequences from most foodborne illnesses, some of the organisms shown below pose grave threats to all persons. Athletes may be of increased risk from foodborne illness due to a possible weakened immune system from over training, from

inadequate nutrition, from improperly cooked foods, and from eating larger quantities of foods that are likely to contain foodborne pathogens.

A major step for reducing the risks of consuming foodborne pathogens is being aware of the sources, types of foods that carry pathogens, proper food handling, and proper food preparation along with reducing consumption of high-risk food sources, especially when eating outside the home. The following table presents some of the top foodborne pathogens. Take note of the common food pathogen food sources. This can provide you with insights on how to reduce the risk of foodborne illnesses, including proper purchasing, handling, and preparation of these foods and/or reducing or avoiding their consumption if foodborne illness problems persist with particular clients, upon confirmation by their physicians.

Foodborne disease-causing organisms					
Organism	**Common Name of Illness**	**Onset Time after Ingesting**	**Signs & Symptoms**	**Duration**	**Food Sources**
Bacillus cereus	B. cereus food poisoning	10–16 hrs	Abdominal cramps, watery diarrhea, nausea	24–48 hours	Meats, stews, gravies, vanilla sauce
Campylobacter jejuni	Campylobacteriosis	2–5 days	Diarrhea, cramps, fever, and vomiting; diarrhea may be bloody	2–10 days	Raw and undercooked poultry, unpasteurized milk, contaminated water
Clostridium botulinum	Botulism	12–72 hours	Vomiting, diarrhea, blurred vision, double vision, difficulty in swallowing, muscle weakness. Can result in respiratory failure and death	Variable	Improperly canned foods, especially home-canned vegetables, fermented fish, baked potatoes in aluminum foil
Clostridium perfringens	Perfringens food poisoning	8–16 hours	Intense abdominal cramps, watery diarrhea	Usually 24 hours	Meats, poultry, gravy, dried or precooked foods, time and/or temperature-abused foods
Cryptosporidium	Intestinal cryptosporidiosis	2–10 days	Diarrhea (usually watery), stomach cramps, upset stomach, slight fever	May be remitting and relapsing over weeks to months	Uncooked food or food contaminated by an ill food handler after cooking; contaminated drinking water
Cyclospora cayetanensis	Cyclosporiasis	1–14 days, usually at least 1 week	Diarrhea (usually watery), loss of appetite, substantial loss of weight, stomach cramps, nausea, vomiting, fatigue	May be remitting and relapsing over weeks to months	Various types of fresh produce (imported berries, lettuce, basil)
E. coli (Escherichia coli) producing toxin	E. coli infection (common cause of “travelers’ diarrhea”)	1–3 days	Watery diarrhea, abdominal cramps, some vomiting	3–7 or more days	Water or food contaminated with human feces

Foodborne disease-causing organisms, continued					
E. coli O157:H7	Hemorrhagic colitis or E. coli O157:H7 infection	1–8 days	Severe (often bloody) diarrhea, abdominal pain and vomiting. Usually, little or no fever is present. More common in children 4 years or younger. Can lead to kidney failure.	5–10 days	Undercooked beef (especially hamburger), unpasteurized milk and juice, raw fruits and vegetables (e.g. sprouts), and contaminated water
Hepatitis A	Hepatitis	28 days average (15–50 days)	Diarrhea, dark urine, jaundice, and flu-like symptoms, i.e., fever, headache, nausea, and abdominal pain	Variable, 2 weeks to 3 months	Raw produce, contaminated drinking water, uncooked foods and cooked foods that are not reheated after contact with an infected food handler; shellfish from contaminated waters
Listeria monocytogenes	Listeriosis	9-48 hrs for gastro-intestinal symptoms, 2-6 weeks for invasive disease	Fever, muscle aches, and nausea or diarrhea. Pregnant women may have mild flu-like illness, and infection can lead to premature delivery or stillbirth. The elderly or immunocompromised patients may develop bacteremia or meningitis.	Variable	Unpasteurized milk, soft cheeses made with unpasteurized milk, ready-to-eat deli meats
Noroviruses	Variously called viral gastroenteritis, winter diarrhea, acute non- bacterial gastroenteritis, food poisoning, and food infection	12–48 hrs	Nausea, vomiting, abdominal cramping, diarrhea, fever, headache. Diarrhea is more prevalent in adults, vomiting more common in children.	12–60 hrs	Raw produce, contaminated drinking water, uncooked foods and cooked foods that are not reheated after contact with an infected food handler; shellfish from contaminated waters

Foodborne disease-causing organisms , continued					
Salmonella	Salmonellosis	6–48 hours	Diarrhea, fever, abdominal cramps, vomiting	4-7 days	Eggs, poultry, meat, unpasteurized milk or juice, cheese, contaminated raw fruits and vegetables
Shigella	Shigellosis or Bacillary dysentery	4–7 days	Abdominal cramps, fever, and diarrhea. Stools may contain blood and mucus.	24-48 hrs	Raw produce, contaminated drinking water, uncooked foods and cooked foods that are not reheated after contact with an infected food handler
Staphylococcus aureus	Staphylococcal food poisoning	1–6 hours	Sudden onset of severe nausea and vomiting. Abdominal cramps. Diarrhea and fever may be present.	24-48 hours	Unrefrigerated or improperly refrigerated meats, potato and egg salads, cream pastries
Vibrio parahaemolyticus	V. parahaemolyticus infection	4–96 hours	Watery (occasionally bloody) diarrhea, abdominal cramps, nausea, vomiting, fever	2-5 days	Undercooked or raw seafood, such as shellfish
Vibrio vulnificus	V. vulnificus infection	1–7 days	Vomiting, diarrhea, abdominal pain, bloodborne infection. Fever, bleeding within the skin, ulcers requiring surgical removal. Can be fatal to persons with liver disease or weakened immune systems.	2-8 days	Undercooked or raw seafood, such as shellfish (especially oysters)
[http://www.fda.gov/Food/FoodborneIllnessContaminants/FoodborneIllnessesNeedToKnow/default.htm]					

CONCLUSION

The contents of this unit bring awareness to a diversity of important topics and considerations related to foods and dietary supplements. Although a major focus for an athlete's diet is to provide good nutrition sources for health and athletic importance, an equally important focus is to also be aware of the non-nutrient substances that can occur in foods that can be unhealthy or unnecessary and the need to eliminate or greatly reduce these non-nutritive substances from an athlete's diet.

Key Words

Essential Nutrient

Macronutrient

Micronutrients

Creatine (also, phosphocreatine)

Antioxidant

Enrichment

Fortification

Emulsifier

Protein

Fat

Energy Expenditure

Thermogenic Response

Thermogenesis

Metabolic Rate

Glucose

Starch

Macronutrient Modulation

Glycogen Depletion

Electrolyte Balance

Nutrient Dense

Bioavailability

Assimilation

Ergogenic Aids

Energy Drink

Blood Pressure

Food Groups

Anemia

Topics Covered In This Unit

UNIT 3

CARBOHYDRATES: THE ULTIMATE PERFORMANCE FOOD

Unit Outline

I. **Introduction**

II. **Carbohydrates and athletes**

a. **Athletic significance of carbohydrates**

III. **Types of carbohydrates**

a. **Simple carbohydrates**

b. **Complex carbohydrates**

i. Fiber

1. Overview of some common dietary and functional fibers

IV. **Digestion of carbohydrates**

a. **About the glycemic index**

b. **Glycemic load**

V. **Carbohydrates in the body—glucose and glycogen**

VI. **Carbohydrates for increased athletic performance**

VII. **Carbohydrates pre-exercise, during exercise, and post-exercise**

VIII. **Food and supplement sources of carbohydrate**

IX. **Conclusion**

Learning Objectives

- After completing this unit, you will be able to:
- Define and describe key terms related to carbohydrates.
- Understand the different types of carbohydrates.
- Determine Glycemic Index and Glycemic Load
- Discuss how carbohydrates affect athletic performance and health.

Introduction

For many people, and even some health professionals, carbohydrates are a macronutrient sometimes surrounded with controversy and misconceptions. Some of these issues have arisen related to the focus on weight loss and weight maintenance, labeling carbohydrates as bad for people watching their weight, whereas other issues related to carbohydrates concern possible adverse health effects (for certain types, that is). However, for athletes and just about everybody else, a plentiful daily intake of healthy carbohydrates is a vital part of the diet.

Taking a closer look at carbohydrates reveals this macronutrient is of vital importance for health and athletic performance. In general,

most people require that a major part of their food intake consist of healthy carbohydrates. The acceptable distribution range (ADR) for adults of daily carbohydrate intake is 45 to 65 percent of total daily calories, reported in the Dietary Reference Intake report.

Regarding health issues related to carbohydrates, what matters is are the types of carbohydrates and the amounts per day, along with other dietary factors. Healthy dietary carbohydrate trends are related to lower intake of simple refined sugars, increasing fiber intake, increasing more whole grain and whole complex carbohydrate-containing foods, and consuming higher amounts of the lower glycemic index value foods. But note that some dilemmas can arise when dealing with athletes, such as the use of the sugary and salty energy drinks and lower fiber foods for quicker digestion related to exercise, training, and competitions. Therefore, fine-tuning carbohydrate intake to best meet the food intake requirements for top athletic performance, balanced by being healthy, can be challenging at times but worth the effort in terms of improved athlete performance and good health.

Carbohydrates and Athletes

For athletes, carbohydrates are vital for high-energy production and peak athletic performance. Most athletes eating for top performance should consume in the range of 55 percent to 60 percent of their total daily calories from carbohydrates for maximum performance, from day to day. For some athletes, the percentage can even be higher, in particular on competition days or during glycogen loading, 60 percent to 70 percent. Then for some other athletes, lower than 55 percent may be required based on individualized needs, in particular in weight class sports and other sports in which achieving low body fat levels is required. Moreover, research has shown that the type of carbohydrate and food source ingested can affect performance, so consuming the right carbohydrate-containing foods and supplements is important for maximum energy, and other carbohydrate type considerations can be appropriate from meal to meal eating, and before, during, and after exercise, training, and workouts.

In addition to maintaining a balanced, diet rich in carbohydrates from meal to meal, with special emphasis on the pre-exercise/competition meal, carbohydrate energy beverage consumption timing can be a crucial factor for improving athletic performance. Properly timing consumption of a carbohydrate energy drink at the start of athletic activity or training and continuing consumption during exercise can help maintain energy levels and can help spare the body's **glycogen** stores, while post-exercise carbohydrate consumption is necessary for adequate replenishment of an athlete's glycogen body stores.

Glycogen: a complex carbohydrate that occurs only in animals; the form in which glucose is stored in the body.

Providing the body with an external source of carbohydrate during exercise may increase the time it takes the body to become exhausted, especially for athletes who train or compete strenuously for 45 minutes or longer. In other words, it increases athletic performance and duration and delays the onset of fatigue. Forty-five minutes may seem on the short side when considering glycogen depletion for endurance athletes that can usually take longer for total glycogen depletion. However, a shorter time period is set is to be mindful of the fact that it is common for athletes to have low glycogen stores from strenuous day-to-day training, and if glycogen stores start out low, then they can be depleted more quickly. When carbohydrate ingestion timing is right, if the body is exercising when the ingested carbohydrate starts to enter the blood stream, it is more readily used for energy and does not cause a rapid rise in **insulin** that could conflict with glucagon function and energy production that is vital for high-performance muscle contractions during athletic activities. This can also spare the use of the body's glycogen stores. More information about this topic is provided later in this UNIT 19.

Insulin: a hormone made by the pancreas, insulin helps move glucose (sugar) from the blood to muscles and other tissues. Insulin controls blood sugar levels.

Research continues to show that carbohydrates are the body's primary "high-energy" fuel source for athletic activities. Fat is important too, especially for endurance athletes. But lessons learned from researchers in the early 1900s who studied the effects of nutrient intake among runners and labor work performance revealed when physical work output was reduced as related to carbohydrates. By putting their subjects on a variety of experimental nutritional regimens, ranging from outright starvation to diets consisting of different proportions of fat, protein, and carbohydrates, these early researchers found a few interesting dynamics that hold true today, based on the volume of redundant research studies in this area of nutrition.

When the body runs out of its stored glycogen and is forced to just use fatty acids as the primary source of energy, physical performance can decline dramatically. Use of protein/amino acids also increases under glycogen depletion conditions. Endurance athletes call this "hitting the wall" or "bonking"—when their body's glycogen stores become depleted and they must rely on fatty acids and amino acids for energy production during training or events. Historically, long-distance athletes experienced the performance reducing effects of glycogen depletion before the performance enhancing benefits of carbohydrate loading, glycogen maintenance, and ingesting carbohydrate drinks during exercise was discovered.

Since the initial research was conducted, more insights about the importance carbohydrates have for athletic performance and health have been revealed. Thus, while the annual barrage of the many low-carb weight-loss fad diets might cause some confusion about carbohydrates, when it comes to optimum health and peak athletic performance, there is no confusion: adequate healthy carbohydrate consumption is an essential part of an athlete's nutrition program.

Also important is consuming an adequate daily supply of carbohydrates as part of a comprehensive, mixed nutrient diet and from use of sports supplements. As such, for peak athletic performance and health, athletes must consider the type of carbohydrates they eat, the time of day they eat them, their intake of nutrient **cofactors**, and adequate intake of the other essential nutrients. All these elements together help maintain the body's glycogen stores and enhance energy production during exercise. Glycogen is a complex molecule that contains glucose and is found in muscle, the liver, and other tissues. Glycogen therefore acts as a reserve of glucose energy, which is released when needed to provide energy for exercising muscles and other parts of the body. As the glycogen stores are small, and thus quickly depleted, daily carbohydrate consumption is mandatory to ensure maximum glycogen stores for peak energy production.

Cofactor: a substance that must be present for another substance to be able to perform a certain function.

The rate of carbohydrate digestion, absorption from the digestive system, rise in blood sugar levels, utilization as energy substrates, and storage in the body as glycogen are all important considerations. To gain a better understanding of these dynamics of carbohydrates in the body, the glycemic index was created, followed by the development of the concept of glycemic load, which will be reviewed herein.

Athletic Significance of Carbohydrates

- Carbohydrates are a high-energy-producing fuel source for muscles and other body tissue cells.
- Glucose is the major carbohydrate in the diet and used by the body for energy.
- Glucose is the primary fuel for the brain and nervous system tissues.
- Complex carbohydrates should be eaten more than simple carbohydrates should be.
- Carbohydrate ingestion before, during, and after exercise needs to be timed properly.
- The body stores glucose in the form of glycogen.
- Carbohydrates are involved in maintaining blood glucose levels, which is vital to physical performance and health.
- Glucose also has a structural role, used to make glucosamine, which is used to form connective tissues.

Types of Carbohydrates

There are several types of energy-yielding carbohydrates and a diversity of common and scientific terminology related to dietary carbohydrates, for example, simple carbohydrates or sugars and complex carbohydrates or starches. The various types of carbohydrates are usually based on the sugar units present. Some of the scientific classification categories that will be elaborated on include monosaccharides, **disaccharides**, oligosaccharides, and **polysaccharides**. [Note that terminology related to carbohydrates and the other nutrients reviewed in the other units continually evolves and can sometimes vary.]

Disaccharide: a simple carbohydrate composed of two sugar molecules.

Polysaccharide: a complex carbohydrate.

The following information reviews some further details about the different types of carbohydrates. One point of interest about carbohydrates is how they behave and function in the body and how to use this knowledge for athletic performance advantage. In addition to the different rates of absorption from the digestive system, the primary monosaccharide's, glucose and fructose, behave differently in the body, with glucose being used more rapidly and efficiently by muscles and fructose being more slowly used. Getting the carbohydrate balancing act perfected is vital for intensively training athletes. This is also important for recreational athletes and fitness exercisers but less critical when compared with competitive elite athletes who have to maintain championship peak performance.

Simple Carbohydrates

The main types of simple carbohydrates include the following:

Monosaccharides. Monosaccharide carbohydrates consist of one sugar unit. Examples of monosaccharide type carbohydrates include glucose (also referred to as dextrose) and fructose.

Disaccharides. Disaccharides are compounds consisting of two sugar units. Examples of disaccharides include sucrose, which is made of one molecule each of glucose and fructose; maltose, made of two molecules of glucose; and lactose, made of one molecule each of glucose and galactose.

The term sugar is a catchall term that refers to various types of carbohydrates. For example, table sugar is sucrose, sugar units may refer to glucose or fructose, and blood sugar usually refers to the glucose present in the blood. This means that your blood sugar levels, glucose levels, are influenced by the type of carbohydrate glucose sources you ingest—complex carbohydrates, sucrose, maltose, lactose, and glucose (dextrose), for example.

The principal monosaccharide's in food are glucose and fructose. Glucose, also called dextrose or grape sugar, is found commonly in fruit, sweet corn, corn syrup, certain roots, and honey. Glucose is also contained in starch/complex carbohydrates. Fructose, also called levulose or fruit sugar, is found occurring freely, as part of the sucrose molecule in honey and fruit, and is part of the fructans.

Although glucose has traditionally been a frequently encountered dietary sugar, fructose's popularity began due to the discovery that it does not cause the rapid rise and fall in the blood sugar level that glucose does. Researchers realized this in the early 1980s when they undertook the first extensive comparisons of the various carbohydrates and carbohydrate-containing foods. They found that the main reason fructose is easier on the blood sugar level is that the body absorbs and metabolizes fructose at a slower rate than it does glucose. In fact, fructose must be converted to glucose in the liver before being used by most cells in the body, which further explains why it causes a slower rise in blood glucose levels. Because of the slower utilization of fructose and slower rise in blood sugar levels, it was thought that fructose ingestion could help people with blood sugar control problems or issues, such as diabetics, manage their blood sugar levels. Keep in mind that useful for nutritional management of diabetics does not necessarily mean good for health or improved athletic performance.

Fructose-containing products began to appear on the market in health food stores, promoted as a healthy alternative natural sweetener to table sugar. Although fructose may seem to have benefits over the other sugars from a blood glucose response point of view, it is still a sugar and supplies raw energy without much other essential nutrition. Another issue with fructose is that increasing the amount being consumed can tend to increase fatty acid production in the liver, leading to fatty liver, higher levels of fatty acids in the blood stream, and an increase in total body fat stores. Furthermore, the athletic benefits of increasing consumption of fructose are not clearly apparent. Glucose can be used by all cells, but fructose primarily needs to be metabolized in the liver first and then is metabolized for energy. This is important in muscle cell bio-energetics because muscle cells can use glucose more quickly than they can use fructose. Some research indicates fructose may play a role in replenishing liver glycogen at a higher rate, at the right amount, based on each athlete and in the context of his or her entire diet composition. Also, some research indicated that athletes engaging in lower intensity, longer duration endurance-type exercise, over two hours for example, may benefit from glucose and fructose ingestion, along with adequate water and electrolytes. This is thought to be because at the lower intensity, longer duration exercise, the metabolism is able to maximize the utilization pathways of glucose and fructose.

In addition, remember that eating too much of any sugar can lead to tooth decay. Concern over cavities is not just for children. Adult athletes with tooth decay may end up with disrupted athletic seasons due to root canal surgery or tooth extractions.

Fructose does have its place in nutrition in minor amounts. In addition to its slow rising effects on the blood-sugar level, fructose has also been found to help replenish the glycogen stores in the liver at a fast rate. Note that glucose replenishes both liver and muscle glycogen quickly. This is important because the brain derives most of its energy supply from the liver, which is especially low in glycogen in the morning. Perhaps the desire to drink juices high in fructose in the morning is more than coincidence, as these juices provide the mental surge of energy that so many people need to start the day. Note that once fructose is mixed with food, its benefits on blood sugar level becomes less clear depending on the other carbohydrates contained in the meal.

The blood sugar balancing act becomes a little tricky based on information that is in circulation, primarily weight-loss related. Weight loss is a special subject treated in UNIT 18, which should not be confused with nutrition for maximum athletic performance. Athletes need to consume two or more times the number of calories per day than nonathletic people do. Athletes need to be eating foods that are more easily digested and can be used by the body for fuel and growth. Athletes typically have the opposite problem compared with overweight people, meaning that athletes use calories at a faster rate and may have trouble ingesting adequate amounts of calories.

Overall glucose, principally from healthy complex carbohydrates, is the primary or preferred carbohydrate energy source for athletic people, but the strategic consumption of sucrose, glucose, and fructose can also play a role in sports nutrition. Pure fructose-containing products can be useful to help slow down the rise in blood sugar level and have applications for people with weight maintenance concerns.

In the current food supply, fructose and glucose come together in a few different ways in prepared foods.

- As sugar, which is 50% fructose and 50% glucose
- As high fructose corn syrup, which is about 42% to 55% fructose, and the remaining portion glucose.
- In varying amounts in energy drinks, sports drinks, gels, nutrition bars, and other prepared foods.

Although most people have a constant struggle with reducing consumption of refined sugars, a variety of synthetic and natural sugar substitutes are present in foods and supplements. The following article from the FDA provides an overview on Sugar Substitutes, followed by short mention about the natural sugar substitute referred to as Stevia. Note that while students requested more information about this topic to have a better understanding of this subject matter for communicating with clients, avoiding or minimizing the use of nonessential nutrient synthetic additives is usually preferred for a high-performance athletic diet.

High-intensity sweeteners: ingredients commonly used as sugar substitutes or sugar alternatives to sweeten and enhance the flavor of foods and beverages. People may choose these sweeteners in place of sugar for a number of reasons, including that they contribute few or no calories to the diet. Because high-intensity sweeteners are many times sweeter than table sugar (sucrose), smaller amounts of high-intensity sweeteners are needed to achieve the same level of sweetness as sugar in food and beverages. (Other terms commonly used to refer to sugar substitutes or alternatives include non-caloric, low-calorie, no-calorie, and artificial sweeteners, which may have different definitions and applications. A high-intensity sweetener may or may not be non-caloric, low-calorie, no-calorie, or artificial.)

Sugar Substitute Overview from the FDA

How Sweet It Is: All about Sugar Substitutes

Whether it's to cut down on the number of calories they consume or any of a variety of other reasons, some people use sugar substitutes—also called **high-intensity sweeteners**—to sweeten and add flavor to their foods. They can be used alone to sweeten foods and beverages such as iced tea or coffee or as an ingredient in other products. There are a number of sugar substitutes on the market from which to choose.

"Sugar substitutes are called 'high-intensity' because small amounts pack a large punch when it comes to sweetness," says Captain Andrew Zajac, US Public Health Service (USPHS), director of the Division of Petition Review at the Food and Drug Administration (FDA).

According to Zajac, unlike sweeteners such as sugar, honey, or molasses, high-intensity sweeteners add few or no calories to the foods they flavor. Also, high-intensity sweeteners generally do not raise blood sugar levels.

The FDA has approved a new high-intensity sweetener called advantame.

Advantame—which does not yet have a brand name (such as Sweet'N Low, a brand name for saccharin, or Equal, a brand name for aspartame)—has been approved as a new food additive for use as a sweetener and flavor enhancer in foods, except meat and poultry.

Examples of uses for which advantame has been approved include baked goods, non-alcoholic beverages (including soft drinks), chewing gum, confections and frostings, frozen desserts, gelatins and puddings, jams and jellies, processed fruits and fruit juices, toppings, and syrups.

How Do You Know It's Safe?

FDA is required by law to review all new food additives for safety before they can go on the market. The process begins when a company submits a food additive petition to FDA seeking approval. One exception is for substances "generally recognized as safe," or GRAS, because those substances are generally recognized by qualified experts as safe under the conditions of intended use and are exempt from the food additive approval process.

Zajac explains that the agency's scientists thoroughly review all the scientific evidence submitted by a company to ensure the product is safe for the intended use.

"In determining the safety of advantame, FDA reviewed data from 37 animal and human studies designed to identify possible toxic (harmful) effects, including effects on the immune, reproductive and developmental, and nervous systems," Zajac says.

Advantame is chemically related to aspartame, and certain individuals should avoid or restrict the use of aspartame. To that end, FDA evaluated whether the same individuals should avoid or restrict advantame, as well.

People who have phenylketonuria (PKU), a rare genetic disorder, have a difficult time metabolizing phenylalanine, a component of both aspartame and advantame. Newborns are tested for PKU using a common "heel-prick" test before they leave the hospital.

Foods containing aspartame must bear an information statement for people with PKU alerting them about the presence of phenylalanine. But advantame is much sweeter than aspartame, so only a very small amount needs to be used to reach the same level of sweetness. As a result, foods containing advantame do not need to bear that statement.

Five Already on the Market

The last high-intensity sweetener approved by FDA was Neotame (brand name Newtame) in 2002. There are four others on the market They include:

- Saccharin, was first discovered and used in 1879, before the current food additive approval process came into effect in 1958. Brand names include Sweet'N Low
- Aspartame, first approved for use in 1981. Brand names include Equal
- Acesulfame potassium (Ace-K), first approved for use in 1988. Brand names include Sweet One
- Sucralose, first approved for use in 1998. Brand name is Splenda

In addition to the six high-intensity sweeteners that are FDA-approved as food additives, the agency has received and has not questioned GRAS notices for two types of plant/fruit-based high-intensity sweeteners: certain steviol glycosides obtained from the leaves of the stevia plant (Stevia rebaudiana (Bertoni) Bertoni) and extracts obtained from Siraitia grosvenorii Swingle fruit, also known as Luo Han Guo or monk fruit.

While these high-intensity sweeteners are considered safe for their intended uses, certain individuals may have a particular sensitivity or adverse reaction to any food substance. Consumers should share with their health care provider any concerns they have about a negative food reaction.

In addition, FDA encourages consumers to report any adverse events through MedWatch: FDA's safety information and adverse event reporting program.

This article appears on FDA's Consumer Updates page, which features the latest on all FDA-regulated products.

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The Natural Sugar-Free Sweetener-Stevia

The plant Stevia rebaudiana, also referred to as Stevia, sugarleaf, sweetleaf or candyleaf, is the source of plant compounds that have sweetness. The active compounds of stevia leaves are referred to as steviol glycosides. The main compounds sold as sweeteners are stevioside and rebaudioside). Currently in the United States, FDA has not objected to the use of highly refined stevia preparations in food products. Rebaudioside A is a principle purified and concentrated molecule recognized by FDA as the sweetener that is obtained from Stevia leaves.

Complex Carbohydrates

The main types of complex carbohydrates include:

Oligosaccharides. Complex carbohydrates containing 3 to 10 sugar units. Some examples include raffinose and stachyose. Note that it is common to encounter oligosaccharides also being referred to polysaccharides.

Polysaccharides. Polysaccharides are complex carbohydrates that have 10 or more monosaccharide molecules linked together. The main dietary, energy yielding food source polysaccharide is referred to as starch (amylum) and consists of amylose (a linear molecule) and amylopectin (made of chains of glucose molecules). Glycogen is an example of another type of polysaccharide that is used to store carbohydrate energy in the body.

Fiber. Another kind of complex carbohydrate is fiber, which is described as the carbohydrates (also lignins, a type of complex organic polymers) that are not digested and not absorbed in the small intestine. Fiber is also referred to as roughage or nonstarchy polysaccharides. Some fiber examples include cellulose, hemicellulose, pectin, fructans, beta-glucans, and a variety of gums, mucilage, and algal polysaccharides. Fibers are usually components of plant cell walls and intracellular structures. The Dietary

Guideline definition is also noteworthy to review as follows: Fiber—Total fiber is the sum of dietary fiber and functional fiber. "Dietary fiber consists of nondigestible carbohydrates and lignin that are intrinsic and intact in plants (i.e., the fiber naturally occurring in foods). Functional fiber consists of isolated, nondigestible carbohydrates that have beneficial physiological effects in humans. Functional fibers are either extracted from natural sources or are synthetically manufactured and added to foods, beverages, and supplements."

The two polysaccharides that are the most important energy contributors to the body are starch from foods and from glycogen stored in the body. Processed forms of polysaccharides include maltodextrin and glucose polymers, which can be shorter glucose polymers than starch, and are commonly used in sports drinks because they are more soluble in water than starch is. Starch occurs in various parts of plants and consists of long chains of glucose units. The primary forms of starch molecules are amylose and amylopectin. Starch occurs in varying amounts in plant foods, such as grains, fruits, roots, vegetables, pasta, bread, and legumes.

Some research indicates the amylopectin is digested faster than amylase is and that the glucose from amylopectin is absorbed into the blood faster. This may explain why different complex carbohydrate-containing foods have different glycemic index values and affect the rise in blood sugar levels at different rates. However, there are other factors, such as fiber content that affect digestibility of carbohydrate foods. Also, the size of how fine flour is ground; the finer the flour, the higher the glycemic index becomes. Finer flour means smaller complex carbohydrate particle sizes, which can be digested more when compared with coarser or lager complex carbohydrate particle sizes.

When starch-containing foods are eaten, they are usually digested at a slow to moderate rate, releasing glucose molecules from the intestines into the bloodstream at a steady rate. This is unlike simple glucose, which is absorbed quickly from the digestive system into the bloodstream. Quick absorption leads to a rapid and high blood sugar level. You will read below that there are certain times a rapid absorption of glucose is advantageous, but for the general population and weight-conscious athletes, for most meals, a slower to moderate rate of carbohydrate digestion is more desirable. Athletes consuming higher numbers of calories, a few to several thousand calories per day, many need to maintain a higher rate of digestion and nutrient absorption, so consuming meals that have a moderate to high rate of carbohydrate digestion can be more desirable.

Fiber

Fiber is generally though as being indigestible by the small intestine. Fiber does play an important role as the main contributor to the roughage content of the diet. Among its protective qualities, roughage, which is also known as dietary fiber, helps promote efficient intestinal functioning and aids the absorption of sugars into the bloodstream. A formal definition of fiber developed in the United States by the Institute of Medicine is as follows: **Dietary Fiber** consists of nondigestible carbohydrates and lignin that are intrinsic and intact in plants. Put another way, dietary fiber consists of nondigestible food plant carbohydrates and lignin in which the plant matrix is largely intact.

There are two types of dietary fiber, and most plant foods contain some of each kind:

Soluble fiber dissolves in water to form a thick gel-like substance in the stomach. It is broken down by bacteria in the large intestine and provides some calories, about 2 kilocals or Calories per gram, from the carbohydrate breakdown products of bacterial metabolism. Soluble fiber can interfere with the absorption of dietary fat and cholesterol. This, in turn, can help lower low-density lipoprotein (LDL or "bad") cholesterol levels in the blood. Soluble fiber also slows digestion and the rate at which carbohydrates and other nutrients are absorbed into the bloodstream. This can help control the level of blood glucose (often referred to as blood sugar) by preventing rapid rises in blood glucose following a meal.

Insoluble fiber does not dissolve in water and passes through the gastrointestinal tract relatively intact and, therefore, is not a source of calories. Insoluble fiber provides "bulk" for stool formation and speeds up the movement of food and waste through the digestive system, which can help prevent constipation.

Both soluble and insoluble fiber may contribute to the feeling of fullness.

Functional Fiber consists of isolated, nondigestible carbohydrates that have beneficial physiological effects in humans. Functional fibers may be isolated or extracted using chemical, enzymatic, or aqueous steps. Synthetically manufactured or naturally occurring isolated oligosaccharides and manufactured resistant starch are included in this definition.

Total Fiber is the sum of dietary fiber and functional fiber.

Fiber is usually found along with digestible simple and complex carbohydrates in various plant foods, such as fruits, leaves, stalks, and the outer coverings of grains, nuts, seeds, and legumes. Dietary fiber helps soften the stool and encourages normal elimination. Fiber-rich diets also promote satiety. In addition, research has shown that people who eat high-fiber diets experience reduced rates of cardiovascular disease, colon cancer, and diabetes. A high-fiber diet works best when it includes plenty of fluids. Some supplements are specifically made to be pure fiber.

How much dietary fiber do adults need to gain these benefits? The National Research Council established the daily adequate intake range of fiber for adults, ranges from 21 to 38 grams. Some health experts recommend even a higher daily fiber intake. The estimated average fiber intake for men and women is only 12 to 18 grams per day. The 2015 Dietary Guidelines recommend 14 grams of fiber per 1,000 calories consumed. A 2,000-calorie-per-day diet would aim at supplying at least 28 grams of fiber. It's clear from these numbers that many people are eating diets too low in fiber. You can achieve this intake goal by eating foods high in fiber and by adding a fiber supplement to your diet.

It is important to note that there is some concern that diets high in fiber may interfere with mineral and other essential nutrient absorption. This interference, however, can be offset by a daily dietary supplement or even by the nutrients already present in the high-fiber foods themselves—another reason for consuming healthy nutrient dense foods. One issue of potential concern for athletes is getting too much fiber from the high-calorie diets required for energy balance during high-volume training periods and competition season. Another concern is fiber's potential effect on slowing down digestion and suppressing appetite. Then there is digestive upset from higher fiber diets experienced by some people, causing gas and having a laxative effect. Thus, health professionals may need to strive to keep fiber intake at a healthy level, but on the low end of the range.

Overview of Some Common Dietary and Functional Fibers

The following is a short overview of the common dietary fibers and functional fibers found in whole foods, processed foods, specialty foods, and dietary supplements.

Cellulose. Cellulose is a nondigestible polysaccharide consisting of glucose molecules linked together with a special bond. Cellulose is the main structural compound of plant cell walls. The beta-(1,4) bond that links the glucose molecules cannot be digested by humans, as humans lack digestive enzymes to break the beta-(1,4) linkages. In addition to cellulose that occurs naturally in foods, it is also separated out to make powder cellulose to use in food and supplement formations. Some uses of powdered cellulose include its being added to foods as a thickening agent. Cellulose may decrease transit time in the GI tract.

Chitin. Chitin, chemically know as (poly-N-acetyl-glucosamine) is one of the most common natural polymers. Chitin is present in the group of animals called arthropods. It occurs in the shells of crustaceans and insects. Chitin is also found in other organisms including fungi, algae, and yeast. Commercially, chitin is isolated from the shells of crustaceans after the edible parts have been removed, such as shrimp, lobsters, and crabs. Chitin is an amino-polysaccharide that contains the beta-(1,4) linkages present in cellulose.

Chitosan. Chitosan, chemically know as poly-D-glucosamine, also occurs naturally and is produced commercially from chitin using a simple manufacturing process. Chitosan is sometimes used in dietary supplements for its fat-binding abilities. Some research has shown that ingesting chitosan may slow down the absorption of cholesterol and fatty acids.

It is interesting to note that in the manufacturing processing of chitin and c hitosan, the glucosamine found in supplement products, can also be produced. As an aside, there is also a process for creating glucosamine from plant sources.

Beta-Glucans (β-Glucans). β-glucans are polysaccharides of branched glucose resides. These β-linked D-glucopyranose polymers are found in fungi, algae, and other plants. Barley, oat, and psyllium products contain beta-glucans. Beta-glucans are considered a soluble fiber and have cholesterol-binding properties. Therefore, foods high in beta- glucans are recognized for their cholesterol-lowering properties.

Fructo-oligosaccharide (FOS). Fructo-oligosaccharides are polymers of fructose and can contain a terminal molecule of glucose at the end of their chains. They are also referred to as fructans. Inulin and oligofructose are examples and occur naturally in a variety of plants. Some plant sources of fructans include chicory root, onions, and Jerusalem artichoke. As most fibers, the human digestive system lacks enzymes to digest them. However, certain bacteria in the colon can metabolize fructans. Fructans tend to be the preferred food for the "beneficial" intestinal bacteria. Fructans, like inulin, are used in dietary supplements aimed at improving gastrointestinal wellness. As dietary supplement ingredients, they are also referred to probiotics because they cause the beneficial intestinal bacterial to increase in number.

Gums. Gums consist of a diverse group of polysaccharides. They are typically derived from seeds for commercial applications. Gums are characteristically viscous in texture. One type of gum used in foods and supplements is called guar gum, which is produced by the milling of the endosperm portion of the guar seed and is high in galactomannans. Galactomannans are highly viscous soluble fibers and are typically used as food ingredients for their thickening and gelling properties. Guar gum is also a common ingredient used in some fiber supplements.

Hemicelluloses. Hemicelluloses are a group of polysaccharides found in plant cell walls. These polymers can consist of glucose, arabinose, mannose, xylose, and galacturonic acid. One type of hemicellulose you will see used in food or supplement products is glucomannan. Glucomannan is a viscous soluble fiber that absorbs water and is sometimes used in the treatment of constipation or to promote intestinal regularity. Glucomannan may also have cholesterol-lowering effects similar to beta-glucan. Some research indicates that it may help with appetite control. Similar to other fiber supplement-type products, glucomannan products are usually ingested by adding the glucomannan powder to water and then ingesting/drinking the beverage.

Pectins. Pectins are found in the cell wall and intracellular tissues of many fruits and berries. Pectins consist of galacturonic acid units with rhamnose interspersed in linear chains. Pectins are also water-soluble viscous fiber. Fruits and vegetables contain about 5 to 10 percent naturally occurring pectin. Commercially, pectins are typically extracted from citrus peels and apple pomace. Isolated pectins have gelling properties and are added to jams, jellies, and other foods. Pectins are sometimes added to dietary supplement and other food products to increase the fiber content, typically along with other types of fibers.

An interesting aside concerning pectins is their use in some cough and sore throat lozenge products. They have the ability to soothe inflamed and irritated tissues, and this helps alleviate sore throat and mouth.

Prebiotics

Prebiotics is a term used in relation to probiotics, the live microorganisms in the digestive tract that have beneficial effects. These types of carbohydrates are usually not very digestible by humans, but digestible by the probiotics and are referred to as prebiotics because they help probiotics to grow and maintain a good population in the intestines. Inulin is a primary prebiotic found in foods and supplements. Inulin is primarily a polysaccharide of fructose units, but also contains a glucose molecule at the end of each fructose chain.

Digestion of Carbohydrates

The chemical digestion of carbohydrates begins immediately in the mouth via enzymes that are present in the saliva and continues in the intestines where digestive juices further break down the long chains of glucose that make up disaccharides or polysaccharides. Maximum absorption occurs once the stomach empties its contents into the intestines. It is important to note that the composition and amount of the beverage, food, or meal being digested will determine the rate at which the stomach empties, also called the gastric emptying rate.

Starting with pure water, in general, water can empty from the stomach quickly. Depending on the amount and temperature of the water being ingested, water can leave the stomach and enter into intestines within a few minutes to several minutes in most cases and perhaps up to 30 minutes. Keep in mind that this is an approximate range of stomach emptying for water and will vary depending on the individual. Also, when it comes to just water intake, in general and during exercise, a larger quantity of ingested water generally empties from the stomach faster than a smaller quantity does.

More details about hydration will be reviewed in UNIT 6, but some basics are needed here too, as drinking a carbohydrate beverage can be useful for most athletes during their training and for many types of athletes depending on the length of the athletic event. Maintaining adequate hydration is important for all athletes and fitness exercisers for all sports and training. Therefore, it is mandatory to begin exercise in a well-hydrated condition and to periodically drink water during exercise and athletic events.

When it comes to regular meals, snacks, and other solid foods, depending on their size and contents, it can take one to a few hours for the stomach contents to completely empty into the intestines. Keep in mind that the stomach usually empties the contents of a meal slowly in squirts of digested fluid, a little at a time. Once the contents are in the intestines, it can take another one to few hours for the nutrients to be absorbed into the body.

Thus, from start to finish, it can take hours for nutrients ingested from a meal to clear the gastrointestinal tract and be completely absorbed into the body. This rate of digestion varies based on the meal size and food/nutrient composition but also based on the individual's digestive system abilities and rate. A nutritional digestion challenge for most athletes is to ingest foods for a healthy but faster rate of digestion to absorb the nutrients they need, which is typically double or more compared to nonathletes. The faster rate of digestion is required to nourish and replenish the body on a daily basis and for some athletes who need to consume calorie-containing beverages during exercise to maintain their peak performance.

For athletes who consume higher amounts of calories, digesting meals at a faster rate can be an important factor to properly nourish the body—allowing for a cleared gastrointestinal track of the previous meal eaten to enable peak performance. During digestion, fluids from the body are used, and blood flow is diverted to the digestive system. As these are also vital bodily resources needed for the exercising muscles, if the body is still digesting a meal when exercise begins, the amounts of fluids and blood flow available to muscles for peak performance could be reduced. Noting that some sports require strategic ingestion of energy-containing beverages during competition and training that work in harmony with the digestive system functioning. In addition, the rules for fitness exercisers have some flexibility because peak athletic performance is not required, although sometimes desirable.

These issues of the relationship between what is being ingested and the rate of digestion are of particular importance to competitive athletes wanting to be certain they are properly fueled for maximum performance. This is important to athletes not just for competitions, but also for training sessions. As such, start thinking about how a pre-competition or pre-exercise meal or beverage is going to be digested and absorbed to be available in your body for utilization and not still in your stomach and or intestines being digested. Also, think about how your competition or workout beverage is being digested to be used during physical activity.

> Ask yourself this: is the pre-exercise meal just sitting in the stomach causing belching and other gastrointestinal disruption?
>
> Is it slowing down the emptying rate of the stomach as to cause dehydration and early onset of fatigue or blood flow conflicts between the digestion system and muscles?

One goal in endurance performance sports nutrition was to determine how to best provide maximum hydration and also provide some energy to spare the body's supply of glycogen during athletic competition and training that lasted for a period that due to its length depleted the body's glycogen stores. During strength and aerobic exercise, glucose is a primary high-energy source, and it is beneficial to prevent the depletion of the body's supply of glucose during physical activity. More will be explained about this below.

Therefore, for some athletes, and other people who are undergoing physical activity for prolonged periods, ingesting a carbohydrate-containing beverage can help the body maintain a supply of high-energy carbohydrates for maintaining peak physical performance and mental performance, too, as glucose is the primary fuel for the brain and for exercising muscles. As the duration of exercise progresses, the body's use of fatty acids for fuel increases, but high-energy glucose is still used at a high rate during exercise as long as glucose is present.

Research continues to focus on determining what type and amount of carbohydrates could be added to water that would not reduce the fast stomach-emptying rate that is possible with water alone. Keeping in mind that most of the initial and majority of research was conducted using endurance athletes, it was determined experimentally that very dilute, low concentration carbohydrate-containing beverages were able to pass through the digestive system quickly during exercise and could be absorbed at a rate that could both rehydrate and supply an external source of carbohydrate energy. It was also determined that providing an ingested source of carbohydrate beverages during exercise can reduce fat metabolism during exercise. This may be a concern of athletes with a primary goal of losing body fat and perhaps may want to maximize fat use during exercise for fat-loss purposes.

Regarding ingestion of a carbohydrate beverage during exercise, generally: dilute 4 percent to 8 percent glucose solutions, empty the stomach at a fast enough rate to supply meaningful amounts of water and energy during exercise, to help maintain high physical performance longer. As the concentration of the solution increases, the rate of stomach emptying can be slower. This depends on the individual and his or her conditioning. Most studies examining the effects of carbohydrate energy beverages during exercise were conducted during single-event observations; the athletes show up that day, with no prior experience drinking the beverage during exercise. This limits the scope of results, as there is evidence that the gastrointestinal system can become conditioned over a period of carbohydrate drink training to be better at absorption during exercise. In other words, when athletes make drinking beverages part of their practice, their gastrointestinal system will become better conditioned to digest and absorb the beverage during exercise. Thus, when practicing to be better "on the run," it is important to also practice being better at "drinking on the run."

In addition, other ingredients added to the beverage must be considered, as their presence will increase the total concentration of the beverage solution. These usually include mineral electrolytes, such as sodium, chloride, magnesium and potassium that are lost via sweat during exercise or might help increase the rate of water and carbohydrate absorption. Sometimes amino acids and other ingredients are added to the exercise energy drinks. As most drinks report the nutrition ingredient content in grams and liquid contents in both ounces and milliliters, you can make a rough estimate of the percent concentration of your exercise beverage using this label information.

For estimating the percentage of a solution, you total carbohydrate and other nutrient contents on a gram basis for a serving size and divide this number by the mL (milliliters) of the serving size and then multiply this number by 100. This will give you the approximate percentage of the solution. For example, 8 grams divided by 200 mL = 0.04. Then, 0.04 times 100 = 4 percent. For multiple servings, use the same approach, adding up the nutrient contents and fluid volume of all of the servings. You can also check with the manufacturer of the product, which is highly recommended for competitive athletes who need the most accurate nutrient content information.

Be aware that as more research is being conducted on the upper range of beverage concentration, there is some indication that under certain circumstances, higher concentrations may also be feasible. For the competitive athlete, this is something to experiment with in conjunction with health professionals to determine what works best for each individual athlete.

Intensity and duration of exercise also play roles in the hydration and carbohydrate utilization dynamics. First it must be realized that there is a replenishment limitation of hydration and carbohydrate beverage intake, where at high-performance levels, water loss and carbohydrate utilization exceeds what can be replenished during exercise. This becomes especially important for athletes and individuals undergoing physical activity for a few to several hours, during which meal breaks are needed. For ultra-endurance events, this means conditioning the body to "eat on the run," in addition to consuming adequate hydration beverages, and becomes an important part of the overall training and conditioning program.

As such, drinking/eating is part of practice for most athletes. Yes, do not wait until the day of the competition to start ingesting beverages or eating performance foods during physical activity. Conditioning an athlete's body during practice and training to ingest drinks and/or performance foods is required to determine what works best with their digestive system. Realize that it can take several days or longer for the digestive system to adjust. For long-distance athletes performing their physical activity on a continual basis, ingesting fluids is usually not a problem. However, for athletes who are in "stop and go sports," like soccer, basketball, tennis, and football, or "jumping sports" like volleyball, there may be certain challenges associated with "stomaching" an exercise beverage that may be swishing around until the stomach empties. Therefore, development of individualized exercise/competition hydration and energy beverage consumption strategies is often needed.

Use of carbohydrate beverages becomes more important in athletic events that are longer, which may result in depleting the body's muscle and liver glycogen stores. This also depends on how adequate the glycogen stores are at the beginning of exercise. Therefore, it is extremely important to maintain proper caloric and carbohydrate intake all day long, each day, to ensure adequate glycogen replenishment and

maintenance. Assuming glycogen stores are adequate to begin with, glycogen depletion to the point of reducing athletic performance may become an issue after about 45 minutes of continuous strenuous exercise. This will be elaborated on in the following sections.

Once carbohydrates reach the intestines, glucose and fructose are absorbed at their respective rates, with glucose taken up more quickly than fructose is; galactose is absorbed similar to how fructose is. When complex carbohydrates are eaten, either alone or with sugars, their short chains of glucose polymers release glucose for absorption at the rate of digestion and digestive enzyme action. This rate of digestion and absorption is usually slower when compared with that of ingesting pure glucose and can provide a prolonged supply of glucose to the bloodstream and a supply of nutritional energy that further spares and replenishes muscle glycogen. One measure of the differential absorption rates of carbohydrates and carbohydrate foods and their effect on blood glucose levels is measured using the glycemic index, reviewed below in detail.

The intensity of exercise also affects the metabolism of carbohydrates during exercise—to maintain a balance of glucose production from liver and muscle glycogen stores and glucose uptake and utilization by the cells for energy. In the early days, it was observed that exercising muscles (contracting muscles) had what appeared to be an insulin-independent ability to take up and use glucose.

Upon closer examination however, from research with athletes and with diabetics, this is partially the case, but insulin levels and function during exercise appear to be more important than previously thought. With low- to moderate-intensity continuous exercise, insulin production and levels are present at a baseline level that is usually lower than measured when compared with levels stimulated from nutrient ingestion during rest. As exercise progresses, the insulin levels eventually begin to decline as the duration of exercise progresses. Some researchers point out that the insulin production and levels during exercise may be skewed on the low side due to rapid insulin use from exercising muscles. Whatever the case may be, with new insights to be determined, when glucose becomes present in the blood stream from ingesting an exercise beverage, or from glucose released from the body's glycogen stores, the production of insulin is expected to be stimulated at some level.

Another group of substances in the body associated with gluco-regulation during exercise is the catecholamines; epinephrine and norepinephrine. As moderate exercise progresses, the catecholamine levels have been measured to increase. However, a more significant rapid rise in catecholamines occurs during higher intensity continuous exercise and intensive anaerobic, explosive-type exercise and athletic performance.

It is thought that the catecholamines simulate a rapid production of glucose from the liver, based on experimentally measuring rates of catecholamine levels and glucose production during exercise. In addition to the production of glucogon-stimulated glucose, this catecholamine-induced glucose production offers the exercising muscles a plentiful supply of high-energy glucose needed for anaerobic metabolism and seems to provide a dual control mechanism to endogenous glucose production.

More research about gluco-regulatory mechanisms is needed to sort out some of these intricate physiological details. Of significance regarding the glucose production and glucose utilization model during exercise is that after intense exercise, a rapid increase in insulin levels is observed. The need for the increase of post-intense exercise insulin levels is thought to be a result of the high-intensity exercise-stimulated endogenous liver production and rapid glucose release and subsequent rapid rise in blood glucose levels. Under intense exercise conditions, the strenuously exercising muscle contractions stimulate glucose uptake, independent of insulin, so during exercise this surge in blood glucose can be delivered and used by the intensively contracting muscles. However, once exercise stops, the muscle contraction-stimulated uptake of glucose stops, and the body needs to increase insulin levels to clear the blood stream of the exercise-induced high levels of glucose to prevent prolonged hyperglycemia: high blood sugar levels.

These differing effects of exercise intensities are of interest to athletes and underscore the importance of properly warming up and cooling down at the physical and physiological levels. Understanding of the rates of glucose production and glucose utilization influenced by exercise is especially important for the diabetic athlete or fitness exerciser and others who need to keep tight control over their blood sugar levels for health reasons.

The concern about the presence of high insulin levels at the beginning of exercise is that it tends to suppress the liberation of glucose from glycogen, and fats from body fat stores, and favors the storage of the ingested nutrients. When the body needs energy, between meals for example, the levels of the hormone glucogon increase to liberate glucose from glycogen stores and fat from fatty acids stores. However, it appears that the presence of glucose, from ingestion or liberation from glycogen can stimulate the release of insulin.

A concern regarding insulin levels is not to be starting exercise or athletic events with insulin levels being too elevated at the start of exercise as caused by the pre-exercise/pre-event meal or beverage. High levels of insulin can suppress the liberation and use of energy in the body during exercise, as insulin's function is to favor cell uptake of nutrients. High insulin levels can also cause a temporary hypoglycemic state: low blood sugar levels. As glucose is a primary fuel for all physical activity, this could reduce athletic performance. In the traditional athletic competition model, starting ingestion of a carbohydrate-containing beverage at the beginning of physical activity and during physical activity, lessens the carbohydrate ingestion insulin level effect, because exercising muscle has the ability to stimulate the uptake of glucose independent of insulin. The ability of muscle to do this appears to increase with increasing levels of exercise intensity / effort.

In general, carbohydrates are more quickly released from the stomach to the intestines than is either protein or fat. The more protein and fat that you eat, the longer your stomach will take to empty. Logically, therefore, you should eat and drink foods that are very high in carbohydrates before and during exercise to take advantage of this process. Again, this is why specially designed sports nutrition drinks can help increase athletic performance during competition and practice, especially the drinks that have been tested in clinical research studies.

About the Glycemic Index (GI)

The glycemic index is a method used to group carbohydrate foods based on their effect on blood glucose levels. When a carbohydrate-containing food is eaten and digested, as it is absorbed from the intestines to the blood stream, a rise in blood sugar occurs, namely glucose. This rise is usually accompanied by a rise in insulin. This rise of blood glucose and insulin that occurs after consumption of carbohydrate-containing foods is then followed by a fall in blood glucose and insulin levels. This rise and fall in blood glucose can be rapid or slow, depending on the types and amounts of carbohydrate contained in foods and sports nutrition products.

Thus, as different carbohydrates and different carbohydrate foods have different rates of digestion and absorption, researchers wanted to devise a way of classifying carbohydrate foods according to their effect on blood glucose levels. This initial interest was primarily motivated to gain a better understanding of the food intake/insulin production relationship to help improve dietary management of diabetes. But as with most research, there are other applications, namely for athletes, fitness, and general health.

The glycemic index is defined (determined) as the area under the curve for the increase in blood glucose after the ingestion of a set amount of carbohydrate in a particular food, in the two-hour post-ingestion period compared with that of a reference food. The standard amount is typically 50 grams, and the reference foods are either glucose or white bread. For example, using glucose as the standard, the GI for glucose would be 100, and the other foods would be compared with this reference curve.

David Jenkins and coworkers reported in their 1981 study, titled "Glycemic index of foods: A physiological basis for carbohydrate exchange," the first research to measure blood glucose response to foods. A copy of this pioneering research can be found at http://www.ajcn.org/cgi/content/abstract/34/3/362. For the majority of the foods and sugars tested, 50 grams were used. Blood samples were taken at 0, 15, 30, 45, 60, 90, and 120 minutes after the meals were eaten. By comparing the area under the plotted data curve for each food versus glucose, the Glycemic Index was born. As the reference point, the GI for glucose is 100. Most foods measured are below this value, with few exceptions.

The international table of glycemic index and glycemic load values was created and updated by scientists Kaye Foster-Powell, Susanna H.A. Holt, and Janette C. Brand-Miller and is located at: http://www.ajcn.org/cgi/content/full/76/1/5. When you review these comprehensive data, you will notice that some of the foods use a three-hour evaluation period, in addition to the original standard two-hour period. In addition, it is important to realize that although the reference tables are useful, the GI is food specific. Thus, similar foods and products may differ from region to region and between different brands of the same types of foods. This will become apparent when you review the table. Also important to note is that when mixing foods, the GI can change.

The initial interest in the glycemic response of foods was thought to have practical applications for creating diets to help people with diabetes control their blood sugar levels. Eventually this glycemic response research provided important insights about carbohydrate digestion and metabolism that have applications for planning diets for health, athletic performance, and management of other diet-related diseases, such as heart diseases and obesity. Some points to keep in mind about the GI reference information are that the 50 grams reference values are small when compared with the amount of foods people eat, especially athletes. Also, a mixed meal will obscure the GI of an individual food. Typically, a meal of different GIs will end up being a weighted average, the final GI of the mixed meal usually being somewhere between the highest and lowest of the individual GI food values.

Glycemic Index (GI) Examples of Common Foods			
100%	**91% to 99%**	**80% to 90%**	**70% to 79%**
Glucose	Lucozade (Sports Drink)	Corn Flakes Carrots Parsnips Instant Potatoes Honey	Whole Meal Bread Millet White Rice Broad Beans Potato
60 to 69		**50 to 59**	**40 to 49**
White Bread Brown Rice Muesli Shredded Wheat Ryvita Water Biscuits Bananas Raisins Mars Bar		Buckwheat Spaghetti Sweet Corn All Bran Cereal Oatmeal Biscuits Tea Biscuits Peas	Oranges & Orange Juice Whole Meal Spaghetti Porridge Oats Sweet Potato Beans Peas
30 to 39		**20 to 29**	**10 to 19**
Butter Beans Tomato Soup Haricot Beans Black-Eyed Peas Chick Peas Golden Delicious Apples Ice Cream Skim or Whole Milk Yogurt		Kidney Beans Lentils Fructose	Peanuts Soya Beans

Source of GI data: David J. A. Jenkins, Thomas M. S. Wolever, Rodney H. Taylor, Helen Barker, Hashmein Fielden, Janet M. Baldwin, Allen C. Bowling, Hillary C. Newman, Alexandra L. Jenkins, and David V. Goff. Glycemic index of foods: a physiological basis for carbohydratre exchange. The American Journal of Clinical Nutrition 34: March 1981, pp. 362–366.

For more examples of GI and GL values for various foods, refer to the following table that is available online: Atkinson FS, Foster-Powell K, Brand-Miller JC. International tables of glycemic index and glycemic load values: 2008. Diabetes Care 2008;31:2281–3.

http://care.diabetesjournals.org/content/31/12/2281?ijkey=a344a60d41d0cb6e6fe9ad93a26bc2c8895be631&keytype2=tf_ipsecsha

By Internet searching “glycemic index” and “glycemic load,” additional reference tables and scientific studies can be located.

Glycemic Load (GL)

Since the advent of the glycemic index, a related concept was developed called the glycemic load, abbreviated as GL. Although the glycemic index of a food provides an expectation of how fast a food will raise blood sugar levels, the GL is a calculation that considers the amount of the carbohydrate from food being ingested. It is ultimately how much of the food ingested that matters from a blood sugar elevation standpoint. Eating a mouthful of a high GI food will have very little short-term effects on raising blood sugar levels. However, eating large amounts, many mouthfuls of a high GI food, will cause a rapid and sustained high blood sugar level, with accompanying stimulation of high insulin levels.

The GL is calculated as follows:

(GI value of the food times the quantity of carbohydrate of the food serving)/100

For example, for a food with a GI of 54, and an available 20 grams of carbohydrate per serving, the GL would be (54 x 20) / 100 = 10.8

Eq. 3.1

It is important to note that the practical applications of using the GI and GL are ongoing. One thing is certain though: both the glycemic index and glycemic load measures can be useful for determining the potential behavior that carbohydrate-containing foods or meals have in the body as related to blood sugar levels and the accompanying rise and eventual fall of insulin levels.

There is some growing evidence at the general population level that people who eat diets with higher than average GI and GL values are more prone to becoming overweight or obese. This notion makes metabolic sense, as the average person overeating a diet abundant in high GI foods will have higher insulin levels, causing a tendency to store more body fat and to hold onto it. The growing consensus is that diets with low to moderate GI and GL values will be digested and processed in the body at a slower rate and cause lower average blood sugar levels and insulin levels. Additionally, the thinking is that this also allows the body to process the calories more effectively for energy use, opposed to the rapid influx of calories from high GI meals, which may cause a surplus of caloric load that encourages fat storage.

When it comes to athletes and physically active people, the picture changes. Athletes are better at using calories and use more of them when compared with sedentary people, who in contrast are leading a low physical activity lifestyle, one with little or no exercise. As indicated herein, there are times that athletes will benefit from ingesting higher GI beverages and foods. Also, considering the large amount of food athletes have to consume each day for meeting caloric and nutrient needs, consumption of a diet that is easily digested and absorbed may be warranted at times for athletes: a diet that consists of foods and meals with moderate to high GI and GL ratings. However, for a healthy athlete, low GI foods/meals can make a good foundation to the athlete's diet, along with moderate to high GI foods, meals, and sports nutrition supplements as may be required to achieve certain athletic performance nutrition goals.

For the athletic person, knowing which carbohydrate foods and sugars will provide a quick supply of energy, or will replenish glycogen stores rapidly, has led to many studies examining the different effects of sugar- and carbohydrate-containing beverages and foods and their effects on athletic performance, glycogen status, muscle growth, immune system function, and other measures of health and performance.

Carbohydrates in the Body-Glucose and Glycogen

Glycogen is similar to the starch found in plants in that it consists of chains of glucose units. However, glycogen and starch differ in structure. In addition, although starch occurs only in plants, glycogen occurs only in animals. Very little glycogen is found in food however. This is mainly because meat contains only small amounts of glycogen. Due to the human body's small storage capacity for glycogen, it needs a relatively constant supply of carbohydrates throughout the day. The body normally converts a portion of all ingested complex carbohydrates into glycogen, thereby replenishing its limited glycogen supply. It is estimated that depending on a person's size, the total glycogen supply is about 1,800 to 2,600 calories. As control of blood sugar levels is important for normal metabolism and health, the body is constantly storing and releasing glucose based on the influx of glucose from ingestion, between meals, or during physical activity when energy demands dramatically are increased.

In the human body, glycogen is found in all the cells. However, it is present in greater percentages in the muscle fibers and liver cells. In this way, the liver and muscles act as reservoirs for glucose. The liver's glycogen supply is used to regulate the blood sugar level. Furthermore, the glucose that is fed into the bloodstream from the liver's glycogen supply is the main source of energy for the brain. The brain can use more than 400 calories per day of glucose from the liver's glycogen. Athletes and other physically active individuals sometimes have a feeling of being bogged down. Many times, this feeling is due to a low level of liver glycogen. Eating a good amount of complex carbohydrates, especially at night, will replenish the glycogen supply and restore mental alertness and physical energy. High fructose-containing drinks also replenish the liver glycogen.

Glycogen is not stored by itself in the liver. Rather, it is stored together with water. In fact, every 1 ounce of glycogen is stored with about 3 ounces of water. This means that when glycogen is used, water is also removed from the body. Many fad diets take advantage of this

Insulin Index

Another index you may encounter related to the glycemic index is called the Insulin Index or Food Insulin Index. Blood levels of insulin are measured in response to an ingested food or meal. As the blood glucose response may not be proportional to the blood insulin response, measuring the insulin response provides additional information about the body. This also allows testing of other foods in addition to carbohydrate foods, such as protein and fats. Data collected can also be used to calculate an Insulin Load. The Insulin Index is primarily used by researchers and may be useful for medical professionals when dealing with people who have blood glucose and insulin-related problems.

phenomenon by requiring a low caloric intake coupled with a high protein consumption, which causes liver and muscle glycogen to be depleted in 24 to 48 hours. This glycogen depletion can result in a loss of several pounds of water, which many dieters mistake for a loss of body fat.

Moreover, because most weight-loss diets are low in calories, the body eliminates a few pounds of gastrointestinal bulk within a few days. Dieters usually mistake this for a loss of body fat. Thus, a week or two of fad dieting may result in a loss of several pounds of water weight and gastrointestinal bulk but perhaps only a mere pound or two of body fat. This is one reason fad dieters quickly, almost overnight, gain back the weight they lost. Understanding this is especially important for weight-conscious athletes, who typically deplete their glycogen supplies on low-calorie diets, blow up when they return to a normal diet, and then have to lose several pounds again a few days later. By keeping their caloric and carbohydrate intakes at normal levels, athletes can help their bodies work better and can maintain their glycogen supplies for better overall performance.

Glycogen depletion followed by glycogen replenishment, which is also known as glycogen loading (or supercompensation or carbohydrate loading), can cause the muscles to increase their water content considerably in association with the increased glycogen stores. When glycogen replenishment is complete, the increased body weight may induce the muscles to feel heavy and stiff. This may interfere with physical performance in certain athletic events, particularly in connection with sports that rely on repeated short bursts of all-out effort, such as sprinting, football, and basketball. Bodybuilders can take advantage of this phenomenon, however, and experienced bodybuilders know how to add size and hardness to their physiques on contest days for an added competitive edge through manipulation of diet composition.

Understanding glycogen storage and dynamics is a cornerstone of improving athletic performance nutritionally. Knowledgeable athletes recognize that they must keep their muscle and liver glycogen stores filled. They acknowledge that they must follow a daily nutrition program that encourages glycogen replenishment and spares glycogen utilization.

Muscle glycogen is preferentially replenished over liver glycogen. As mentioned previously, this can diminish the supply of glucose available to the brain. Researchers have determined a direct correlation between glycogen supply and performance. When glycogen supplies run low or are depleted, physical performance is reduced. This is especially true for endurance sports that are more than one to one and a half hours in duration. But strength sport and team sport athletes must also conserve and replenish glycogen stores every day to keep energy levels high and to maximize recovery. This glycogen maintenance translates into steady, faster improvements in performance.

Thus, for the athlete, some carbohydrate management goals include the following:

1. Keep muscle and liver glycogen stores filled;
2. Structure a daily nutrition program that encourages glycogen replenishment and spares glycogen utilization; and
3. Maximize glycogen stores using glycogen loading for endurance sports and for tournaments (long competition days) for other sports.

Carbohydrates for Increased Athletic Performance

To maintain glycogen stores, carbohydrate intake must be considered on a 24-hour per-day basis and pre-event basis. This means devoting your attention to several important factors:

1. Daily maintenance of carbohydrate balance for each meal
2. Pre-event and pre-exercise carbohydrate intake increase
3. Selective carbohydrate ingestion during exercise
4. Carbohydrate ingestion after exercise, and in some cases, the methodical buildup of muscle and liver glycogen prior to an event
5. Carbohydrate loading; for events lasting more than 1 or 1.5 hours or for tournaments of most sports
6. High intake of complex carbohydrates, with larger amounts of simple carbohydrates with breakfast, during exercise, and directly after exercise to quickly replace depleted glycogen stores

Maintaining carbohydrate balance is easily accomplished by eating several servings of carbohydrates per day. In general, eating a plentiful amount of complex carbohydrates with each meal is recommended, with simple carbohydrate intake reserved for special parts of the day. This means making sure to maintain consumption of carbohydrates every meal and with snacks.

Carbohydrates Pre-Exercise, during Exercise, and Post-Exercise

Details regarding pre-, during, and post-exercise carbohydrate intake are contained in Unit 17 along with details regarding sports nutrition approaches. The following will provide some overview information.

Pre-exercise, exercise, and post-exercise carbohydrate ingestion also needs to include fluid and electrolyte requirements. The pre-exercise meal is ideally high in carbohydrates, moderate to low in protein and fat, and eaten about two to three hours prior to exercise depending on the size of the meal, composition, and an athlete's rate of digestion. Carbohydrate type is generally complex and in the low to medium glycemic index range to provide a sustained blood sugar level response that can be useful for providing carbohydrate energy in addition to pre and during exercise energy drinks. This is important because it takes this long for the stomach to empty and glucose to enter the bloodstream. Too much protein, fiber, and fat in the pre-exercise meal will serve to lengthen the time it takes the stomach to empty. Several glasses of water should be consumed after the pre-exercise meal and 30 minutes before exercise. Studies have shown that several minutes before exercise, drinking fluids with glucose and some electrolytes is the most beneficial in sparing the body's supply of glycogen.

During exercise, water and/or a sports beverage with water and dilute carbohydrates per serving and a supply of electrolytes should be ingested. If the carbohydrate and electrolyte content is too high, the time it takes the stomach to empty will increase. For practice sessions and events exceeding 90 minutes in length, it is important to make sure a carbohydrate source and a supply of electrolytes are in the drink. Preferably, glucose or sucrose is mixed with a complex carbohydrate like maltodextrin. For events under 90 minutes, it is still a good practice to drink at least water to rehydrate, along with carbohydrates and electrolytes, depending on the athlete's specific training goals and requirements.

The benefits of drinking beverages containing carbohydrates and electrolytes are less clear for exercise lasting less than 90 minutes for performance, assuming glycogen levels are replenished prior to exercise. The benefits might not be immediate but may help reserve glycogen stores and prevent glycogen depletion on a daily basis. Research indicates that many athletes may suffer from chronic glycogen depletion, with decreased performance and increased recovery time. Therefore, pre-exercise and during-exercise carbohydrate beverages and other appropriate carbohydrate supplements, with personalized hydration and electrolytes, is an important sports nutrition practice to enable athletes to maintain a high level of athlete performance during exercise/training and competition.

After any exercise, it is vital to replenish the body with water, carbohydrates, protein, and other essential nutrients. This can be accomplished by preparing or purchasing a supplement drink designed for this purpose, followed by a full meal. If training after the last evening meal, one option is to prepare and drink a high carbohydrate multi-nutrient supplement drink that contains 300 to 600 calories, with vitamins,

minerals, protein and essential fatty acids. Additional water consumption will also be required during the post-exercise period, which is appropriate to replenish the water loss from sweat that could not be prevented during exercise hydration.

Note: Details about "Glycogen Loading" are provided in Unit 19.

Food and Supplement Sources of Carbohydrate

Carbohydrates tend to be the cheapest of the macronutrients when compared with protein and fat. For example, athletes can purchase several pounds of potatoes for only a few dollars and have a week's supply of high-quality complex carbohydrates. Some foods high in carbohydrates (more than 60 percent of calories) include ready-to-eat and cooked cereals (oats being one of the favorites) whole-grain breads, crackers, popcorn, rice, pasta, corn, potatoes, winter squash and yams, and some carbohydrate supplements.

Supplement sources include carbohydrate sport drinks that vary in caloric content and carbohydrate type. Caloric content generally runs from 90 to 400 calories per 8-ounce serving. There are many types, but they primarily contain either a simple carbohydrate source or a complex formula containing a mixture of simple carbohydrates, glucose polymers, and micronutrients. Some research indicates that although you can use foods alone for **glycogen sparing** and carbohydrate loading, use of these

Glycogen sparing: the saving of glycogen by the body for other functions.

special supplement products is slightly better for improving performance. However, they are also more expensive. Most athletes on a tight budget will use these special products during the season or the weeks directly preceding an important competition.

Some examples of foods that contain carbohydrates include the following:

- grains, such as bread, noodles, pasta, crackers, cereals, and rice
- fruits, such as apples, bananas, berries, mangoes, melons, and oranges
- dairy products, such as milk and yogurt
- legumes, including dried beans, lentils, and peas
- snack foods and sweets, such as cakes, cookies, candy, and other desserts
- juices, soft drinks, fruit drinks, sports drinks, and energy drinks that contain sugars
- vegetables, especially "starchy" vegetables such as potatoes, corn, and peas

Potatoes, peas, and corn are called starchy vegetables because they are high in starch. These vegetables have more carbohydrates per serving than nonstarchy vegetables do. Examples of nonstarchy vegetables are asparagus, broccoli, carrots, celery, green beans, lettuce and other salad greens, peppers, spinach, tomatoes, and zucchini.

Conclusion

Carbohydrates are a diverse group of macronutrients that contribute a major source of high-yielding energy for athletic performance. Athletes commonly are deficient in total daily carbohydrate intake and need to make an extra effort to consume the required intake of carbohydrates. Focusing on healthy types of carbohydrates is also important. Unit 17 will provide details regarding carbohydrate nutrition guidelines for athletes, including specialty topics, such as timing nutrient intake and percentage versus grams per kilogram of body weight carbohydrate-intake approaches.

Fiber-Containing Food Examples.					
Food	**Standard Portion Size**	**Calories in Standard**	**Dietary Fiber in Standard Portion (g)**	**Calories per 100**	**Dietary Fiber per 100 grams (g)**
High fiber bran ready-to-eat cereal	½ to ¾	60	9.1	200	29.3
Navy beans, cooked	½	127	9.6	140	10.5
Small white beans, cooked	½	127	9.3	142	10.4
Yellow beans, cooked	½	127	9.2	144	10.4
Shredded wheat ready-to-eat cereal (various)	1	155	5.0	321	9.6
Cranberry (roman) beans, cooked	½	120	8.9	136	10
Adzuki beans, cooked	½	147	8.4	128	7.3
French beans, cooked	½	114	8.3	129	9.4
Split peas, cooked	½	114	8.1	116	8.3
Chickpeas, canned	½	176	8.1	139	6.4
Lentils, cooked	½	115	7.8	116	7.9
Pinto beans, cooked	½	122	7.7	143	9
Black turtle beans, cooked	½	120	7.7	130	8.3
Mung beans, cooked	½	106	7.7	105	7.6
Black beans, cooked	½	114	7.5	132	8.7
Artichoke, globe or French, cooked	½	45	7.2	53	8.6
Lima beans, cooked	½	108	6.6	115	7
Great northern beans, canned	½	149	6.4	114	4.9
White beans, canned	½	149	6.3	114	4.8
Kidney beans, all types, cooked	½	112	5.7	127	6.4
Pigeon peas, cooked	½	102	5.6	121	6.7
Cowpeas, cooked	½	99	5.6	116	6.5
Wheat bran flakes ready-to-eat cereal (various)	¾	90	4.9	310	16.9
Pear, raw	1 medium	101	5.5	57	3.1
Pumpkin seeds, whole, roasted	1 ounce	126	5.2	446	18.4
Baked beans, canned, plain	½	119	5.2	94	4.1
Soybeans, cooked	½	149	5.2	173	6
Plain rye wafer crackers	2 wafers	73	5	334	22.9
Avocado	½	120	5	160	6.7
Broadbeans	½	94	4.6	110	5.4
Pink beans, cooked	½	126	4.5	149	5.3
Apple, with skin	1 medium	95	4.4	52	2.4

Food	Standard Portion Size	Calories in Standard	Dietary Fiber in Standard Portion (g)	Calories per 100	Dietary Fiber per 100 grams (g)
Green peas, cooked (fresh, frozen, canned)	½	59	3.5	69	4.1
Refried beans, canned	½	107	4.4	90	3.7
Chia seeds, dried	1 Tbsp	58	4.1	486	34.4
Bulgur, cooked	½	76	4.1	83	4.5
Mixed vegetables, cooked from frozen	½	59	4	65	4.4
Raspberries	½	32	4	52	6.5
Blackberries	½	31	3.8	43	5.3
Collards, cooked	½	32	3.8	33	4
Soybeans, green, cooked	½	127	3.8	141	4.2
Prunes, stewed	½	133	3.8	107	3.1
Sweet potato, baked in skin	1 medium	103	3.8	90	3.3
Figs, dried	¼	93	3.7	249	9.8
Pumpkin, canned	½	42	3.6	34	2.9
Potato, baked, with skin	1 medium	163	3.6	94	2.1
Popcorn, air-popped	3 cups	93	3.5	387	14.5
Almonds	1 ounce	164	3.5	579	12.5
Pears, dried	¼	118	3.4	262	7.5
Whole wheat spaghetti, cooked	½	87	3.2	124	4.5
Parsnips, cooked	½	55	3.1	71	4
Sunflower seed kernels, dry roasted	1 ounce	165	3.1	582	11.1
Orange	1 medium	69	3.1	49	2.2
Banana	1 medium	105	3.1	89	2.6
Guava	1 fruit	37	3	68	5.4
Oat bran muffin	1 small	178	3	270	4.6
Pearled barley, cooked	½	97	3	123	3.8
Winter squash, cooked	½	38	2.9	37	2.8
Dates	¼	104	2.9	282	8
Pistachios, dry roasted	1 ounce	161	2.8	567	9.9
Pecans, oil roasted	1 ounce	203	2.7	715	9.5
Hazelnuts or filberts	1 ounce	178	2.7	628	9.7
Peanuts, oil roasted	1 ounce	170	2.7	599	9.4
Whole wheat paratha bread	1 ounce	92	2.7	326	9.6
Quinoa, cooked	½	111	2.6	120	2.8

Key Words

- Glycogen
- Insulin
- Cofactor
- Disaccharide
- Polysaccharide
- High-intensity sweeteners
- Glycogen sparing

Topics Covered In This Unit

UNIT 4

PROTIEN AND AMINO ACIDS: MUSCLE BUILDERS AND MORE

Unit Outline

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a. The amino acids
b. Proteins/amino acids and energy

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b. Protein efficiency ratio
c. Net protein utilization
d. Biological value
e. Amino acid score
f. Protein quality for athletes
g. Nitrogen balance
h. Designing protein and amino-acid products
i. Free form and peptide-bonded amino acids

IV. Digestion of protein and amino acids

V. Amino Acid Review

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b. Arginine (GH, IGF, Nitric Oxide stimulation and more)
c. Asparagine
d. Aspartic Acid
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   i. Leucine, a key BCAA
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h. Cystine
i. Glutamic acid
j. Glutamine
i. Creatine and glutamine
k. Glycine
l. Histidine
m. Isoleucine
n. Leucine
o. Lysine
p. Methionine
q. Ornithine
r. Phenylalanine
s. Proline
t. Serine
u. Taurine
v. Threonine
w. Tryptophan
x. Tryosine
y. Valine
z. A final word on amino acids

VI. Special protein and amino acid needs for the athlete

a Food and Supplement Sources of Protein.
b. Whey protein gets results too
c. Effects of creatine monohydrate plus whey
d. Recommended dietary allowances for protein
e. Estimating daily protein requirements
   i. Cofactors
   ii. Check those labels
   iii. Connective tissue
f. Summary of protein and the athlete

VII. Conclusion

Learning Objectives

After completing this unit, you will be able to:

- Define and describe key terms related to protein and amino acids.
- Understand the different types of protein and amino acids and their major functions.
- Determine essential and nonessential amino acids
- Discuss how protein and amino acids affect athletic performance and heath.

INTRODUCTION

In this unit, the basics of protein are reviewed and the building blocks of proteins, referred to as amino acids, are discussed. The relationship between protein and the athlete has become something of legendary importance. Dating back to the first Olympic Games in ancient Greece, one of the earliest recorded athletic nutritional practices was that of consuming large amounts of protein to improve strength and performance. The most recent research confirms protein's role as a vital component of health and performance. However, studies have also established that diets that are too high in protein may be as counterproductive as are diets that are too low in protein. One thing is certain: active athletes require at least twice or more protein as nonathletes do.

Protein is an essential part of the diet and plays many roles in the body. Protein's roles are primarily structural but can be used by the body for energy during intensive exercise or when nutrition is inadequate. In these situations, to meet its metabolic needs, the body breaks down precious muscle tissue, which is a setback for an athlete who has been training hard to make gains. In addition, athletes need to eat just the right amount of protein to minimize the formation of metabolic waste products. When too much protein is consumed, the body converts the excess to fat and increases the blood levels of **ammonia** and **uric acid**. Ammonia and uric acid are metabolic waste products.

Ammonia: A toxic metabolic waste product.

Uric acid: toxic metabolic waste product.

The athlete's goal therefore is to maintain proper protein intake based on body weight, activity level, and muscle fiber composition. In general, endurance athletes with a higher level of slow-twitch muscle fibers require more protein than nonathletes do but not as much as strength athletes do. Strength athletes have larger muscles and more of the fast-twitch muscle fibers, requiring these athletes to increase the amount of protein intake. Then there are the athletes who are somewhere between these two extremes of endurance and strength. In addition to muscle fiber growth and repair, there are also different bio-energetics that need to be considered among the different athletes.

What Is Protein?

Polypeptide: four or more amino acids linked together.

Protein is a large molecule called a macromolecule or super-molecule. It is a **polypeptide**, a compound containing from 10 to 100 amino acid molecules. The amino acids are linked together by a chemical bond

Athletic Significance of Proteins and Amino Acids

- Protein is a source of amino acids.
- Athletes require a higher intake of protein.
- Amino acids are essential building blocks for growth, recovery, and production of many proteins occurring in the body.
- Branched Chain Amino Acids are a special group of amino acids that can be used for energy and are required in extra amounts.
- Individual Amino Acids can elicit targeted effects, for example, increasing growth hormone, IGF, testosterone, and nitric oxide production.
- Collagen—connective tissue—makes up one-third of total body protein content, making it one of the most common proteins in the body.

called a peptide bond. When we consider protein from a nutritional standpoint, we are concerned with the amino acid subunits. There are about 22 amino acids that are considered biologically important, but many more exist in nature, including in the body. Amino acids are important not only for being the building blocks of protein but also for the individual roles that they play in the body. For example, some amino acids are used by the body in metabolic processes such as the **urea cycle**, and others act as neurotransmitters, the chemical substances that help transmit nerve impulses.

Protein is needed for the growth, maintenance, and repair of cells, including muscle cells, and for the production of enzymes, **hormones**, and **deoxyribonucleic acid (DNA)** expression. Protein occurs in various sizes and shapes and is divided into two main categories—simple proteins and conjugated proteins. Simple proteins consist only of amino acids, whereas conjugated proteins also have non-protein molecules as part of their structures. Some simple proteins are serum albumin, which is present in blood; lactalbumin, which is present in milk; ovalbumin, which is present in eggs; myosin, present in muscle; **collagen**, present in **connective tissue**; and keratin, present in hair. Examples of conjugated proteins are nucleic acid, found in chromosomes; **lipoprotein**, found in **cell membranes**; glycoprotein, chromoprotein, and metaloprotein, all found in blood; and phosphoprotein, found in casein (milk protein). Protein constitutes the majority of the dry weight of most body cells.

Some of the major properties of proteins include:

- Contractile, such as actin and myosin found in skeletal and other muscles, required for movement
- Hormonal, such as insulin, growth hormone, and insulin-like growth factors
- Structural, such as collagen, a component of connective tissues
- Transporter, such as **hemoglobin** for transporting oxygen
- Enzymes, for digestion and required as catalysts for many biochemical reactions in the body DNA/Gene expression, as the information stored in genes is replicated into proteins
- Receptors, protein molecules that are imbedded in cell membranes and detect signals

Urea cycle: the metabolic process in which ammonia is converted to the waste product urea, which is then excreted from the body.

Hormone: one of the numerous substances produced by the endocrine glands that regulate bodily functions.

Deoxyribonucleic acid (DNA): the substance in the cell nucleus that contains the cell's genetic blueprint and determines the type of life form into which the cell will develop.

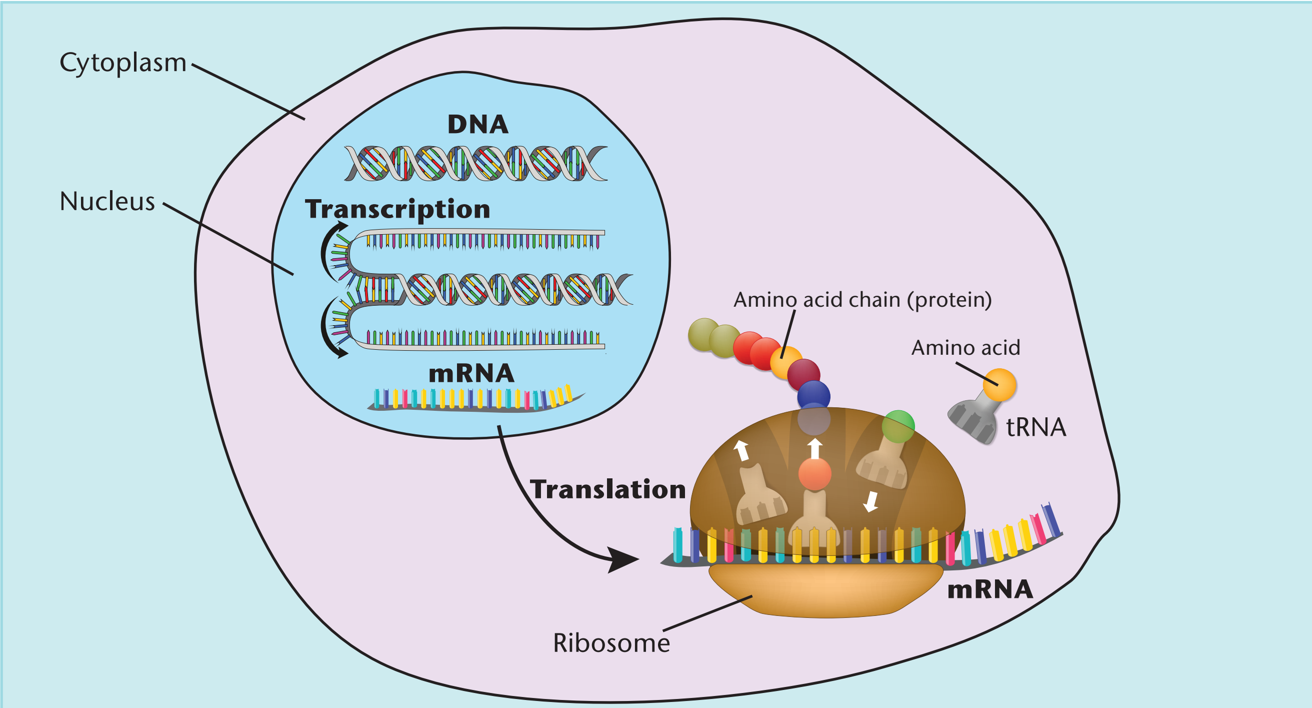
Collagen: a simple protein that is the chief component of connective tissue.

Connective tissue: tissue that either supports other tissue or joins tissue to tissue, muscle to bone, or bone to bone. It includes cartilage, bone, tendons, ligaments, reticular tissue, areolar tissue, adipose tissue, blood, bone marrow, and lymph.

Lipoprotein: a compound made up of fat and protein that carries fats and fat-like substances, such as cholesterol, in the blood.

Cell membrane: the outer boundary of a cell. Also called the plasma membrane.

Hemoglobin: the oxygen carrier in red blood cells.



How genes direct the production of proteins.

Most genes contain the information needed to make functional molecules called proteins, whereas just a few genes produce other molecules that help the cell assemble proteins. Going from gene to protein consists of two major steps: transcription and translation. Together, transcription and translation are known as gene expression.

Ribonucleic acid (RNA): the substance that carries the coded genetic information from the deoxyribonucleic acid (DNA), in the cell nucleus, to the ribosomes, where the instructions are translated into the form of protein molecules.

During the process of transcription, the information stored in a gene's DNA is transferred to a similar molecule called RNA **(ribonucleic acid)** in the cell nucleus. Both RNA and DNA are composed of a chain of nucleotide bases, but they have slightly different chemical properties. The type of RNA that contains the information for making a protein is called messenger RNA (mRNA) because it carries the information, or message, from the DNA out of the nucleus into the cytoplasm.

Translation takes place in the cytoplasm of the cell. The mRNA interacts with a specialized complex called a ribosome, which "reads" the sequence of mRNA bases. Each sequence of three bases, called a codon, usually codes for one particular amino acid. A type of RNA called transfer RNA (tRNA) assembles the protein, one amino acid at a time. Protein assembly continues until the ribosome encounters a "stop" codon (a sequence of three bases that does not code for an amino acid).

THE AMINO ACIDS

Nutritionally, amino acids are classified based on their dietary need by the body. Indispensable refers to the amino acids the body cannot synthesize and requires from dietary intake. Conditionally indispensable amino acids are those requiring a dietary source when the body's rate of synthesis cannot meet metabolic needs. Then there are some amino acids that are categorized as dispensable, which implies that the body can make them in sufficient quantities on an as-needed basis. Keep in mind that most foods contain proteins with most of the amino acids present, as do most protein supplements, too. Maintaining a nutritional source of all types of the amino acids (indispensable, conditionally dispensable, and dispensable), will help provide the athlete with a rich supply of amino acids for immediate use by the body in addition to the amino acids the body can make more of.

The amino acids listed in the tables are the major ones that are important to the body and commonly encountered in the diet from foods and supplements. As amino acid nutritional science has evolved the past few decades, so too have the terminology and concepts. For example, originally the amino acids were considered essential or nonessential depending on whether the body can make them. Now the new terminology is indispensable, conditionally indispensable, and dispensable. Indispensable is similar to essential, and dispensable is similar to nonessential. Conditionally indispensable amino acids are amino acids that are needed from the diet when the body's biosynthesis cannot meet the metabolic demands.

The following tables summarize the amino acids using two approaches wherein the USA DRI approach uses the new terminology and the Canadian approach uses the essential and

Amino Acids and Their Nutritional Status (USA DRI Terminology)

Indispensable	Conditionally Indispensable	Dispensable
Histidine	Arginine	Alanine
Isoleucine	Cysteine	Aspartic Acid
Leucine	Glutamine	Asparagine
Lysine	Glycine	Glutamic Acid
Methionine	Proline	Serine
Phenylalanine	Tyrosine	
Threonine		
Tryptophan		
Valine		

Note: The letters D and L sometimes precede the name of the amino acid and indicate which form is present; or isomer. In general, the L form of amino acids is the biologically active form and used to make proteins. In nutrition products, however, examples of two DL mixtures of amino acids reported to have metabolic advantages are reported for the amino acids phenylalanine and methionine. Glycine has no D or L form. There is inconsistent use of these letters on products and in the research. Check with the manufacturer if you have a question about the amino acids contained in their products.

Amino Acids and Their Nutritional Status (Canadian Terminology)		
Essential	**Nonessential**	
L-Histidine	L-Alanine	Alanine
L-Isoleucine	L-Arginine	L-Serine
L-Leucine	L-Asparagine	L-Tyrosine
L-Lysine	L-Aspartic acid	
L or DL-Methionine	L-Cysteine	
L or DL-Phenylalanine	L-Glutamic Acid/L-Glutamate	
L-Threonine	L-Glutamine	
L-Tryptophan	Glycine (Aminoacetic acid)	
L-Valine	L-Proline	

nonessential terminology, which also lists the amino acids preceded by their L, D, or DL designations. Note that the amino acid glycine has one molecular configuration and does use the D or L designation.

Keep in mind that the Dietary Reference report is primarily for the general population. From this progression in amino acid research and development, it is easy to acknowledge how ingesting specialty protein and amino acid products for athletes has a scientific basis and importance for promoting health and performance.

Another important amino acid nutrition concept is designing nutrition programs and sports nutrition products that enable fortification of certain amino acids or groups of amino acids to maintain the higher demands of an athlete's protein building or to stimulate the body's production of certain hormonal and metabolite substances—for example, providing the body with extra branched-chain amino acids, which are essential (indispensable) amino acids, but get used for energy at a higher rate by athletes. This will help offset the amounts used for energy and provide adequate branched-chain amino acids to be available for growth and repair functions. Then there are the amino acids that help support and promote peptide hormone production growth hormone, insulin and insulin-like growth factors. One of the recent uses of certain amino acids is for boosting the production of nitric oxide production, which is important in blood circulation and other body functions.

Proteins/Amino Acids and Energy

In addition to the functions discussed above, protein—the same as fat and carbohydrates—can also be used for energy, but this occurs in a minor role. Under conditions of severe calorie restriction and starvation, the body releases amino acids from muscle tissue for use as energy or in energy cycles. In a well-fed state, athletes use some amino acids for energy at a higher rate during exercise and even at rest. This catabolism (breakdown) of protein occurs during exercise—especially during intensive workouts, in particular power exercises and prolonged endurance activities—or when the body runs out of carbohydrates from the diet or glycogen from its muscle and liver stores. Even though the body can depend on the fat it has stored, it still may use some muscle protein, unless it is fed protein as food. When dietary circumstances cause the body to use amino acids as a source of energy, the body cannot also use these amino acids for building muscle tissue or for performing their other metabolic functions. This is why personalized daily protein intake is essential for the athlete—to best meet the individual's protein needs.

Even if athletes consume a proper diet, their bodies will still use certain amino acids as fuel during grueling exercise bouts. The muscles use the branched-chain amino acids (BCAAs)—isoleucine, leucine, and valine—to supply a limited amount of energy during strenuous exercise. However, research has shown that although the body can use all three BCAAs for energy during exercise, it uses leucine the most. As demonstrated by studies, a trained person's muscles use leucine even while that person is at rest. This disproportionate use of leucine, along with the other BCAAs, affects the body's overall use of amino acids for growth. Here, the BCAAs, especially leucine, are **limiting nutrients**: that is, nutrients which, through their absence or presence, restrict the utilization of other nutrients or the functioning of the body.

Limiting nutrient: a nutrient that has the ability, through its absence or presence, to restrict the utilization of other nutrients or the functioning of the body.

For optimum muscle growth, cellular growth, metabolism, and recovery, the body needs to receive the amino acids in the proper proportions. Merely eating amino acid sources, such as meat and eggs, does not ensure that the amino acids they supply will be available for muscle growth or for the formation of other proteins. For example, suppose an athlete consumes a total of 100 grams of protein, with all the essential amino acids present in equal amounts. How will his or her body use these amino acids? To begin, it will use a considerable percentage of the leucine for energy for exercising muscles. This means that a reduced amount of leucine will be available for growth and repair purposes. When leucine supply runs out, protein formation will be negatively affected because leucine is an essential amino acid—that is, the body cannot manufacture it. The result is that perhaps only a portion of the original 100 grams of protein will be available for growth and repair.

Rating the Quality of Proteins

Just as there are differences among the carbohydrates, the various proteins are not created equal. Some proteins have a more complete amino acid content than others do and are therefore better suited for growth purposes. Scientists are currently using a number of methods to rate proteins. Most of these rating methods do not account for the extra protein and the specific amino acids required by athletes, but they offer a baseline of information to work from. The following reviews some of the approaches and methods used by scientists to rate the quality of proteins for the general population.

Complete Versus Incomplete Proteins

Because adequate protein intake is essential for optimum growth in children, the World Health Organization (WHO) has conducted significant research on protein requirements. What the WHO researchers determined was that not all proteins supply the proper amounts and proportions of the amino acids necessary for adequate growth and development. **Complete proteins** are proteins that contain the essential or indispensable amino acids in amounts that are sufficient for the maintenance of normal growth rate and body weight. Indispensable amino acids are those that the body cannot make, and it therefore requires a constant dietary supply of these. Complete proteins are therefore said to have a high biological value. Most animal products have complete proteins.

Complete protein: a protein that contains the essential amino acids in amounts that are sufficient for the maintenance of normal growth rate and body weight.

Incomplete proteins are usually deficient in one or more of the indispensable amino acids. This amino acid deficiency creates a limiting-amino-acid condition, which adversely affects growth and development rates. Most plant proteins are incomplete. However, considering the dynamics of amino acids in the body, even high-quality proteins can be incomplete for athletes' needs. Furthermore, research indicates that the proper proportions of both the essential and nonessential amino acids are required for optimum growth and recovery. This means that athletes should consume protein supplements along with high-quality food protein sources. Athletes' dietary goals should be to eat a diet fortified with the amino acids that are used for energy and non-growth functions and to ensure an adequate intake of the amino acids needed for optimum performance, growth, and recovery.

Incomplete protein: a protein that is usually deficient in one or more of the essential amino acids.

Protein Efficiency Ratio

Another method of determining the quality of protein is the protein efficiency ratio (PER). The PER is calculated using laboratory animals. It refers to the amount of weight gained versus the amount of protein ingested. For example, casein has a PER of 2.86, which means that 2.86 grams of body weight are gained for every 1 gram of casein eaten.

One criticism of the PER system as a method for determining the quality of proteins for human consumption is that the values were derived through testing on animals, mostly rats. Does a rat's growth rate correlate to a human's? Perhaps not. Additionally, rats and other laboratory animals have a large amount of fur all over their bodies. This places an extra demand on amino acids such as methionine, which is used in fur growth and is a common limiting amino acid in plant protein sources. Moreover, we now realize that athletes need higher amounts of certain amino acids, such as the BCAAs. Therefore, the PER and other similar data should be used only as guidelines for determining minimum intakes of protein for nonathletes. Additionally, different proteins can be combined to improve the quality of the individual proteins. This is commonly done to increase the PER of plant proteins. Many powder supplements now include a mixture of two or more of the less expensive lesser quality proteins, such as soy and casein, which boost each other's PERs when used together, instead of using one of the more expensive high-quality protein sources, such as egg white.

An interesting note is that the WHO recommended that newborns need complete dietary proteins containing about 37 percent of the protein's weight in indispensable amino acids. Adults, however, require complete dietary proteins containing just 15 percent of the protein's weight in indispensable amino acids. This demonstrates that the proportion of essential to nonessential amino acids is an important factor in growth and development. Athletes training to develop stronger and bigger muscles should try to maintain higher proportions of the essential amino acids in their diets.

Net Protein Utilization

Net protein utilization (NPU) is a way of determining the digestibility of a protein. It does this by measuring the percentage of nitrogen that is absorbed from a protein's amino acids. Generally, the more nitrogen that is absorbed from a protein, the more digestible the protein is.

The NPU of a protein is calculated by measuring an individual's intake of nitrogen from amino acids, comparing that amount to the amount of nitrogen that the individual excretes, and determining how much of the protein in question is needed to balance out the two amounts. If a protein has a low NPU, more of it is needed to achieve nitrogen balance. (For a more complete discussion of this, see "Nitrogen Balance," below.) Therefore, proteins with high NPU values, such as egg and milk proteins, are more desirable for athletes.

Biological Value

Although the methods used to determine a protein's biological value (BV) are not entirely standardized, the one that most scientists prefer is described as "the efficiency with which that protein furnishes the proper proportions and amounts of the indispensable amino acids needed for the synthesis of body proteins in humans or animals."

The general formula for determining BV is as follows:

BV = nitrogen retained divided by nitrogen absorbed x 100

Eq. 4.1

The BV value does not indicate the ultimate fate of the amino acids in the body—that is, it does not show whether they will be used for muscle growth or enzyme synthesis. In addition, BV measurements vary for the same protein according to the animal species tested. For example, chickens have different amino acid needs than do rats do because, among other things, chickens have feathers, and rats have fur. Because feathers require different amino acids than fur does, the two animals need different proportions of the amino acids. Therefore, unless the BV for a particular type or brand of protein was determined specifically for humans, that protein may not offer any advantages to humans, even though it may have a high BV according to the testing done with animals.

Amino Acid Score

The previous protein quality methods and research made scientists realize that the primary magic of proteins is the amino acids that they contain along with the digestibility of the proteins being digested. Due to the limitations of using biological testing to evaluate the protein quality of different foods, there was a movement toward developing a protein quality rating system based on the amino acid content in relationship to what would be an ideal protein for humans.

In the 1980s, the concept of using a system based on amino acid content began to emerge. This eventually evolved into the development of what has become known as the PDCAAS (Protein Digestibility Corrected Amino Acid Score). The PDCAAS is based on creating a reference standard of the indispensable amino acid composition that would be considered ideal for humans. This method therefore considers the indispensable (essential) amino acid composition of a protein, the digestibility, and the ability of the protein source to supply the indispensable amino acids in adequate amounts required by humans.

It is interesting to note that when a type of protein gets a low rating, it can have the rating improved with fortification of the low content amino acid(s). In fact, many plant proteins are limiting in one or more of the essential amino acids, thereby giving them low ratings on an individual food basis. However, when these plant protein sources are fortified with the essential amino acids, or combined with other plant proteins that have amino acid content profiles that fill in each other's amino acids gaps, the result can be a higher quality plant protein source.

Protein Quality for Athletes

For athletes, trying to ingest high-quality proteins based on the ratings systems for the general population is mandatory. In addition to this, using protein and amino acid supplements to fortify the athlete's diet has led to the development of a variety of products to help athletes meet their total protein needs along with their amino acid specific needs. In addition to the basic protein needs athletes must maintain, the increased ingestion of certain amino acids to help further boost metabolic processes has become commonplace. In addition to the branched-chain amino acids, the extra ingestion of amino acids like arginine, glutamine, lysine, and glycine is practiced to enhance anabolic hormone production and immunity, boost protein synthesis, increase strength, improve body composition, foster better healing, and improve athletic performance. Thus as scientific discoveries continue, so too will the evolution of the athlete's diet and sports nutrition. Unit 17 contains information about putting today's science into practice for creating the ultimate sports nutrition and supplement plans.

Nitrogen Balance

Nitrogen balance is a topic frequently encountered when one reads articles about athletes' protein and amino acid requirements. In addition to carbon and hydrogen, amino acids also contain nitrogen as part of their molecular structure. This is a unique characteristic, one that we can use to our advantage, because it allows us to determine whether protein intake is adequate. Specifically, nitrogen balance refers to the condition in which the amount of dietary nitrogen taken in is equal to the amount of nitrogen excreted. A nitrogen balance that is positive indicates a possible net growth in body tissues. A nitrogen balance that is negative indicates an inadequate protein intake and the possibility that the body is **cannibalizing** its muscle tissue. An important nutritional goal for athletes is to aim for achieving and maintaining a positive nitrogen balance.

Cannibalization: the breakdown of muscle tissue by the body for the purpose of obtaining amino acids for other metabolic purposes and may also include other body tissues.

Determining nitrogen balance is not an easy task though. Because nitrogen from broken-down amino acids can be excreted in both the urine and the feces, and because some is lost as sweat, all these excretions must be collected and analyzed. In addition, all the nitrogen ingested from protein must be accurately measured. This is impractical for most individuals. However, some companies have now developed methods that enable athletes to get a rough idea of their nitrogen balance by taking measurements using just their urine and by measuring their nitrogen ingested as protein. This approach makes assumptions about the relative amount of nitrogen lost in feces and sweat. Although you would have to spend time making calculations every day, you would probably find it interesting to learn what your nitrogen balance is to give you an approximate guideline for what your daily protein intake should be. You could then experiment with combining different food and supplement protein sources to tailor-make an efficient protein-intake program for yourself.

Designing Protein and Amino Acid Products

The direction and application for protein and amino acid sports science lies in designing an amino acid source that brings about nitrogen balance using a minimum amount of protein. This goal can be reached in several ways, and manufacturers have already developed pioneering ingredients and products that accomplish it. Creating an amino acid profile that has all the essential amino acids with extra BCAAs and the nonessential amino acids is a start. Products with a variety of amino acid combinations are available. Among their benefits are growth hormone (GH) stimulation, blood ammonia detoxification, increased mental alertness, and mental relaxation.

Absorption is also an important factor. Some protein manufacturers are inventing better ways to purify the protein from milk and other sources. The development of whey protein isolate is an example of improving the quality of a food source protein. Adding non-protein ingredients can further improve utilization as well as supply other growth factors, such as glucosamine for connective tissue, along with other cofactors, including the basics like vitamins and minerals. The diversity of amino acid combinations possible and the benefits they offer can make protein and amino acids a very interesting field of research, a practical application, and a vital part of the athlete's nutrition program.

The take-home lesson about protein quality is that although some protein sources are naturally higher quality than others are, by combining various types of proteins and/or adding specific amino acids, the quality of any protein product or diet can be improved with modern food science technology.

Free Form and Peptide-Bonded Amino Acids

When referring to the amino acid content of food or supplements, the terms free form and peptide bonded are used. In fact, the debate seems to be constant over which supplement form is better. **Free form amino acids** are amino acids that are in their free state, or single. When protein is digested, some of its amino acids are eventually broken down into their free forms for transport and use in the body. Peptide-bonded amino acids are amino acids that are linked together. **Di-peptides** are two amino acids linked together, **tri-peptides** are three amino acids linked together, and polypeptides are four or more amino acids linked together. Interestingly, the intestines can absorb free form, di-peptide, and tri-peptide amino acids but not polypeptides.

Because the body has the capacity to digest protein, it can make use of whole-protein supplement sources. However, many supplements now contain free-form amino acids or combinations of free form and peptide-bonded amino acids. Some also contain **hydrolyzed proteins**. Hydrolyzed proteins are already broken down, usually by enzymes, and are a mixture of free form, di-peptide, and tri-peptide amino acids. Many people consider them better than non-hydrolyzed proteins because their partial digestion possibly makes them more easily absorbed by the body.

The use of free form amino acids is still common in clinical applications when intravenous solutions are used to supply amino acids directly into the bloodstream. Free form amino acids can also be used to fortify food proteins. Taking the BCAAs with meals can be useful for compensating for the amino acids already used for energy. Additionally, when you just want to take extra amounts of one or several amino acids, a free form amino acid formulation makes perfect sense. Free form amino acids are also sometimes added to protein products to selectively increase the amount of specific amino acids.

Another reason a mixture of free form and peptide-bonded amino acids could be better than free form amino acids alone are for general protein intake is that the intestines can better absorb mixtures for transport into the bloodstream. Although it might seem logical that free form amino acids could be absorbed more quickly, the upper part of the small intestine is better able to absorb amino acids in twos and threes.

Free-form amino acids: amino acids that are in their free state, or single.

Di-peptide: two amino acids linked together.

Tri-peptide: three amino acids linked together.

Hydrolyzed protein: a protein that has already been broken down, usually by enzymes, and is a mixture of free-form, di-peptide, and tri-peptide amino acids.

Digestion of Protein and Amino Acids

The mechanical digestion of protein begins in the mouth during chewing. In the stomach, the enzyme pepsin joins in, breaking down the protein into shorter peptides. The partially digested protein then passes into the intestines, where the free form, di-peptide, and tri- peptide amino acids are absorbed—beginning immediately. Enzymes continue to digest any polypeptides as they travel down the intestines.

Once the free form, di-peptide, and tri-peptide amino acids enter the bloodstream, they are transported to the liver, where a few things may happen to them. They may be converted into other amino acids, they may be used to make other proteins, they may be further broken down and either used for energy or excreted, or they may be placed into circulation and continue on to the rest of the body.

Proteins empty from the stomach in two to three or even more hours depending on how much fat is present and how much food was consumed. This means that you should keep the protein content of pre-competition meals on the low side, fat too, to enable the digestive system to be clear of the meal and to pass nutrients into your bloodstream and cells before you begin your athletic event. However, take note that the specially prepared various protein sports nutrition and supplement products in ready-to-drink and protein powders made in to drinks can be digested and absorbed faster, usually within an hour. Whey protein isolate is an example of a protein sports nutrition product that can be digested and absorbed at a fast rate. However, whey's naturally occurring companion milk protein, casein, is slower digested and absorbed over a longer period. Thus, taking advantage of these different digestion and absorption dynamics can prove useful when targeting in on fine-tuning meeting an athlete's protein needs under the challenging demands of athletic training and event schedules. More about meal composition and timing will be reviewed in the Digestion Unit.

Amino Acid Review

The following provides an overview of the primary amino acids of nutritional and biological importance. This includes the indispensable, conditionally dispensable, and dispensable amino acids. When applicable, the athletic performance significance is noted. While most of these amino acids have well-established functions and importance based on historical use and more than a hundred years of research, there are always new functions of amino acids being discovered, especially for athletic performance. Therefore, some of the amino acid entries include a few highlights of recent research discoveries relating to athletic performance as well as reviewing the well-established, time-tested functions.

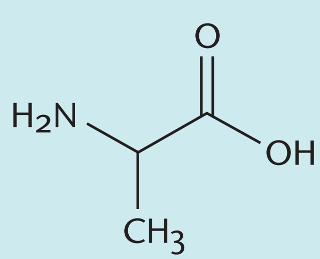
When reviewing the functions of amino acids, we see that most amino acids have multiple functions and multiple benefits to health and athletic performance. Some amino acids are just part of proteins, others function in the body as biochemical intermediates or precursors of other amino acids or substances, and some amino acids can function in the body as part of proteins, as metabolic intermediates, or directly in their intact form. Whatever the functionality of these amino acids may be, it will be easy to appreciate their use in sports nutrition products: ranging from single amino acid products to multiple amino acid products to a variety of multiple ingredient sports nutrition products that use amino acids in different ways to create comprehensive and balanced sports nutrition products for specific uses.

Alanine & Beta-Alanine

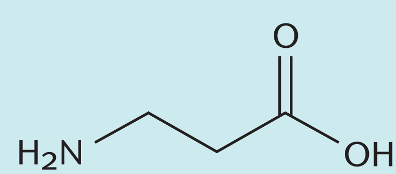
Alanine is a dispensable amino acid found in high concentrations in most muscle tissue and is grouped with the dispensable amino acids because the body can manufacture it. Alanine is involved in an important biochemical process that occurs during exercisea; the glucose-alanine cycle. In the muscles, glycogen stores are broken down to glucose and then to a 3-carbon-atom molecule called pyruvate. Some of the pyruvate is used directly for energy by the muscles. Some of it, however, is converted to alanine, which is transported through the bloodstream to the liver, where it is converted once again into glucose. The glucose is then transported back to a muscle and again used for energy. The glucose-alanine cycle serves to conserve energy in the form of glycogen. Sports physiologists postulate that this helps maintain the glucose level during prolonged exercise. In this way, supplementing with L-alanine may be useful in a similar way to supplementing with the BCAAs—the supplemental L-alanine may help spare muscle tissue and liver glycogen. However, research studies exploring the exact dosages and benefits of supplemental alanine need to be conducted on athletes to clearly confirm athletic performance benefits. In the general population, dietary intake of alanine is reported to be approximately a mean of 3.6 grams per day to a high of 8.5 grams per day.

Beta-alanine is a relatively new comer in sports supplements compared with the other amino acids, but it has gained in popularity due to numerous clinical research studies demonstrating certain exercise and athlete performance benefits. Beta-alanine differs slightly in molecular configuration from the conventional alanine molecule.

Analine



Beta-Analine



Attention was directed toward beta-alanine when it was found that taking beta-alanine supplements can increase the body's supply of carnosine. Carnosine is found occurring in skeletal muscles and other tissues of animals including humans. Thus, carnosine is present in the diet. Carnosine is reported to be synthesized in the body from beta-alanine and L-histidine. Carnosine has a few biological functions. These include antioxidant activity, activation of myosin ATPase activity, enhancement of copper update, and of particular interest to athletes, buffering the acidic pH increase from exercising muscles. Exercise and athletic competition performance may therefore be enhanced from an increase in intracellular buffering capacity, which can delay the fatigue caused by increasing muscle acidosis, noting that a majority of the research studies reported exercise performance increases. Highly significant benefits reported in the research studies were especially observed for high-intensity exercise bouts lasting between one and four minutes.

The body of beta-alanine human performance research continues to grow. The following includes overviews of some of this body of research. For example, research by R. C. Harris and coworkers published in 2006 observed an increase in muscle carnosine from a few weeks of dietary supplementation of beta-alanine. Regarding athletic performance effectiveness from dietary supplementation of beta- alanine, scientific evidence is beginning to be reported. For example, C. A. Hill and coworkers reported that four to ten weeks of beta-alanine supplement use increased carnosine levels and increased total work done in exercise tests using males who undertook a cycle capacity test. The beta-alanine-taking group increased total work done by 13 percent at four weeks, compared with the placebo group and then an additional 3.2 percent increase was observed at ten weeks, a total of 15.2 percent increase. Another group of researchers, J. R. Stout and coworkers reported that 28 days of beta-alanine supplementation improved submaximal cycle ergometry performance and time to exhaustion in young women. This was attributed to an increased buffering capacity due to elevated muscle carnosine concentrations.

It is important to note that beta-alanine is different from creatine, and some articles have mistakenly reported beta-alanine as being the next creatine. Metabolically, creatine functions differently from beta-alanine. Additionally, creatine has hundreds of scientific studies backing its effectiveness, whereas the research indicated benefits of beta-alanine are in the early stage.

With these differences in mind, some research was aimed at determining what effects would occur by combining creatine and beta-alanine. One research study examined the effects of 28 days of beta-alanine, creatine, and beta-alanine & creatine supplementation compared with a placebo group. The researchers wanted to measure the effects of the supplements of the onset of neuromuscular fatigue in untrained men. After 28 days, the beta-alanine and beta-alanine & creatine-taking groups exhibited a delay of neuromuscular fatigue using a continuous incremental cycle ergometry test. Keep in mind that other research reported that creatine loading might delay the onset of fatigue.

Another research study examined the effects of creatine and beta-alanine supplementation on performance and endocrine responses in strength athletes, football players. The football players followed a 10-week resistance training program. They were divided into groups that ingested creatine, creatine & beta-alanine, or a placebo. Significant changes in lean body mass were measured in the group of football players taking creatine and beta-alanine together, football players taking either creatine or creatine & beta-alanine together experienced significant increase in strength performance, and football players taking just creatine also experienced an increase in testosterone levels.

Smith and coworker (2009) reported benefits experienced by recreationally active men from taking beta-alanine supplementation for six weeks. Significant improvements were observed in high-intensity interval training endurance exercise performance measurements. A significant increase in lean body mass was also determined. Brisola and coworkers (2016) examined the effects of beta-alanine on repeated sprint ability in male water polo players. After 28 days of beta-alanine supplementation, slight improvements were measured in swimming performance, especially in the first set of sprint ability tests, which would be related to the first quarter of a water polo match.

The beta-alanine research is growing and encouraging for the use of beta-alanine supplements by both athletes and fitness exercisers as part of a total nutrition program. Although more studies may be needed to conclusively determine the dosages and duration of use, dosages used in the studies ranged from a few to several grams per day. While Health Canada has established a maximum total daily dosage of 3 grams per day, the research and some organizational guidelines establish up to 6 gram per day. Beta-alanine is taken in divided dosages 2 to 4 per day, for example, two 1.5-gram dosages per day, for 3 grams total per day. Results may be experienced in two to four weeks of use. Long-term studies are required to determine how long beta-alanine may be used, but based on the research, two to three months is likely a safe duration of use but needs to be closely supervised by a doctor.

A word of caution concerning beta-alanine supplement use is a minor annoying side effect that has been reported by supplement users and documented in the research studies. For example, Health Canada notes the following for their beta-alanine use instructions: "May cause a flushing, tingling and/or prickling sensation of the skin, in which case, reduce the dose." Of course, individuals experiencing these skin reaction symptoms should consult their doctor, and discontinue use, until a safe, minimum daily dosage can be established. Athletes can start with smaller dosages and work up to higher dosages, for example, 0.5 grams twice a day week 1; 1 gram twice a day week 2; and 1.5 grams twice a day week 3 or longer. Current thinking is that beta-alanine may have measurable benefits for exercise and athletic performance under 25 minutes in duration, high intensity. Keep in mind however, as with the water polo research study, improved performance in the first quarter can benefit subsequent quarters. Although beta-alanine use may be considered experimental for other sports and durations, keeping good exercise, training, and competition performance notes may reveal benefits for all types of athletes.

Arginine (GH, IGF, Nitric Oxide stimulation, and more)

Arginine is a conditionally indispensable amino acid that influences several metabolic factors that are important to athletes. Arginine is most popular for its role in stimulating the release of human GH (somatotropin) and related Insulin-like Growth Factors (IGF) levels. Several studies have measured the ability of supplemental L-arginine, both alone and in combination with other amino acids, to increase the GH level in athletic and nonathletic individuals. Potential benefits of an increased GH level include reduction in body fat, improved healing and recovery, and increased muscle growth rate and muscle mass. Other major benefits of arginine supplementation include improving immune system function, protein synthesis, nitrogen detoxification (reducing ammonia levels/ ammonia removal, and increasing the production), creatine synthesis, and increasing levels of nitric oxide (NO).

Arginine dosages used in research studies vary considerably; a gram, a few grams, several grams, or even higher daily dosage amounts. Based on the results of numerous arginine studies, a variety of favorable responses is reported, ranging from minor responses to larger significant improvements in the attributes being measured. This would be expected when you consider that the human body can manufacture arginine, but as it is a conditionally indispensable amino acid, this indicates that from time to time, people may not be able to produce enough of it. For the athlete, especially strength athletes, supplemental arginine is considered essential.

Some of the types of the arginine-containing molecules used in supplements include: Arginine HCl, Arginine AKG, Arginine-2-pyrrolidone-5-carboxylate. The primary purpose of these arginine-containing molecules is to increase the body's levels of arginine. Arginine has also been combined with other amino acids in research studies, such as lysine, glycine, ornithine, and aspartate, and is found naturally occurring with all of the other amino acids.

In addition to the other benefits reported from consuming arginine supplements, the nitric oxide (NO) boosting effects are among the most recent addition of interest to certain athletes. It is first interesting to note that previous to the athletic performance interest, when researchers discovered that arginine supplements can stimulate NO production, they immediately began testing it for treating erectile dysfunction. Nitric oxide in the blood stream causes relaxation of the vascular tissues and vasodilatation, thereby promoting improved blood flow. Some cases of erectile dysfunction are thought to be related to poor NO production. As NO is made from arginine, researchers wanted to evaluate whether male subjects with erectile dysfunction would show improvements from taking arginine supplementation. After taking 2,800 milligrams of arginine a day for a two-week period, six of fifteen subjects reported an improvement of erection function from taking the arginine supplements. The responders were the younger males of the experimental group, age rage 25–43. Other researchers have also evaluated arginine supplement taking for improvement in patients with cardiovascular disorders with promising results.

From an athlete's perspective, maintaining good blood flow is essential for athletic performance and recovery. The NO stimulating action of arginine supplements, as it relates to increasing athletic performance is a new area of research. A study in 2006 revealed that taking an arginine supplement, in the form of Arginine AKG, daily for eight weeks increased blood levels of arginine. At the end of the study period, it was determined that the strength-training athletes significantly increased their 1RM bench press and peak power performance. This is consistent with previous studies of strength athletes ingesting arginine-containing supplements.

Based on the numerous research studies, supplemental intake of arginine can benefit athletes because of its ability to detoxify nitrogenous wastes, increase GH & IGFs, increase nitric oxide, increase creatine production, improve immune system function, and improve the rate of healing. L-arginine supplementation can especially help athletes involved in strenuous sports or training. In addition to athletics, arginine supplementation may have benefits for people with diabetes, insulin resistance, and metabolic syndrome.

Existing research reports measurable responses from daily arginine supplement dosages ranging from 1,000 to 5,000 milligrams for periods up to four months. Higher amounts may be required based on individual needs. Note that in the majority of studies, arginine supplements were taken during the day, and improvements in GH, IGF and NO were observed during the day and were also reported in the evenings. In the general population, dietary intake of arginine is reported to be approximately a mean of 4.2 grams per day to a high of 10.1 grams per day. Arginine supplementation does not always produce significantly positive results in all individuals, which may be due to such factors as dietary arginine being already optimum, age, level of training, and metabolic differences.

Health Canada has established the following benefits for L-arginine supplementation: May help support a modest improvement in exercise capacity in individuals with stable cardiovascular diseases. (This is of course a disease treatment indication, not applicable to competitive athletes and requires medical supervision. And L-Arginine is a non-essential amino acid that is involved in protein synthesis.) Health Canada further notes a maximum single dosage of 8 grams, and a wide range of dosages depending on the use, from 0.21 to 21 grams per day. Also, duration limits are specified and other conditions, which can be found online in the monograph if you want more details:

http://webprod.hc-sc.gc.ca/nhpid-bdipsn/monoReq.do?id=124&lang=eng

Note that arginine products in Canada will have detailed dosage, duration, and other use instructions the product labeling.

Asparagine

Asparagine is a dispensable amino acid manufactured in the body from aspartic acid. Asparagine appears to be involved in the proper functioning of the central nervous system because it helps prevent both extreme nervousness and extreme calmness. L-asparagine supplementation by athletes has not yet been evaluated. Asparagine can be found occurring naturally in foods and supplements containing whole protein ingredients. In the general population, dietary intake of asparagine is reported to be approximately 7.4 g/100 g of dietary protein consumed.

Aspartic Acid

Aspartic acid, also referred to as L-aspartic acid or L-aspartate, is a dispensable amino acid that has been shown to help reduce the blood-ammonia level after exercise. Aspartic acid occurs naturally in plants and animals and is found in the diet. In addition, the artificial sweetener aspartame contains aspartic acid. Aspartic acid is an amino acid that is typically present in products containing whole proteins, such as whey protein, but occurs in all protein-containing foods, both animal and plant origin.

Aspartic acid is metabolized from glutamic acid in the body. It is involved in the urea cycle and in the Krebs cycle. In the Krebs cycle, energy is released from glucose, fatty acid, or protein molecules and used to form adenosine-triphosphate (ATP) molecules, which are the form of energy that the body can utilize. The exact benefits of single-ingredient aspartic acid supplement use for well-conditioned athletes in active training require further research. In the general population, dietary intake of aspartic acid is reported to be approximately a mean of 6.5 grams per day to a high of 15.4 grams per day.

Branched-Chain Amino Acids (Leucine, Isoleucine and Valine)

The branched-chain amino acids (BCAAs) are the indispensable amino acids isoleucine, leucine, and valine. Together, these three amino acids make up about 35 percent of the amino acid content of muscle tissue. Each of these amino acids is also used by the body for energy. Studies confirm that under conditions of stress, injury, or exercise, the body uses a disproportionately high amount of the BCAAs to maintain nitrogen balance. Studies also indicate that leucine is used at a rate two or more times greater than those of isoleucine and valine. Many amino acid formulations on the market therefore have about twice as much leucine as the other two BCAAs do.

The BCAAs have a history of use starting in medical settings with people in stressed states, such as burn victims, surgical and trauma patients, and those experiencing starvation. These patients were given BCAAs to stimulate their protein synthesis and nitrogen balance. Then, during the 1980s, sports nutrition companies picked up on these clinical practices and sponsored research using animals and athletes that revealed that the BCAAs are used for energy, especially by exercising skeletal muscle. The researchers hypothesized that taking supplemental BCAAs would compensate for the BCAAs used for energy, promote muscle growth, and restore nitrogen balance. Additionally, leucine was found to have other growth-related metabolic effects including releasing GH and insulin and playing a role in controlling protein production.

Eventually, research began to examine the benefits that the taking supplemental amounts of the BCAAs would have on athletic performance, body composition, and health. Some of the exercise-related benefits observed in research studies include:

- Increase in exercise endurance
- Reduction of exercise-related fatigue
- Improved mental performance and increased energy levels
- Stimulation of protein synthesis
- Improved nitrogen balance
- Improved immune system function
- Increase in lean body mass and increased strength

The amounts of the BCAAs supplied vary with the different products available. Some products contain just the BCAAs, others have the BCAAs along with a few additional ingredients, and still others contain the full spectrum of amino acids with extra amounts of the BCAAs.

Athletes, especially bodybuilders, report muscle growth and strength benefits from effective BCAA formulations. However, the BCAAs are not just for bodybuilders and power athletes. Endurance athletes can also benefit from BCAA supplementation. Research has determined that endurance athletes use more than 50 percent of their total daily leucine for energy purposes. This means that endurance athletes might need to eat several times the normally recommended amount of protein to maintain nitrogen balance. An alternative method these athletes can use is to fortify their base diet of food proteins with supplement BCAAs.

Leucine, a Key BCAA

It is important to note that in addition to luecine's being a crucial BCAA use for energy production, the most recent research has shown that leucine plays a major role in protein synthesis. In addition to BCAA supplements coming in capsule form, powdered protein products contain extra leucine plus other important amino acids of athletic importance. The special report at the end of this unit reviews this important research and product development trend. In the general population, dietary intake of the BCAAs is reported to be approximately 6.1 grams per day for leucine to a high of 14.1 grams per day; 3.6 grams per day for isoleucine to a high of 8.2 grams per day; and 4 grams per day for valine to a high of 9.1 grams per day.

Based on a scientific conference about BCAAs, it was determined that BCAAs are very safe. A wide range of BCAA supplement intake has been experimented with. The exact amount of BCAA will depend on your level of activity, protein intake, and other protein/amino acid supplements you are taking. In addition to the BCAA product instructions you may be using, here are some further guidelines. In general, daily intake of between 10 to 30 grams of BCAAs, which are high in leucine, has been reported to be safe and effective. BCAAs are typically ingested in divided dosages taken two or more times a day. This way, your body will be supplied a constant supply of BCAAs, in particular leucine, which plays an important role in protein synthesis control.

One approach to getting more BCAAs into your diet is to include a product that is high in BCAA content before or with meals. This can include protein powders fortified with BCAAs, products that just contain BCAAs, or high-quality multi-ingredient specialty products that contain extra BCAAs, protein, other amino acids, and a variety of additional clinically proven muscle-building and fat-metabolizing ingredients. This will ensure that you have enough of these vital essential amino acids during mealtime to maximize protein synthesis, growth, and recovery of muscle.

Another approach for taking BCAA supplements is before and after exercise. Supplemental amounts of the BCAAs could range from 1,500 to 6,000 milligrams for L-leucine and 1,000 to 3,000 milligrams each for L-isoleucine and L-valine. Divide the dosage between two servings a day. Depending on your rate of stomach emptying, experiment with taking a serving about 60 to 30 minutes before exercising and another serving after exercising on training days, or along with meals on non-training days, to fortify the dietary proteins. Note that BCAA dosage can be approached based on body size (lean body mass) and activity, with larger and more active individuals, for example, requiring higher amounts of the ranges. Another BCAA dosage approach reported in the research is based on milligrams per kilogram of body weight. For example, 77 milligrams per kilogram of body weight caused a benefit of reducing muscle protein breakdown during exercise. In addition, approaching safe and effective BCAA use will depend on the total daily protein intake and doctor supervision.

BCAAs Help Increase Training Strength, Endurance, and Muscle Mass

A study reported in the journal *Medicina Dello Sport* examined the effect that supplemental BCAAs have on athletic progress. The study involved 31 male bodybuilders between the ages of 18 and 34, all of whom were drug free, or "natural," bodybuilders. The subjects were divided into two groups: 16 took a placebo and fifteen took a BCAA supplement. The results showed that while both groups experienced increases in body weight, the BCAA group had greater weight gains. An analysis of the weight gain in the BCAA group showed increases in the lean body mass in both the legs and arms, with no changes in the trunk area of the body. In contrast, the group taking the placebo showed no lean mass gains in these areas. The BCAA group also showed strength gains in both the squat and bench press exercises, whereas the placebo group gained strength only in the squat exercise. In addition, the BCAA group showed improvements in measures of exercise intensity.

Using BCAAs to fortify whey protein can further enhance the anabolic and strength-boosting actions. In July 2004, independent researchers reported findings of their newest research that serves to reconfirm my earlier discovery that fortification of whey protein with BCAAs, in particular leucine, will result in greater gains in strength and muscle size. D. J. Housh and coworkers conducted their study at the exercise physiology lab at the University of Nebraska -Lincoln. Men were divided into either a placebo group or a leucine-fortified whey protein group. Subjects trained three times a week for eight weeks. At the end of the eight weeks, the males who had strength trained and ingested the leucine-fortified whey protein had significantly greater increases in strength and muscle size compared with the males who had taken a placebo.

Citrulline

Citrulline is a dispensable amino acid and has a role in the urea cycle for the removal of ammonia from the blood. As more research continues using citrulline supplementation, the benefits of citrulline supplementation are evolving. For example, research reports preliminary observations of citrulline-containing supplements used in experimental settings increasing nitric oxide levels and exercise performance. Based on these reports, nitric oxide-boosting supplements have appeared in the sports nutrition market containing citrulline as a main ingredient. Other related potential exercise and athletic performance benefits of citrulline supplementation reported in the research may include ammonia detoxification; increase in muscle protein synthesis, reduction of exercise-related muscle soreness, a decrease in fatigue during exercise, improved vascular health and function, and improved blood flow.

Some common supplemental citrulline dosage ranges used in the research are 3 to 6 grams per day. Note that Health Canada has established a 3-gram per day maximum dosage. Citrulline is taken in divided dosages, two to three times a day for example. Like other supplements, it is best used under doctor supervision. Short-term use has been reported in the research studies, but long-term supplement use safety is yet to be determined. Consult with product use instructions or contact a citrulline supplement company for use recommendations.

Cysteine

Cysteine is a conditionally dispensable sulfur-bearing amino acid. The body manufactures it from methionine and serine. Cysteine is important in the production of protein, hair, skin, connective tissues, connective tissue growth factor, glutathione, taurine, and insulin. Besides its major role as a component of proteins, it functions as a detoxifying agent, helping to rid the body of dangerous chemicals. In addition, it helps form glutathione, which is an important antioxidant and detoxifying agent. Cysteine also plays a role in energy production. Like other amino acids, it can be converted to glucose and either used for energy or stored as glycogen. As it is naturally occurring, L-cysteine is a common ingredient found in protein and multi-amino acid formulas. Some supplements also contain the N-acetyl-L-cysteine form. In the general population, dietary intake of cysteine is reported to be approximately 1 gram per day to a high of 2.2 grams per day.

Cystine

Cystine is another conditionally dispensable sulfur-bearing amino acid related to cysteine, as it is made from two molecules of cysteine, and the two are typically considered together for nutritional evaluation purposes. Cystine plays a vital role in helping many protein molecules hold their shape as they are carried around the body. It is generally poorly absorbed when taken in supplemental form and is more effectively derived by formation from cysteine. The same as cysteine, cystine is important in the formation of hair and skin. It is also a detoxifying agent. The athletic benefits of supplementation with free form cystine have not yet been evaluated.

Glutamic Acid

Glutamic acid, also known as glutamate, is a dispensable amino acid occurring in proteins. It acts as an intermediary in the Krebs cycle and is therefore important for the proper metabolism of carbohydrates. It is also involved in the removal of ammonia from the muscles. It does this by combining with the ammonia to form glutamine. Glutamic acid is also needed for the production of energy from the BCAAs. In fact, some research has indicated that the amount of energy produced from the BCAAs may depend on the available supply of glutamic acid.

Fortunately, glutamic acid is plentiful in the diet and easily made by the body. Similar to glucose, glutamic acid can pass readily through the **blood-brain barrier**, a semi-permeable membrane that keeps the blood that is circulating in the brain away from the tissue fluids surrounding the brain cells. Glutamic acid is typically present in full-profile amino acid products like protein powders and other protein-containing products. In the general population, dietary intake of glutamic acid is reported to be approximately a mean of 15 grams per day to a high of 33.7 grams per day.

Blood-brain barrier: a semipermeable membrane that keeps the blood that is circulating in the brain away from the tissue fluids surrounding the brain cells.

Glutamine

Glutamine is a conditionally dispensable amino acid found in dietary proteins and made by the body. Glutamine is generally one of the most plentiful amino acids present in the body. However, researchers observed in medical settings from people who were under stress from injury or disease that their glutamine levels were decreased below normal levels. Eventually doctors determined that this decrease in glutamine among stressed patients was related to poor immune system function and reduced protein synthesis. When patients were provided with supplemental amounts of glutamine, their immune system function was improved, and their nitrogen balance was restored, indicating anabolic effects.

Glutamine is also reported to have anti-catabolic effects, reduce cortisol levels, improve wound healing, act as an energy source in certain cells, elevate growth hormone levels, stimulate glycogen synthesis, combat overtraining syndrome, promote protein synthesis (anabolic effects), support the blood buffering system, and promote gastrointestinal tract health. From this list of the primary benefits of using glutamine supplements in research studies, it is easy to understand why use by athletes eventually caught on.

Like the BCAAs, glutamine began in medical settings. Eventually the ability of glutamine to restore immune system function attracted attention by the athletic community. Researchers in the mid 1990s from Oxford University, UK, are credited with being among the first to hypothesize that amino acid imbalances may result from strenuous exercise and, consequently, induce a number of phenomena that are collectively referred to as the "overtraining syndrome."

The initial athlete glutamine supplement research was conducted among long-distance athletes, like marathon runners, who were known to have lower glutamine levels after their races and suppressed immune system function and subsequently were thought to be at greater risk for a higher rate of infections. When athletes were given 5 grams of glutamine supplement after running a marathon, the researchers observed a reduced number of infections among the athletes taking glutamine during the seven days following exercise. In other similar research, a similar result was observed, in which the athletes taking glutamine supplements experienced a reduced rate of infection compared with athletes not taking glutamine.

Although these benefits are of importance for all athletes, in addition to the endurance athletes tested, using glutamine supplements has become very common among strength athletes, in particular bodybuilders. This common use has been promoted from glutamine's reported benefits in boosting protein synthesis, having anti-catabolic effects and blood buffering effects, boosting growth hormones and offering other muscle-building-related benefits, in addition to use based on case studies.

Similar to the other amino acids, glutamine products range from single-ingredient to multi- ingredient mixtures. In research studies, glutamine has been shown to be effective in dosage ranges as low as 2 to 5 grams per day. Athletes typically consume supplemental amounts of glutamine in the 5 to 10 gram a day range, with some athletes periodically ingesting even higher daily amounts of glutamine, such as bodybuilders. Glutamine is taken by dividing the total daily dosage into two to three smaller dosages during the day to help maintain adequate levels.

Creatine and Glutamine

A study conducted by M. Lehmkuhl and coworkers who recruited 29 athletes, 17 men and 12 women, who were collegiate track and field athletes. Ten were randomly assigned to take creatine monohydrate, ten to take creatine monohydrate and glutamine, and nine to take a placebo. The creatine monohydrate-taking group received 0.3 grams creatine per kilogram of body mass per day for one week, followed by 0.03 g creatine per kilogram of body mass per day for 7 weeks. The creatine monohydrate–glutamine-taking group received the same creatine dosage scheme as the creatine monohydrate taking group did plus 4 grams of glutamine per day. All three treatment groups participated in the same strength and conditioning program during preseason training. Measurements observed during the study included body composition, vertical jump, and cycle performances before and after the eight-week supplementation period. After the study period, it was determined that body mass and lean body mass increased at a greater rate for the creatine monohydrate and creatine monohydrate–glutamine-taking groups compared with the placebo treatment. Additionally, the creatine monohydrate and creatine monohydrate–glutamine-taking groups exhibited significantly greater improvement in initial rate of power production compared with the placebo treatment.

Glycine

Glycine is a conditionally dispensable amino acid that is synthesized from serine, with folate acting as a **coenzyme (enzyme cofactor)**. Glycine gets its name from the Greek word meaning "sweet." It is a sweet-tasting substance. Glycine is an important **precursor** of many substances in the body, including protein, DNA, phospholipids, collagen, and creatine. It is also a precursor in the release of energy and has been shown to increase growth hormone levels. Glycine is found in high amounts in connective tissues: collagen and gelatin.

Coenzyme: an enzyme cofactor.

Precursor: an intermediate substance in the body's production of another substance.

Additionally, glycine is used by the liver in the elimination of toxic substances and in the formation of bile salts, exhibiting hepato-protective effects. It is necessary for the proper functioning of the central nervous system and is an inhibitory neurotransmitter. During rapid growth, the body's demand for glycine increases. Studies have confirmed that the use of glycine supplements causes an increase in growth hormone. Some studies have also noted that glycine ingestion causes an increase in strength, possibly due in part to its elevation of the GH level or increased collagen synthesis. Supplemental glycine has additionally been shown to increase body creatine levels.

The use of supplemental glycine for increasing athletic performance is still in the early stages of development. However, short-term use of 1 to 6 grams per day, in divided dosages, may be beneficial for power athletes and bodybuilders training for increased strength and muscle mass and for connective tissue repair and maintenance. As with all free-form amino acids, use glycine supplements with caution. In full profile amino acid products, glycine is typically contained in protein supplements and supplements that contain hydrolyzed collagen and gelatin. In the general population, dietary intake of alanine is reported to be approximately a mean of 3.2 grams per day to a high of 7.8 grams per day.

Histidine

Histidine is an indispensable amino acid, important in the growth and repair of human tissue. Histidine is also important in the formation and maintenance of hemoglobin, the oxygen transport protein in red blood cells. In addition, histidine is used in the body to make histamine and carnosine (as previously reviewed in the Alanine entry). Carnosine is chemically beta-alanyl-L-histidine.

The benefits of prolonged use of extra supplemental free form histidine by athletes needs to be established in terms of improved athletic performance, beyond histidine's role as a required amino acid to promote growth and health. Histidine is typically found in all proteins, and you will see it listed on protein supplement labels along with the other common amino acids. The mean dietary intake is reported to be 2.2 grams per day with the highest intake about 5.2 grams per day in the general population.

Isoleucine

Isoleucine is an indispensable acid that, along with leucine and valine, is one of the BCAAs. Isoleucine is found in proteins and is needed for the formation of hemoglobin. It is involved in the regulation of blood sugar and is metabolized for energy in muscle tissue during exercise. Supplemental intake of L-isoleucine, along with the other BCAAs, has been shown to help spare muscle tissue, maintain nitrogen balance, and promote muscle growth and healing. For dosage recommendations, refer to "The Branched-Chain Amino Acids" heading.

Leucine

Leucine is an indispensable amino acid found in proteins that is, like the other BCAAs, important in energy production during exercise. For many years, the three BCAAs were assumed to contribute equally to energy. Recent studies, however, have shown that both exercising and resting muscle tissue uses far more leucine for energy than either of the other two BCAAs do. According to estimates, over 50 percent of dietary leucine may be used for energy in exercising muscles. This makes leucine a very limiting amino acid if supplemental amounts are not taken to compensate for the loss. Leucine may also stimulate the release of insulin, which increases protein synthesis and inhibits protein breakdown. The most recent new function attributed to leucine is in controlling protein synthesis, via the mTOR pathway. Review the special article at the end of this unit for more details about this. For supplemental L-leucine dosage examples, refer to "The Branched-Chain Amino Acids" heading.

Lysine

Lysine is an indispensable amino acid that is found in large quantities in muscle tissue. It is needed for proper growth and bone development, and it aids in calcium absorption. Lysine has the ability to enhance immune system function and is reported to be useful for fighting cold sores and herpes viruses. It is required for the formation of collagen, enzymes, antibodies, and other compounds. Together with methionine, iron, and vitamins B1, B6, and C, Lysine helps form carnitine, a compound that the body needs in the production of energy from fatty acids. Mean dietary intake of lysine is 5.3 grams per day, and the highest intake is about 12.6 grams per day in the general population.

Lysine deficiency can limit protein synthesis and the growth and repair of tissues, in particular the connective tissues. Lysine has been shown to increase growth hormone levels, usually in association with other amino acids, like arginine. Lysine should be part of all full-spectrum amino acid supplements and in protein powders. Beyond lysine's importance as an indispensable amino acid for good nutrition and health, the effects of the use of supplemental free form L-lysine by athletes needs to be determined for measures in significant training or athletic performance improvements.

Methionine

Methionine is an indispensable sulfur-bearing amino acid. It is involved in **transmethylation**, a metabolic process that is vital to the manufacture of several compounds, is involved in the synthesis of creatine and important in muscle performance. In transmethylation, an

Transmethylation: the metabolic process in which an amino acid donates a methyl group to another compound.

amino acid donates a methyl group to another compound. These methyl donors often function as intermediaries in many biochemical processes. Methionine is the major methyl donor in the body. Mean dietary intake of methionine is 1.8 grams per day, with the highest intake about 4.1 grams per day in the general population.

Methionine is a limiting amino acid in many proteins, especially in plant proteins. It functions in the removal of metabolic waste products from the liver and assists in the breakdown of fat and the prevention of fatty buildup in the liver and arteries. It is used to make choline, which makes taking supplemental choline a mandatory practice for athletes to spare methionine for its other functions. Methionine is commonly added to meal replacement drinks and other nutrient beverages containing soy protein because it increases the quality of the protein.

Ornithine

Ornithine is a dispensable amino acid that does not occur in proteins. Ornithine's primary role in the body is in the urea cycle, which makes it important in the removal of ammonia. It is formed from arginine in the urea cycle. Like arginine, ornithine has been proven to be an effective GH releaser. This specific role has brought ornithine widespread recognition among athletes in recent years.

Supplementation with L-ornithine in various dosages, ranging from 2,000 to 4,000 milligrams per day, has been studied. Research using L-ornithine with other amino acids has also been conducted. Research study using 1,000 milligrams of L-ornithine and 1,000 milligrams of L-arginine per day along with five weeks of weight training showed a decrease in body fat and an increase in muscle mass. However, indications are that the effective dose of L-ornithine might be higher. Another study examining the effects of bodybuilders taking only ornithine supplements reported an increase in growth hormone levels. More research needs to be conducted to determine the exact dosage and the specific benefits. Ornithine-containing supplements may be particularly beneficial for bodybuilders, powerlifters, sprinters, and other strength athletes.

Ornithine is also an important component of ornithine alphaketoglutarate, a compound that is gaining popularity among bodybuilders and power athletes. Ornithine Alphaketoglutarate (OKG). OKG is used in clinical nutrition based primarily on its anabolic action.

Studies report the use of OKG in Europe for a number of years—as far back as the early '70s—mainly for the treatment of burn victims, trauma, post-surgical healing, and cases of severe malnutrition. OKG consists of two ornithine molecules and one alphaketoglutarate molecule. OKG is a stimulus for a variety of metabolic functions. It acts as an ammonia scavenger; improves nitrogen balance; increases glutamine pool in muscle tissue, thereby reducing muscle break down (catabolism); elevates growth hormone levels; increases protein synthesis; increases insulin secretion; plays a role in glutamine synthesis; and provides an anti-catabolic effect. OKG is used in multi-ingredient formulas from 1 gram to a few grams and in single-ingredient formulas at higher dosages, typically a few grams or more, twice daily.

Phenylalanine

Phenylalanine is an indispensable amino acid and a precursor of the nonessential amino acid tyrosine. Ingestion of supplemental tyrosine therefore spares phenylalanine for its other functions. Mean dietary intake is 3.4 grams per day, with the highest intake about 7.7 grams per day.

Phenylalanine has many functions in the body and is a precursor of several important metabolites, such as the skin pigment melanin, and several catecholamine neurotransmitters, such as epinephrine and norepinephrine. The catecholamines are important in memory and learning, locomotion, sex drive, tissue growth and repair, immune system functioning, and appetite control. Phenylalanine suppresses appetite by increasing the brain's production of norepinephrine and cholecystokinin (CCK). CCK is the hormone thought to be responsible for sending out the "I am full" message. These functions of phenylalanine can be of tremendous value to athletes, especially those who need to stimulate mental alertness, to lose weight, or to maintain low levels of body fat.

DL-phenylalanine (DLPA) has been shown to be useful in combating pain. This can be beneficial for athletes who suffer from acute or chronic pain from injury. Dosages of 500 to 1,500 milligrams of DLPA per day have been reported to be effective for this purpose. The theorized mechanism is that DLPA "protects" the endorphins in the body from destruction, thereby allowing them to distribute their morphine like pain relief. Endorphins are a thousand times more powerful than morphine is. Remember, however, that more is not always better. If you experience just partial pain relief, contact your health-care practitioner to evaluate your condition. Do not take mega doses of DLPA, especially without medical supervision.

Dosages of supplemental L-phenylalanine ranging from 100 to 500 milligrams, taken one to three times a day, has been reported to produce no major side effects. However, note that higher dosages have been reported to cause headaches in some people. Cofactors that appear to be necessary in phenylalanine metabolism include vitamin B3, vitamin B6, vitamin C, copper, and iron.

A word of caution: The artificial sweetener aspartame is a di-peptide made up of phenylalanine and aspartic acid. Soft drinks containing aspartame carry warnings that are aimed at people with phenylketonuria (PKU), a disease in which phenylalanine is not properly metabolized and can be very damaging. People with phenylketonuria should not take any supplemental L- or DL-phenylalanine.

People who drink a great number of caffeine-containing beverages or take energy supplements with caffeine-containing herbs, such as guarana, may need more phenylalanine. Caffeine tends to cause some of the neurotransmitters that are made with phenylalanine to become depleted in the central nervous system. This is one of the reasons people sometimes feel mentally fuzzy after drinking a lot of coffee. Taking supplemental L- or DL-phenylalanine may help offset the depletion, or reduce your caffeine consumption.

Proline

Proline is a conditionally indispensable amino acid. It occurs in high amounts in collagen tissue. It can be synthesized from and also converted to glutamic acid. Hydroxyproline, which is also abundant in collagen, is synthesized in the body from proline. Proline is important in the maintenance and healing of collagen tissues such as the skin, tendons, and cartilage. Proline and hydroxyproline are typically provided in supplements from hydrolyzed collagen or gelatin, which contain high amounts of these amino acids in addition to other amino acids. Hydrolyzed collagen and gelatin have been used in studies and were found to promote improved joint function and improved mobility and to reduce pain and stiffness, in particular, in knee joints. The mean dietary intake of proline is 5.2 grams per day, with highest intakes reported to be about 12 grams per day.

Serine

Serine is a dispensable amino acid found in proteins and derived from glycine. Its metabolism leads to the formation of many important substances, such as choline and phospholipids, which are essential in the formation of some neurotransmitters and are used to stabilize membranes. It is part of an important phospholipid called phosphatidylserine found in cell membranes, is reported to have anti-catabolic effects, and is important in brain and nervous system health and function. Serine is important in the metabolism of fat and the promotion of a healthy immune system. Serine is usually found occurring in supplements from whole proteins. The mean dietary intake of serine is 3.5 grams per day, with a highest reported intake of about 7.9 grams per day.

Taurine

Taurine is a dispensable sulfur-bearing amino acid that plays a major role in brain tissue and in nervous system functioning. It is involved in blood pressure regulation and in the transportation of the electrolytes across cell membranes. It is found in the heart, muscles, central nervous system, and brain. Taurine is also found in the eye and may be important for maintaining good vision and eye functioning. Other reported functions of taurine include bile acid function, detoxification of xenobiotics (foreign substances in the body), membrane stabilization, antioxidant activity, osmoregulation, cell proliferation, modulation of neuronal excitability, and **intracellular** and **extracellular** calcium regulation. A more recent suspected function of taurine is as a constituent of mitochondrial tRNA. Taurine is made in the body from cysteine and methionine, with vitamin B6 as a cofactor. Taurine is typically found in sports nutrition products and energy drinks due to its diverse and important functions to ensure adequate levels in strenuous training athletes.

Intracellular: inside the cell.

Extracellular: outside the cell.

Threonine

Threonine is an indispensable amino acid found in proteins. It is an important component of collagen, tooth enamel, protein, and elastic tissue. It can also function as a lipotropic agent, a substance that prevents fatty buildup in the liver. Mean daily dietary intake of threonine is about 3 grams per day with a high intake of 7.1 grams per day.

Supplemental threonine has a reported medical use in the treatment of depression in patients with low threonine levels. Studies still need to be undertaken to determine the exact benefits of taking extra threonine supplementation for athletes, besides the expected benefits associated with its essential functions in protein synthesis and other tissues.

Tryptophan

Tryptophan is an indispensable amino acid necessary for the production of vitamin B3 and neurotransmitter serotonin. Taking supplemental vitamin B3 can help conserve tryptophan for its other functions. The mean daily intake of tryptophan is about 0.9 grams per day, with an upper intake of 2.1 grams per day in the general population.

Supplemental tryptophan has been taken for years by millions of people for its pronounced calming effects, which include the promotion of sleep and the treatment of depression. Serotonin helps control the sleep cycle, causing a feeling of drowsiness. Research reported that taking supplemental tryptophan was effective in correcting certain sleep disorders. Tryptophan has also been reported to increase the GH levels and was a popular ingredient in nighttime GH-releasing supplement products.

Tryptophan is one of the least abundant amino acids in food, which makes it one of the limiting essential amino acids. Some foods high in tryptophan are cottage cheese, pork, wild game, duck, and avocado. Eating these foods along with vitamin B3 and the cofactors vitamin B6 and magnesium may help athletes derive some of the benefits that tryptophan offers.

Tryptophan has been commercially used as a single-form amino acid for many years. It has been used by doctors and self-prescribed for treating depression, managing pain, and helping with sleep. In 1989, there was a sudden outbreak of a rare blood disorder observed in the United States. The National Institute of Health quickly linked development of the disorder to use of certain tryptophan supplements. As a result of this occurrence, the US Food and Drug Administration (FDA) limited the use of tryptophan as an individual supplement and only allowed its use to fortify protein and other limited applications. The vast majority of supplement users were surprised because, based on decades of use, the rare blood disease had never before been linked to tryptophan. Almost immediately during the investigation, health officials found that the tryptophan supplements used by people who developed the blood disease came from the same manufacturer located in Japan. Upon further investigation, it was finally discovered that there was a contaminant in several batches of tryptophan and that the contaminant was responsible for causing the blood disease, not the supplemental tryptophan. Time has passed, and tryptophan products are beginning to appear on the market again.

Tryptophan is also found in many protein and amino acid products in the amino acid profile information section of the nutrition labels. Tryptophan, like many amino acids, is a naturally occurring essential amino acid found in all dietary proteins. In fact, you cannot live without it. As a result, many of the supplements you purchase indicate that the tryptophan content is from natural sources, not to be confused with the synthetic form of tryptophan. However, some companies have begun to sell single-ingredient tryptophan supplements again.

Tyrosine

Tyrosine is a conditionally indispensable amino acid and is made from the essential amino acid phenylalanine. Supplementation with L-tyrosine can have a sparing effect on phenylalanine, leaving phenylalanine available for functions not associated with tyrosine formation. Mean daily intake of tyrosine is reported to be about 2.8 grams a day, with high daily intake of 6.4 grams per day in the general population.

Tyrosine plays many roles in the body. It is a precursor of the catecholamines dopamine and norepinephrine, regulates appetite, and aids in melanin skin pigment production. These functions are similar to the ones with which phenylalanine is associated as a precursor of tyrosine. However, tyrosine is believed to be better at stimulating these effects because it is one step closer as a precursor. An antidepressant effect and an increased sex drive in men have also been observed with tyrosine supplementation. Studies conducted under experimental conditions have yet to report any improved athletic performance from ingesting tyrosine supplements. A word of caution: tyrosine supplement use may trigger migraine headaches in some people when it is broken down into a product called tyramine.

Valine

Valine is an indispensable amino acid and a member of the branched-chain amino acids. The same as the other BCAAs, isoleucine and leucine, valine is an integral part of muscle tissue and may be used for energy by exercising muscles. It is involved in tissue repair, nitrogen balance, and muscle metabolism. For supplemental L-valine dosage recommendations, refer to "The Branched-Chain Amino Acids" heading.

A Final Word on Amino Acids

Although the above information is comprehensive, many uses for the individual amino acids were not included. These mainly deal with clinical and metabolic disorders and their treatment, which is beyond the scope of this course. As more research is being performed on amino acids and the athlete, new discoveries and uses of amino acids will very likely be discovered. Also, be aware that just because a clinical research study reports a positive finding for an amino acid, or other dietary substance, the application of research findings needs to be evaluated for each individual athlete, in the context of his or her health, training, and nutrition and under doctor supervision—along with other suitable health professionals as required. Duration of use may also be of some concern, as the clinical research studies generally are conducted over a few to several weeks, with some longer. As such, long-term use safety and efficacy may not be established. In addition, the research studies typically use small study groups, which may not provide a comprehensive representation of how all people will respond to supplementation.

Special Protein and Amino Acid Needs of the Athlete

Based on the above information, which explains some of the dynamic metabolic aspects of amino acids, sport nutritionists now realize that simply eating a fixed amount of protein is not the only requirement of optimum protein intake. The type of protein will affect how it is used by the body, and fortification of certain amino acids and other cofactors can be used to make more efficient use of food source proteins. At the very least, protein intake for athletes is becoming a sophisticated science. Just how much protein an athlete requires will depend on his or body weight, the quality of protein eaten, and the intensity and duration of exercise.

A look at the RDA guidelines for protein will provide a baseline for the athlete's protein requirements. The following guidelines are what the National Research Council recommends for average protein consumption for different age groups and genders. The protein allowances are determined on a body weight basis. These values assume that you are of normal body weight. If you are over fat, you will end up over calculating your protein needs from the RDA basis.

It is interesting to observe that on a weight basis, children require more protein per kilogram of body weight for growth. For an adult male between the ages of 25 and 50, getting 63 grams of protein per day can be obtained by eating about 6 ounces of chicken. However, research has shown that athletes engaged in daily exercise have difficulty maintaining nitrogen balance when dietary protein intake is less than 1.5 grams/kilogram of body weight (Hoerr, Young, and Evans), which is about 50 percent higher than the RDA.

It is estimated that, depending on your type of sport, the requirement for protein is about 1.5 to 2.5 grams/kilogram of ideal body weight. And in some special instances, for example a bodybuilder preparing for a contest, the requirement may exceed 3 grams/kilogram of body weight. How much food does this translate to? For an athlete weighing 79 kilograms, protein intake should be between 118 to 198 grams per day. That's two to three times the RDA and a lot of protein to eat (about 14 ounces to 22 ounces of chicken per day). Remember that excess protein does not get converted to muscle. It is either broken down and used as energy in the liver, or converted to fat. Because protein is also one of the most expensive nutrients, you should take special care to eat just the right amount for your sport, lean body weight and activity level. Another consideration for protein consumption is making the proteins you eat more efficient. This can be accomplished by using a multi-amino acid and BCAA supplement to fortify the protein you are eating. By providing potential limiting amino acids from supplement sources, you may be able to maintain nitrogen balance or positive nitrogen balance with less protein intake. While some general protein supplement guidelines will be given, the only way you can determine this for sure is to monitor how your nitrogen balance varies with different levels of protein intake and supplement use.

Also, protein cofactors are required for the proper metabolism of amino acids. Vitamin B6 (pyridoxine) is the most important amino acid cofactor because it is required for the function of amino acid metabolizing enzymes. Niacin is an important vitamin because it can spare tryptophan, which is converted to niacin in the body. However, don't take large amounts of niacin during exercise, as studies have shown that large intakes of niacin can increase glycogen use, resulting in faster fatigue. Intake of all the other essential vitamins and minerals is important for optimum amino acid use. Researchers have determined that there is an increase in calcium excretion with increased protein intake. An increase in phosphorus seems to minimize this effect, as does an increase in calcium intake for individuals on high protein diets.

Food and Supplement Sources of Protein

Proteins are found in both animals and plants, and in special supplement formulations. Protein and fat are usually found together in foods, especially animal products. Most animal proteins tend to be of higher quality than plant proteins in that animal proteins contain the proper proportions of essential amino acids. Most plant protein sources, such as beans and peas, are often incomplete in their essential amino acid content. Combinations of different plant proteins are required to obtain an adequate balance of amino acids. Some combinations include combining peas with corn or kidney beans with brown rice. If you are a vegetarian or decide to become one, you must learn to combine legumes with grains to formulate complete proteins. That is beyond the scope of this course book.

Some good low-fat sources of protein include the following: low-fat/skim milk and other low-fat dairy products; most fish – cod, sole, halibut, tuna, sardines, salmon; most shellfish – scallops, lobster, crab, shrimp, mussels; lean red meats with the fat trimmed; poultry skinned.

You may find it interesting to note though that if you were to search the scientific literature for human studies, you would find that one of the more impressive studies was conducted on SUPRO isolated soy protein. The research was conducted in 1992 by I. Dragan and coworkers, who worked with 66 Romanian

Olympic endurance athletes (30 kayak-canoe, 36 rowing, 45 males and 21 females). These athletes participated in this 12-week study to determine the biological effects of SUPRO-isolated soy protein. The athletes were split into two groups: the A group received 1.5 grams per kilogram of body weight of SUPRO a day. The athletes in the B group did not receive any protein supplement. This means that right from the start the A group ingested about twice the protein per day than the B group did. Here are the results reported from the A group; the group experienced an increase in body mass of about 6 pounds, strength improved, and there was a decrease in fatigue after training sessions. No damage to the liver, kidney, or fat metabolism were noted.

Whey Protein Gets Results, Too

While high-quality whey protein isolate is the most expensive of the primary protein sources used in protein products, it has some distinct nutritional advantages. It enhances the production of glutathione, one of the body's most powerful natural antioxidants. It has high levels of BCAAs and has been shown to boost immune system functioning and promote and support protein synthesis. It is high in glutamine and arginine. It has a good proportion of essential and nonessential amino acids. Additionally, whey protein has been clinically proven to build muscle and improve athletic performance. It has also been shown to help reduce body fat, while at the same time increase lean muscle mass when taken as part of an exercise program. Another important benefit of the protein is its ability to raise levels of IGF-1, a muscle-building biochemical, and decrease levels of cortisol, a muscle and tissue degrading substance.

Effects of Creatine Monohydrate plus Whey Protein

A study conducted by D. G. Burke and coworkers sought to measure muscular developments during six weeks of resistance training, among 36 males who were randomly assigned to supplementation with whey protein, whey protein and creatine monohydrate, or a placebo (maltodextrin). At the end of the six-week study period, the following results were observed:

Lean body tissue mass increased to a greater extent in the whey-creatine group compared with the other groups and also in the whey group when compared to the placebo group: + 4 kg, 6.5% in the whey-creatine group; +2.3 kg, 3.8% in the whey group; and +0.9 kg, 1.5% in the placebo group. Bench press strength increased to a greater extent in the whey-creatine group compared with that of the other groups: +15.2 kg, 17% in the whey-creatine group; 6.3 kg, 7% in the whey group. Knee extension peak torque increased significantly with training in the whey-creatine and whey groups, but not for the placebo group. The researchers also observed that continued training for an additional six weeks without supplementation resulted in maintenance of strength and lean tissue mass in all groups. The study's results revealed a synergistic effect among males taking the whey protein and creatine supplement, which resulted in greater increases in lean tissue mass and bench press performance.

W. Derave and coworkers wanted to determine the effects of creatine monohydrate and creatine plus protein supplementation on GLUT-4 and glycogen content of human skeletal muscle. Note that GLUT stands for glucose transporter. There

Adipose tissue: fat tissue in the body.

are five main GLUTs, which tend to be tissue specific, and GLUT-4 is more abundant in skeletal muscle tissue and in **adipose tissue**. This double blind, placebo-controlled trial was performed on 33 young healthy subjects (26 men and 7 women). The subjects' right legs were immobilized with a cast for two weeks, followed by a six-week resistance-training program for the right knee extensor muscles.

The research participants were supplemented throughout the study with placebo (maltodextrin) or creatine & maltodextrin, or with creatine plus protein during immobilization, and creatine plus protein, maltodextrin, amino acid blend, and multivitamin blend during retraining. Needle biopsies were bilaterally taken from the vastus lateralis (a muscle of the quadriceps group, of the thigh). GLUT-4 protein expression was reduced by the immobilization in all groups. During retraining, GLUT-4 content increased in both creatine (+24%) and creatine-protein (+33%) groups, which resulted in higher post-training GLUT-4 expression.

When compared with the placebo group, the muscle glycogen content was higher in the trained leg in both creatine and creatine-protein groups. Supplements had no effect on GLUT-4 expression or glycogen content in control legs. Area under the glucose curve during the oral glucose tolerance test was decreased from 232 mmol per liter per minute at baseline to 170 mmol per liter per minute at the end of the retraining period in the creatine-protein group, but it did not change in the creatine or placebo groups. The researchers concluded that creatine intake stimulates GLUT-4 and glycogen content in human muscle only when combined with changes in activity level and that combined protein and creatine supplementation improved oral glucose tolerance. Unit 9 contains details about creatine.

Another type of milk protein, called casein, is ingested from dairy products along with whey and is used in its isolated from as an ingredient in sports nutrition products. Casein is more slowly digested compared with whey and provides a sustained delivery of amino acids into the bloodstream. This could offer an advantage during longer periods of eating separation due to daily schedules and during sleep. Research has been conducted examining the benefits of pre-sleep ingestion of casein along or in combination with whey to gain the benefits of shorter-term boost in amino acids into the body followed by a more sustained delivery of amino acids. Pre-sleep protein, and other nutrient-ingestion strategies, may help improve exercise-related recovery for all athletes and increase muscle mass and strength gains for resistance-training athletes. Amounts and timing of pre-sleep protein ingestion need to be personalized to consider tolerance and what works best for an athlete. Some studies include carbohydrate and other nutrients in the pre-sleep protein formulas.

Recommended Dietary Allowances for Protein

The following table contains a list of some of the Protein Recommended Dietary Allowance values for a sample of adult age groups. The Appendix contains the entire table. These are the 2002/2005 Dietary Reference Intake values issued by the Institutes of Medicine, National Academy of Sciences, minimum protein intake goals for the general population. Note that the Protein RDA values were calculated based on grams protein per kilogram of body weight for reference body weights; for adults 0.8 g/kg body weight times the age group reference body weight. Details can be found in the IOM publication. It is obvious that these protein values are low in general for active adults and would be considered very low for most competitive athletes.

Recommended Dietary Protein Allowances		
Protein (some adult age group examples)		
Category	**Age Group Years**	**Protein RDA g/day**
Males		
	14–18	52
	19–30	56
	31–50	56
	51–70	56
Females		
	14–18	46
	19–30	46
	31–50	46
	50–70	46

Estimating Daily Protein Requirements

The following table for Estimating Daily Protein Requirements was developed by coauthor Dr. Frederick Hatfield. It uses a "dynamic" approach that considers individual differences based on an individual's lean body mass and need factor (activity).

Estimating Daily Protein Requirements

Lean Body Weight (lbs) x Need Factor = Daily Protein Requirement (g)

Need Factors:

- 0.5 - Sedentary, no sports or training
- 0.6 - Jogger or light fitness training
- 0.7 - Sports participation or moderate training 3X a week
- 0.8 - Moderate daily weight training or aerobic training
- 0.9 - Heavy weight training daily
- 1.0 – Heavy weight training daily plus sports training, or "2-a-day" training

LBW* (lb.)	**Need Factor** (protein requirements expressed in grams per day)					
	0.5	**0.6**	**0.7**	**0.8**	**0.9**	**1.0**
90	45	54	63	72	81	90
100	50	60	70	80	90	100
110	55	66	77	88	99	110
120	60	72	84	96	108	120
130	65	78	91	104	117	130
140	70	84	98	112	126	140
150	75	90	105	120	135	150
160	80	96	112	128	144	160
170	85	102	119	136	153	170
180	90	108	126	144	162	180
190	95	114	133	152	171	190
200	100	120	140	160	180	200
210	105	126	147	168	189	210
220	110	132	154	176	198	220
230	115	138	161	184	207	230
240	120	144	168	192	216	240

*LBW – Remember that your fat cells do not require protein Thus, it doesn't make any sense to compute your protein requirements from total Body weight. Your LBW (lean body weight, or fat-free weight) can be estimated using any one of several anthropometric, ultrasound, electrical impedance, or under water weighing techniques.

Developed byDr. Fredrick Hatfield, PhD

Cofactors

The vitamin and mineral cofactors are also important, as are herbal factors that have been found to benefit protein utilization. Many sports nutrition companies now understand this and as such are including these cofactors into their formulations, such as Vitamin B6, glutamine, and glucosamine.

Check Those Labels

Amino acids and proteins come in many forms and combinations. When purchasing supplement formulations that supply one or several amino acids, it is important to learn how to determine how much of the actual amino acid you are getting. For example, the ingredient list for a supplement containing L-Arginine and L-Ornithine may read:

Each Capsule Supplies:
L-Arginine | 500 mg
L-Ornithine | 500 mg

This means that the amounts of arginine and ornithine are being reported as their molecular amounts. Now, you may also come across products that contain arginine and ornithine combined with other molecules. For example, the label may read:

Each Capsule Supplies:
L-Arginine Hydrochloride | 500 mg
L-Ornithine Hydrochloride | 500 mg

This can also be written L-Arginine HCL. This means that each capsule has 500 mg of the entire molecule of L-Arginine Hydrochloride, of which arginine may only make up 60 percent. The first example actually has 500 mg of arginine and ornithine per capsule and is a better product. The label may report the ingredient as follows:

Each Capsule Supplies:
L-Arginine (HCL or Hydrochloride) | 500 mg
L-Ornithine (HCL or Hydrochloride) | 500 mg

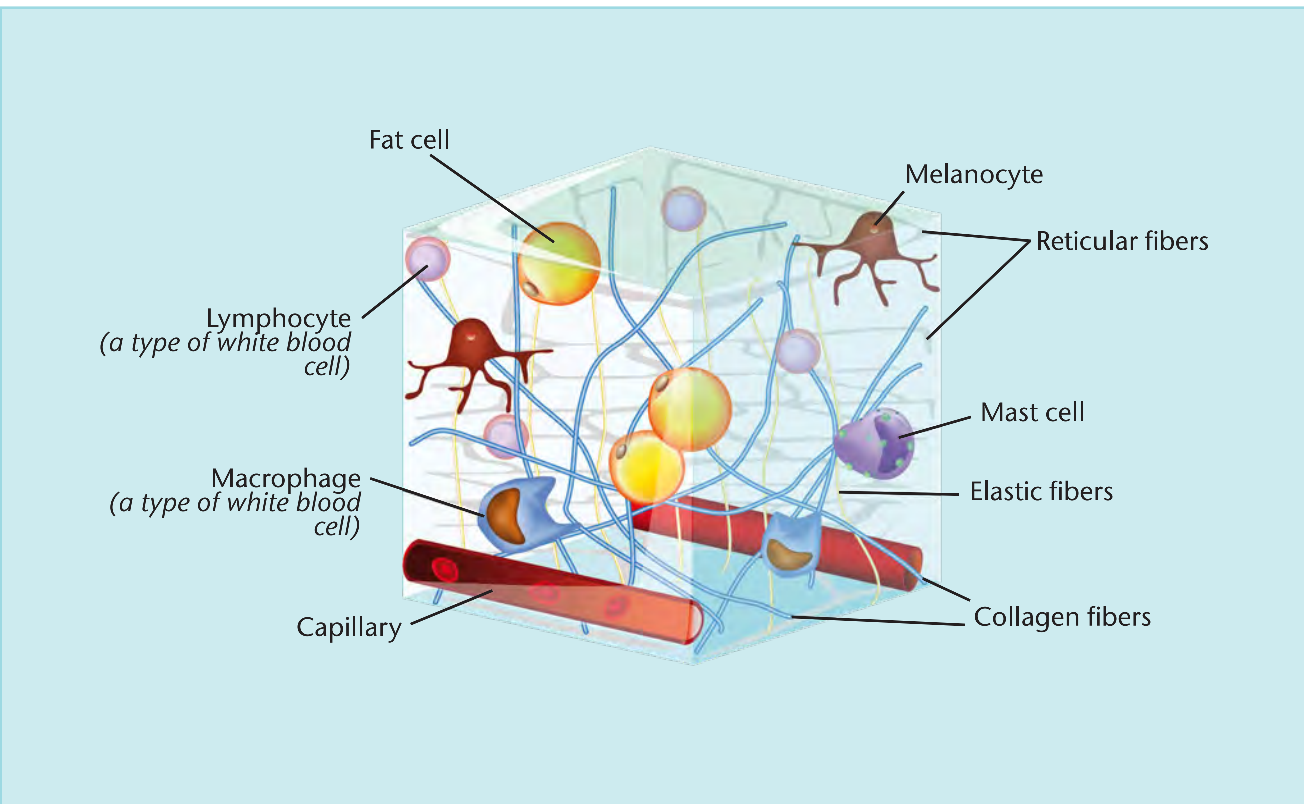
The parentheses around the Hydrochloride let you know that the product contains in each tablet 500 mg of arginine and ornithine in the form of Hydrochloride, which means that you are getting the full 500 mg per capsule as in the first example. This is important to understand, especially when you are comparing formulations from different companies.

Always beware of a product that does not give the amount of the amino acid you desire. Some products only list the amino acid in the ingredient listing and do not give its quantity. This is of no use to you, as there is no way of determining your daily amount needed.

Connective Tissue

Hyaluronic acid: a polysaccharide molecule which is one of the chief components of connective tissue, forming a gelatinous matrix that surrounds cells.

There are several types of connective tissues. Cartilage, tendons, ligaments, intervertebral discs, pads between joints, and cellular membranes all are comprised of connective tissue. All connective tissues have two common components, chief of which is collagen. One-third of your body's total protein volume is comprised of collagen, making it the most common protein in the body. The other component is proteoglycans (PGs). PGs form the "framework" for collagenous tissue. These huge structural "macromolecules" are comprised mainly of glycosaminoglycans (GAGs) -- long chains of modified sugars. The principal sugar in PGs is called **hyaluronic acid**, of which 50 percent is



Connective tissue components

composed of glucosamine. The principal amino acids forming collagen are glycine, proline, lysine, hydroxyproline, and hydroxylysine.

Collagen and PGs must somehow "get together" during the production of new connective tissue. Of the multitude of biochemical reactions that must take place during the synthesis of connective tissue, there is one critical "rate-limiting" step that once reached guarantees that new connective tissue is being successfully synthesized. That rate-limiting step is the conversion of glucose to glucosamine. Refer to Unit 9 for details about glucosamine and chondroitin sulfate.

Summary of Protein and the Athlete

- Athletes need about two to three times the amount of the DRI for protein.
- Ideally protein requirement should be calculated on a lean body weight basis.
- High quality proteins should be a dominant part of the diet.
- Protein supplements and amino acid tablets can be used to fortify dietary proteins from food sources.
- Protein should be consumed with each meal, but not for pre-event meals.
- Branched Chain Amino Acids and Multi-Amino Acid formulations high in Branched Chain Amino Acids can be taken with meals to fortify food proteins and alone before exercise to spare muscle tissue. Protein powders can be used as well.
- Vitamin B6 and calcium might need to be increased for athletes on high protein diets, and should be part of amino acid formulations taken for muscle growth and recovery.
- Individual amino acids can be taken alone or in combination for special uses, like growth hormone release, ammonia detoxification, relaxation, stimulation, or as antioxidants.
- Remember that collagen is the most abundant protein in the body, comprising fully one third of the total body protein volume. Its importance to athletes is clearly critical due to the connective tissue repair requirement brought on by microtrauma during intense training and competition.

Conclusion

Proteins and amino acids are a diverse group of macronutrients, which are vital building blocks of the human body for growth, maintenance, and repair; used to make a variety of biomolecules required for body function and structure; and also contribute a minor source of high yielding energy for athletic performance. Protein requirements for athletes are generally high for less active nonathletes, and protein intake can be even further fine-tuned based on each athlete's individual requirements and type of sport. Focusing on healthy types of protein sources is also important. Unit 17 will provide details regarding protein nutrition guidelines for athletes, including specialty topics, such as timing nutrient intake.

Keywords

Ammonia

Uric acid

Polypeptide

Urea cycle

Hormone

Deoxyribonucleic acid (DNA)

Collagen

Connective tissue

Lipoprotein

Cell membrane

Hemoglobin

Ribonucleic acid (RNA)

Limiting nutrient

Complete protein

Incomplete protein

Cannibalization

Free-form amino acids

Di-peptide

Tri-peptide

Hydrolyzed protein

Blood-brain barrier

Coenzyme

Precursor

Transmethylation

Intracellular

Extracellular

Adipose tissue

Hyaluronic acid

Topics Covered In This Unit

UNIT 5

LIPIDS AND THE ATHLETE: ENERGY AND GROWTH FACTORS

Unit Outline

Learning Objectives

After completing this unit, you will be able to:

- Define and describe key terms related to lipids (fats and oils).
- Understand the different types of lipids and their major functions.
- Determine essential and nonessential lipids, such as fatty acids.
- Discuss how lipids affect athletic performance and heath.

Introduction

Lipids compose the third major macronutrient category. Like carbohydrates, lipids are made up of carbon, hydrogen, and oxygen. Lipids are necessary for numerous reasons. They are involved with the storage and supply of the fat-soluble vitamins A, D, E, and K. They are a source of essential fatty acids, which play many vital roles in maintaining the function and integrity of cellular membranes. They serve as a concentrated source of energy; they add palatability to the meal; and they are important in other biochemical and biophysical functions, such as steroid hormone synthesis.

Prevalent types of lipids used for energy include **triglycerides** (consisting of glycerol and three fatty acids), also referred to as triacylglycerol, and the free fatty acids. As an energy substrate, the importance of lipids will depend on the type of exercise being performed. During endurance events, more triglycerides are used for energy. For high-intensity sports, like sprinting, glycogen is used as a primary fuel, but some lipids are also used. It is important to understand that lipids are always being metabolized for energy by the body; it's just a matter of degree. Research also shows that the trained athlete will use more lipids for energy than the untrained athlete will.

Triglycerides: a type of fat in your blood, triglycerides can contribute to the hardening and narrowing of your arteries if levels are too high. This puts you at risk of having a heart attack or stroke. Triglycerides are measured along with cholesterol as part of a blood test. Normal triglyceride levels are below 150 mg/dL. Levels above 200 mg/dL are high.

Strength athletes are prone to becoming fat because of this differential use of energy substrate. That is, they use mostly glycogen stores for energy and ingested carbohydrate, with a minor amount from body fat stores. This category of athletes must therefore follow nutrition programs that are low in fat and high in fat metabolizing nutrients. But even though the marathon runner can get away with eating a high-fat diet, too much fat in the diet can impede performance and prove unhealthy, especially when high-fat diets are lower in adequate amounts of carbohydrates and protein.

Athletic Significance of Lipids

- Essential fatty acids are required for growth, recovery, and overall health.
- Essential fatty acids are part of each cell, including muscle cells.
- Fatty acids are an important source of energy, especially for endurance athletes.
- Intake of saturated fats and cholesterol should be kept at healthy intake levels to avoid development of coronary heart diseases their over consumption is linked to, plus other diseases.
- Daily intake of fat metabolizing vitamin and mineral cofactors is necessary for efficient fat metabolism.
- Omega-3 fatty acids, such as gamma-linolenic acid, DHA, and EPA cause beneficial effects on the cardiovascular system, act as moderators of inflammation, and play possible roles in improvement of strength and aerobic performance.

Lipids — The Most Misunderstood Macronutrient

Some dietary lipids (also referred to just fats) have gained a bad reputation over the years. Medical research has linked a diet high in saturated fats and cholesterol to many diseases, such as cancers, coronary heart disease, and obesity. The fact remains, however, that certain lipids are essential to your health. It's really a matter of balance and a habit of trimming down the total amount of fat in your diet. Be aware that even with the healthy lipids, athletes need to keep total daily lipid intake in check, to allow for consumption of high carbohydrates and extra protein intake that athletes require. Regarding lipids, a focus on the healthy essential lipids is a crucial goal.

Historically, the primary problem with lipid intake in the diet is simple: most people get too much total lipid, too much of the wrong kind of lipids, and not enough of the good lipids. The ultimate goal for the athlete will be to keep total lipid intake below 30 percent of total daily calories or less, maximize the essential fatty acids and omega 3 fatty acids, and minimize saturated fatty acids and cholesterol. The main functions of dietary lipids include:

- To provide fuel; fatty acids are a major fuel source during exercise
- To provide insulation as body fat stores
- To aid in the absorption of fat-soluble vitamins
- To act as an energy storehouse
- To supply essential fatty acids
- To provide protective padding for body structures and organs
- To serve as a component of all cell membranes and other cell structures
- To promote healthy skin
- To supply building blocks for other biomolecules

For the athlete, getting enough lipid in the diet is usually not a problem. In fact, the opposite is more often the case. Although fats are necessary for health, too many of the wrong kinds of fats can have negative effects on the body and lead to certain cancers and atherosclerotic cardiovascular diseases. Saturated fats and cholesterol are common culprits. Of course, too much dietary intake of any fat can contribute to excess body fat and, for some, obesity. Most experts recommend a total dietary fat intake of less than 30 percent of the total daily calories. Some sources even recommend keeping fats at 20 percent or lower; for example, "The IOC (International Olympic Committee) recommends following a diet that does not contain less than 15–20% fat of total energy" (in Potgieter 2013, Sundgot-Borgen 2011). Ingestion of a high amount of saturated fats and cholesterol is clearly linked to various cardiovascular diseases and certain cancers. Because the athlete generally consumes more than 3,000 calories a day during the competitive season, they can easily get an overdose of fat in the diet. Getting adequate amounts of the right fats is therefore a major focus for sports and fitness nutrition, while being careful not to overdo lipid ingestion, to leave room for the other important macronutrients vital to athletic performance and health: carbohydrates and protein.

About the Different Lipids

Lipids occur in both plants and animals but vary slightly in chemical composition. By definition, lipids are compounds soluble in organic solvents but not in water. Mammal fats tend to be more saturated than fish oils and plant oils are. Beef tends to be more saturated than pork and poultry are. The degree of hardness of a fat at room temperature is an indication of how saturated the fat is. Compare hard beef fat with soft fish fat and vegetable oils, which have lower amounts of saturated fats and high amounts of polyunsaturated fats.

The following summarizes the major lipids found in the diet and body. They include:

- Triglycerides (consisting of glycerol and 3 fatty acids)
- Fatty Acids (saturated, monounsaturated, and polyunsaturated)
- Essential Fatty Acids (Linoleic, Alpha-Linolenic)
- Omega 3 Fatty Acids (EPA and DHA)
- Gamma-Linolenic Acid (GLA)
- Medium-Chain Triglycerides
- Phospholipids
- Lecithin
- Cholesterol

Oils: lipids that are liquid at room temperature, oils come from many different plants and from seafood. Some common oils include canola, corn, olive, peanut, safflower, soybean, and sunflower oils. A number of foods are naturally high in oils, such as avocados, olives, nuts, and some fish.

Saturated fatty acids: fatty acids that have no double bonds. Fats high in saturated fatty acids are usually solid at room temperature. Major sources include animal products such as meats and dairy products, and tropical oils such as coconut or palm oils.

Unsaturated fat: unsaturated fats are liquid at room temperature. Vegetable oils are a major source of unsaturated fat in the diet. Unsaturated fats include polyunsaturated fats and monounsaturated fats. Other foods, such as avocados, fatty fish like salmon and tuna, most nuts, and olives are good sources of unsaturated fat.

Polyunsaturated fatty acids (PUFAs): fatty acids that have two or more double bonds and are usually liquid at room temperature. Primary sources are vegetable oils and some nuts and seeds. PUFAs provide essential fats such as n-3 and n-6 fatty acids.

Solid fats: fats that are usually not liquid at room temperature. Solid fats are found in animal foods, except for seafood, and can be made from vegetable oils through hydrogenation. Some tropical oil plants,

Triglycerides and Fatty Acids

Triglycerides and fatty acids are the lipids that compose the fats and **oils** in your diet and in the fat that your body stores. They make up about 98 percent of all the fats in the diet. The difference between fat and oil is simple: fats are solid at room temperature, and oils are liquid. This solid and liquid state of fatty acids also tells us something about their composition. Triglycerides consist of 3 fatty acids attached to a 3-carbon glycerol molecule. The hundreds of different fatty acids come in various lengths, between 4 and 24 carbons. Fatty acids are then grouped as follows: short chain (4–5 carbons), medium chain (6–12 carbons), long chains (13–19 carbons), and very long chain (20 or more carbons).

Fatty acids are also rated by the degree of hydrogen atoms that are attached to the carbon chain. **Saturated fatty acids** have the maximum number of hydrogen atoms they can hold, with no double-bonded carbon atoms. This is why saturated fatty acids are more solid. The process of hydrogenation takes **unsaturated fatty acids** and saturates them to become solid, like the vegetable oil fatty acids in margarine are. **Monounsaturated fatty acids** have one double bond, and **polyunsaturated fatty acids** have more than one double bond.

Saturated fatty acids tend to be solid at room temperature. Therefore, **solid fats** are high in saturated fatty acid content. Polyunsaturated fatty acids tend to be liquid at room temperature. Oils are high in polyunsaturated fatty acids. Saturated fatty acids, along with fatty acids containing 16 carbons or less, are always used for energy or stored as body fat. The shorter the fatty acid length, the easier it is to use it as energy. The longer fatty acids can also be used as energy or stored as body fat but have other functions as well, such as being used in structures of cell membranes.

Out of the many fatty acids that exist, only two are considered essential: linoleic and linolenic. Both are 18 carbons long and unsaturated. The following section will review the so-called essential fatty acids.

The Essential Fatty Acids

The three fatty acids that make up a triglyceride molecule will vary in composition. Composition depends upon whether the fatty acid's origin is from plants or animals. Out of the many fatty acids, only two are of essential dietary concern, and one is conditionally essential in the diet. **Linoleic acid** (an Omega-6 fatty acid) is a primary essential fatty acid the body cannot manufacture. It therefore must be obtained from the diet for normal growth and health. However, recent research indicates that diets too high in linoleic acid may cause the metabolism to be sluggish and promote a tendency toward developing a condition that favors storage of body fat. Such diets may also cause an increase in some inflammatory substances the body produces naturally.

A major researcher in this area of fatty acid balance and obesity, Artemis P. Simopoulos, MD, believes that our food supply may be too high in linoleic acid (Omega 6 fatty acid) and too low in <bl>alpha-linolenic acid (an Omega-3 fatty acid). She contends that humans evolved on a diet that was much higher in protein, lower in carbohydrates, but higher in fruits and vegetables, and much lower in saturated fat than today's conventional diets are. Furthermore, the consumption of refined carbohydrate products–sugar, fructose, high-fructose corn syrup, and trans fatty acids from hydrogenated vegetable oils and margarines–adds to the metabolic disruption. The issues of proportions of dietary fat-carbohydrate-protein are more involved for athletic performance, and guidelines are presented as part of the "Dynamic Nutrition" approach to planning a nutrition program.

A modified form of linoleic acid called conjugated linoleic acid (CLA) has emerged on the shelves of health food stores in various supplement product, including some sports nutrition products. The marketers promote CLA as having fat-metabolizing effects that result in burning more fat, thereby increasing lean body mass and decreasing body fat. Recent human studies confirm this effect. CLA details are presented in a following section.

Another fatty acid, arachidonic acid, is made in the body from linoleic acid. Arachidonic acid is thought to become essential when linoleic acid deficiency exists. However, because arachidonic acid must be made from linoleic acid and arachidonic acid is a polyunsaturated fatty acid, the presence in the diet will have a linoleic sparing effect. This may be beneficial to the athlete because arachidonic acid is also an important structural fatty acid present in cell membranes.

Alpha-Linolenic acid is the other essential fatty acid (an Omega-3 fatty acid). Alpha-Linolenic acid has several functions, is important

such as coconut and palm, are considered as solid fats due to their fatty acid composition. The fat component of milk and cream (butter) is solid at room temperature. Solid fats contain more saturated fats and/or trans fats than liquid oils (e.g., soybean, canola, and corn oils), with lower amounts of monounsaturated or polyunsaturated fatty acids. Common fats considered to be solid fats include: butter, beef fat (tallow), chicken fat, pork fat (lard), shortening, coconut oil, palm oil and palm kernel oil. Foods high in solid fats include: full-fat (regular) cheeses, creams, whole milk, ice cream, marbled cuts of meats, regular ground beef, bacon, sausages, poultry skin, and many baked goods made with solid fats (such as cookies, crackers, doughnuts, pastries, and croissants).

Linoleic acid (LA): one of the n-6 fatty acids, is essential in the diet because it cannot be synthesized by humans. Primary sources are nuts and liquid vegetable oils, including soybean oil, corn oil, and safflower oil. Also called omega-6 fatty acids.

Alpha-linolenic acid (ALA): an n-3 fatty acid that is essential in the diet because it cannot be synthesized by humans. Primary sources include soybean oil, canola oil, walnuts, and flaxseed.

in growth, and is the precursor of two other important fatty acids (EPA and DHA) discussed below. As with protein/amino acids, the body would rather use the essential fatty acids for growth and functional needs instead of fuel needs. A diet that is high in essential fatty acids and low in nonessential fatty acids will therefore increase metabolism and discourage increased body fat formation, assuming that a person is not overeating. Remember, excess carbohydrates and amino acids can be converted to body fat stores. Flax seed oil, fish, and poultry are good foods to eat to increase your intake of alpha-linolenic acid.

Some of the specific functions of the essential fatty acids include the following:

- Presence in phospholipids, which are important for maintaining the structure and function of cellular and subcellular membranes
- Function as precursors for eicosanoids, which are important in regulating a wide diversity of physiological processes
- Involvement in the transfer of oxygen from the lungs through the alveolar membrane
- Formation of a structural part of all cells
- Maintenance of proper brain and nervous system function
- Production of prostaglandin, group of hormones important in metabolism
- Formation of healthy skin and hair
- Wound healing
- Growth enhancement

The following is some information regarding Dietary References Intakes for Total Fat and the essential fatty acids linoleic acid and alpha-linolenic acid as published by the Institute of Medicine 2006:

Linoleic Acid. DRI-Adequate Intake examples: 17 grams per day for men ages 19 through 50 years; 12 grams per day for women 19 through 50 years of age.

Alpha-Linolenic Acid. DRI-Adequate Intake examples: 1.6 grams per day for men 19 to 50 years; 1.1 grams for women ages 19 to 50 years.

For Total Fat. DRIs for men or women were not determined (ND).

These essential fatty acid DRI-AI values are general, and each individual requires intake determination, especially for athletes, with higher levels being expected, especially for alpha-linolenic acid.

Eicosapentaenoic Acid (Epa) and Docosahexaenoic Acid (Dha)

During the 1980s, there was a resurgence of attention focused on two fatty acids belonging to the Omega-3 family of fatty acids: eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA). Researchers in the 1950s documented the cholesterol-lowering effects of EPA and DHA. However, it was not until 25 years later, when reports of low rates of cardiovascular diseases were documented among fish-eating Greenland Eskimos, that conclusive results were achieved. This early research put these dietary fatty acids in the spotlight.

EPA and DHA can be made in the body from the essential fatty acid alpha-linolenic acid, and they are found in human tissues as normal components. Even though the body can manufacture EPA and DHA, dietary sources have beneficial effects when part of a diet low in saturated fatty acids. Some experts refer to EPA and DHA as semi-essential, in particular for people with low production levels due to inadequate precursor alpha-linolenic acid, or for other individual reasons. EPA and DHA have the tendency to disperse fatty acids and cholesterol in the bloodstream, which seems to be how their presence helps reduce arterial clogging. They have a blood-thinning effect and discourage excessive blood clotting. They also may lower blood triglycerides and raise **HDLs** (**high-density lipoproteins**, the good lipoproteins).

High-density lipoprotein (HDL): HDL is a compound made up of fat and protein that carries cholesterol in the blood to the liver, where it is broken down and excreted. Commonly called "good" cholesterol, high levels of HDL cholesterol are linked to a lower risk of heart disease. Men should aim for an HDL of 40 mg/DL or higher. Women should aim for an HDL of 50 mg/DL or higher.

EPA and DHA exert an anti-inflammatory effect and work by competing with arachidonic acid, which forms pro-inflammatory compounds. Besides all of these known health benefits, recent studies on athletes have documented improvement in athletic performance. Studies using 2 to 4 grams per day of EPA and DHA from supplements and fish have reported significant increases in strength and aerobic performance. Improvements include higher repetitions in bench press, increased one-repetition maximum, faster running times, reduction in muscular inflammation, and longer jumping distances. Scientists believe that these improvements in various athletic performance parameters are due to the combined effects that EPA and DHA have on the body, including growth hormone production, anti-inflammatory action, enhanced aerobic metabolism, lower blood viscosity leading to better oxygen and nutrient delivery to muscles, and improved recovery.

Gamma Linolenic Acid (GLA)

Gamma linolenic acid is another important fatty acid that can be made in the body from the main essential fatty acid, linoleic acid. GLA is an important precursor for the series 1 prostaglandins, a group of hormones that regulates many cellular activities. The series 1 prostaglandins keep blood platelets from sticking together, control cholesterol formation, reduce inflammation, make insulin work better, improve nerve function, regulate calcium metabolism, and are involved in immune system functioning. Therefore, ingestion of foods and supplements high in GLA can benefit overall health. However, getting GLA containing foods is not that simple. GLA is not found in many foods. In fact, the major sources are evening primrose oil, borage oil, and black currant oil. These oils are also high in linoleic acid.

Phospholipids

Phospholipids are a second major class of lipids, next to fatty acids/triglycerides. They are a major structural lipid in all organisms and part of every living cell. In combination with proteins, phospholipids are constituents of cell membranes and membranes of subcellular particles. Phospholipids consist of two fatty acids attached to glycerol and a phosphate-containing compound attached to the third carbon. For example, in lecithin, choline is part of this phospholipid molecule.

The phospholipids' main function is maintaining the structural integrity of cell membranes. They also act as emulsifiers in the body which, during digestion, help disperse fats in water mediums. Phospholipids are important structural components of brain and nervous system tissue and of lipoproteins – the carriers of cholesterol and fats in the blood. Phospholipids are manufactured by the body but become deficient in the diet.

Phospholipids are generally contained in the "invisible" fat of plants and animals, not the visible fat. Out of the many phospholipids, supplemental use has been mainly focused on lecithin. Studies have also been conducted regarding the inositol containing phospholipids, "phosphoinositides." Their primary role is that of precursors to messenger molecules. In this capacity, they can exert a profound effect on cellular function and metabolism, particularly the metabolism of fats. This research was promoted on observations associated with choline and inositol-deficient diets. Both nutrients are important in fatty acid metabolism and are said to help de-fat the liver. Nutrients that have this defatting action on the liver have come to be called **lipotropics**. Diets deficient in choline have also been associated with memory impairment. For the athlete, these important structural, metabolic, memory, and lipotropic roles of phospholipids are vital for peak performance. Krill has become a popular supplement due to containing phospholipids, EPA and DHA, and the compound astaxanthin (a natural antioxidant pigment with associated health benefits).

Lipotropic: a substance that prevents fatty buildup in the liver and helps the body metabolize fat more efficiently.

Bile: a substance secreted by the liver that is essential for the digestion and absorption of fats.

Lecithin (Phosphatidylcholine)

Lecithin is a type of phospholipid that contains choline attached to the phosphate molecule, plus 2 fatty acids. It is high in linoleic acid. Lecithin supplies choline, which is essential for liver and brain function. Egg yolk, liver, and soybeans contain high amounts of lecithin. The body also manufactures lecithin.

Use of lecithin supplements came into vogue when researchers made the choline–memory link. That is, choline-deficient diets impair memory function. Lecithin's emulsifying properties are also thought to help keep the blood system clean of fatty deposits. Researchers have documented reduced choline levels among athletes running in the Boston Marathon and speculate that lower choline levels might adversely affect performance and have detrimental long-term nervous system effects. Choline is also important in creatine synthesis and is therefore suspected as playing a role as a strength-building nutrient. Studies on athletes using dosages of 20 to 30 grams of lecithin have produced mixed results, some reporting beneficial effects on muscular power, performance, and endurance.

Phosphatidylserine

Research has been directed to another phospholipid, phosphatidylserine (PS), to determine its health benefits. In the PS molecule, serine is attached to the phosphate molecule. Serine is an indispensable amino acid whose metabolism leads to the synthesis of PS. Serine functions in fat metabolism and is vital to the health of the immune system. Intake of 200 to 300 milligrams of PS has been associated with improved memory and learning. Intake of 400 to 800 milligrams has been linked to a reduced level of cortisol, which is a catabolic hormone, and to improved muscle growth and recovery after exercise.

A double-blind crossover study measured the effects of 800 milligrams a day of phosphatidylserine (PS) compared with a placebo on the serum-hormone level of cortisol, the perception of well-being, and muscle soreness during two-week intensive training sessions. In this study, the subjects were given either a PS supplement or a placebo for the first two-week session, and then the opposite for the second two-week session. The subjects rested for three weeks in between the two sessions. During both of the two-week sessions, the subjects did five sets of exercises, each set consisting of ten repetitions of thirteen exercises, four times a week. Well-being and muscle soreness were estimated using a 10-point scale. PS supplement-taking subjects experienced reduced delayed onset muscle soreness and an improved state of well-being. This research and other research provide interesting insights to this beneficial phospholipid.

Cholesterol

Cholesterol is a member of a group of fats called sterols. Cholesterol is made by the body and only occurs naturally in foods of animal origin. The highest concentrations are found in liver and egg yolk and are also high in meats, poultry (especially the skin), whole milk, and cheese. Cholesterol has many important functions. It is a component of all cells, precursor of **bile** acids, precursor of various sex and adrenal hormones, precursor of vitamin D, and an important aid in brain and nervous system tissues.

The body needs a constant supply of cholesterol for proper health and performance; however, too much has been linked with a variety of cardiovascular diseases in some people. For promotion of general health, it is recommended to keep cholesterol nutrition intake levels under 300 mg per day. Considering most meats contain about 90 mg per 3 ounces, this is an almost impossible task for athletes, who generally need to consume high protein levels. Athletes therefore need to take special care to include cholesterol-free or lower cholesterol sources in their diets, such as vegetable source proteins, egg whites, high-protein/low-fat and low cholesterol-containing food and supplements, in particular during the periods of high calorie consumption, such as preseason and competition season times of the year, in addition to the cholesterol-containing animal sources. Family history of cholesterol-related health problems and other potential metabolic issues related to cholesterol should be determined by the athlete's doctor.

Conjugated Linoleic Acid (CLA)

CLA is a very interesting supplement that has gained popularity with people, including some athletes, concerned about maintaining healthy body composition. The fatty acid CLA occurs naturally in a number of foods, primarily beef and dairy products. The word "conjugated" in its name refers to the variation in chemical structure that sets it apart from the essential fatty acid linoleic. Linoleic acid belongs to a family of essential fatty acids called the omega-6 fatty acids and performs a number of important metabolic functions in the body. A slight change in the double bonds that hold its atoms together transforms it from linoleic acid to CLA. This molecular reconfiguration has profound effects on its function and bestows upon CLA nutritional benefits different from those of regular linoleic acid.

CLA's rising popularity among athletes stems from its ability to significantly increase muscle mass and it help to stimulate reduction of body fat stores. Additionally, scientists foresee broader applications for human health. Research has reported that CLA acts as a powerful antioxidant, benefits the immune system, and possesses other beneficial health properties. CLA supplementation has benefits for people who need to burn fat while preserving or building muscle mass, particularly athletes such as bodybuilders and other strength athletes. Based on the research, for healthy people, an example of a daily dose of CLA ranges from 3,000 to 5,000 (or 6,000) milligrams per day, typically taken in divided dosages, and for use of several months, based on physician supervision to determine personal needs.

In Canada, CLA has an authorized monograph and is an approved ingredient for Natural Health Products. Some of the approved claims in the monograph are related to CLA supplementation and may helping support a modest improvement in body composition and reduction in fat mass when used with a program of reduced intake of dietary calories and increased physical activity.

Medium-Chain Triglycerides

Medium-chain triglyceride (MCT) formulations were first made in the 1950s using coconut oil. MCTs contain saturated fatty acids with chains of six to twelve carbon atoms. MCT formulations are high in caprylic acid and capric acid, which are saturated fatty acids.

MCT formulations were originally developed as calorie sources for individuals who have certain pathologic conditions that do not allow normal digestion and utilization of long-chain fatty acids. MCTs tend to behave differently in the body from long-chain triglycerides (LCTs). MCTs are more soluble in water, and they can pass from the intestines directly into the bloodstream. Fatty acids usually pass from the intestines first into the lymphatic system and then into the bloodstream. Because MCTs get into the bloodstream more quickly than LCTs do, they are more easily and quickly digested. In addition, it has been reported in the medical literature that although MCTs can be converted to body fat, they are not readily stored in fat deposits and are quickly used for energy in the liver. They can also pass freely, without the aid of carnitine, into the mitochondria of cells. MCTs are therefore a potentially quick source of high energy for the body. MCTs reportedly also have a thermogenic effect, estimated to be 10 to 15 percent higher than their caloric value, but only when the MCTs in the diet exceed 30 percent of the total calories. Thermogenesis is the process by which the body generates heat, or energy, by increasing the metabolic rate to above normal.

These features of MCTs have attracted the attention of athletes, especially bodybuilders. Bodybuilders feel that these features benefit their restricted contest-preparation diets, which are aimed at reducing body fat and sparing muscle tissue. The implications of the use of large amounts of MCTs by athletes on restricted diets are not entirely clear though. Some bodybuilders report that they are able to get "super lean" when they eat about 400 calories per day of MCTs as part of pre-contest low-calorie diet. Remember, though, that bodybuilders are not concerned with physical athletic performance. In bodybuilding contests, physique development is judged. Long-term use of MCTs is of a concern due to their saturated fatty acid content.

Do MCTs have a place in every athlete's diet? More research is needed to determine the exact benefits of MCT's for athletes in general. While bodybuilders appear to derive certain benefits, some people can experience mild side effects from eating too much MCT.

The most common complaints are abdominal cramping and diarrhea. Prolonged use may also be of concern to cardiovascular wellness. MCTs are saturated fatty acids, and consuming more than 10 percent of total daily calories from saturated fatty acids is not recommended because of the link to various diseases. Additionally, in recent research, some individuals who ingested only moderate amounts of MCTs developed elevated triglyceride and cholesterol blood levels. This concern will depend on the individual's total saturated fat intake, sensitivity to saturated fat intake, and duration of use. If planning to experiment with MCTs, start slowly, with low dosages, using formulations that also contain the essential fatty acids and the EPA and DHA omega-3 fatty acids under physician supervision to monitor for any potential health effects that might arise due to increased saturated fatty acid consumption. Another approach could be to just try using healthy essential fatty acid EPA- and DHA-containing oil products and food sources.

Marie-Pierre St-Onge and Aubrey Bosarge (2008) reported the results of their study examining the weight-loss aid effects of MCTs versus olive oil. Their study used a 1,500 kcal/day diet for women and an 1,800 kcal/day diet for men. Women consumed 18 grams of MCT oil or olive oil per day in their diet, and men consumed 24 grams of MCT oil or olive oil in the diet. Both oil groups lost body fat by the end of the 16-week study,

Trans fatty acids: a type of fat produced when liquid fats (oils) are turned into solid fats through a chemical process called hydrogenation. Eating a large amount of trans fatty acid, or "trans fats," also raises blood cholesterol and risk of heart disease.

Hydrogenation: a chemical process that turns liquid fats (oils) into solid fats, hydrogenation creates a fat called trans fatty acid (also known as "trans fat"). Trans fats are found in frostings, shortening, some margarines, and some commercial baked foods, like cakes, cookies, muffins, and pastries. Eating trans fats may raise heart disease risk. Federal dietary guidelines [found at http://www.health.gov/dietaryguidelines/External Link Disclaimer] recommend keeping trans fat intakes as low as possible.

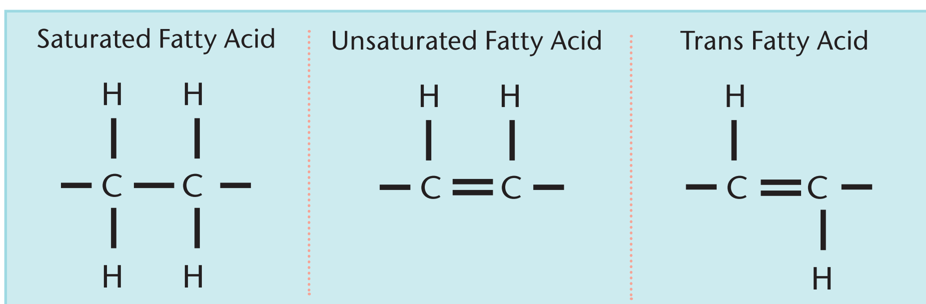
Low-density lipoprotein (LDL): LDL is a compound made up of fat and protein that carries cholesterol in the blood from the liver to other parts of the body. High levels of LDL cholesterol, commonly called "bad" cholesterol, cause a buildup of cholesterol in the arteries and increase the risk of heart disease. An LDL level of less than 100 mg/dL is considered optimal, 100 to 129 mg/dL is considered near or above optimal, 130 to 159 mg/dL is considered borderline high, 160 to 189 mg/dL is considered high, and 190 mg/dL or greater is considered very high.

with the MCT subjects losing slightly more body fat versus the olive oil subjects. However, regarding lean body mass, the olive oil subjects gained lean body mass, whereas the MCT subjects lost lean body mass. Computed tomography scans revealed significantly greater muscle area with olive oil and greater loss of trunk fat mass with MCT oil.

Note that although there seems to be a lack of unanimous scientific evidence regarding MCTs' playing a nutrition role for athletic performance, there is a possible benefit as a weight-loss aid. Because MCTs are used in some sports nutrition, weight loss, and other food products, this information may be useful when addressing questions from clients or evaluating its potential use.

Trans Fatty Acids

Trans fatty acids, also known as *trans* fats, are made during partial hydrogenation of vegetable oils. **Hydrogenation** is the process by which hydrogen atoms are added to unsaturated sites on fatty acids, thereby eliminating double bonds. Partial hydrogenation relocates some double bonds, and hydrogen atoms end up on different sides of the chain. This type of configuration is called "*trans*" (means "across" in Latin). The structure of a *trans* unsaturated chemical bond is represented in the following diagram.



The primary reason for attention directed toward *Trans* Fats was due to human studies demonstrating increased bad cholesterol levels (**low-density lipoprotein-cholesterol, LDL-C**), similar to saturated fatty acids. It is now a requirement to list the amount of *Trans* Fats on food labeling. The following FDA press release provides an update regarding the FDA's actions related to partially hydrogenated oils, the primary source of artificial *trans* fats.

June 16, 2015

Release

Based on a thorough review of the scientific evidence, the U.S. Food and Drug Administration today finalized its determination that partially hydrogenated oils (PHOs), the primary dietary source of artificial trans fat in processed foods, are not "generally recognized as safe" or GRAS for use in human food. Food manufacturers will have three years to remove PHOs from products.

"The FDA's action on this major source of artificial trans fat demonstrates the agency's commitment to the heart health of all Americans," said FDA's Acting Commissioner Stephen Ostroff, M.D. "This action is expected to reduce coronary heart disease and prevent thousands of fatal heart attacks every year."

This determination will significantly reduce the use of PHOs, the major source of artificial trans fats, in the food supply. In 2013, the FDA made a tentative determination that PHOs could no longer be considered GRAS and is finalizing that determination after considering public comments.

Since 2006, manufacturers have been required to include trans fat content information on the Nutrition Facts label of foods. Between 2003 and 2012, the FDA estimates that consumer trans fat consumption decreased about 78 percent and that the labeling rule and industry reformulation of foods were key factors in informing healthier consumer choices and reducing trans fat in foods. While trans fat intake has significantly decreased, the current intake remains a public health concern. The Institute of Medicine recommends that consumption of trans fat be as low as possible while consuming a nutritionally adequate diet.

"Studies show that diet and nutrition play a key role in preventing chronic health problems, such as cardiovascular disease and today's action goes hand in hand with other FDA initiatives to improve the health of Americans, including updating the nutrition facts label," said Susan Mayne, Ph.D., director of the FDA's Center for Food Safety and Applied Nutrition. "This determination is based on extensive research into the effects of PHOs, as well as input from all stakeholders received during the public comment period."

The FDA has set a compliance period of three years. This will allow companies to either reformulate products without PHOs and/or petition the FDA to permit specific uses of PHOs. Following the compliance period, no PHOs can be added to human food unless they are otherwise approved by the FDA.

The FDA encourages consumers seeking to reduce trans fat intake to check a food's ingredient list for partially hydrogenated oils to determine whether or not a product contains PHOs. Currently, foods are allowed to be labeled as having "0" grams trans fat if they contain less than 0.5 grams of trans fat per serving, including PHOs, the primary dietary source of artificial trans fat in processed foods.

Many companies have already been working to remove PHOs from processed foods and the FDA anticipates that many may eliminate them ahead of the three-year compliance date.

The FDA, an agency within the U.S. Department of Health and Human Services, protects the public health by assuring the safety, effectiveness, and security of human and veterinary drugs, vaccines and other biological products for human use, and medical devices. The agency also is responsible for the safety and security of our nation's food supply, cosmetics, dietary supplements, products that give off electronic radiation, and for regulating tobacco products.

Source: http://www.fda.gov/NewsEvents/Newsroom/PressAnnouncements/ucm451237.htm

Lipid Digestion

Most lipids take the longest time and the most effort to digest due to their insolubility in water and their complex structure. As they pass through the mouth and stomach, they are retreated mechanically and chemically for their main digestive processes to take place in the intestines. Fats take the longest to empty from the stomach (three to four hours or more depending on the size of the meal). Digestion of fats takes place chiefly in the small intestines, where **bile** from the liver assists in bringing fat in contact with fat splitting enzymes from the pancreas and from the intestinal wall. In the intestines, the fatty acids are disassociated from the glycerol molecules and are reassembled as they pass through the intestinal cells. Along the way, they become coated with protein and pass into the lymph system.

Under normal dietary fatty acid conditions, about 60–70 percent of ingested fat is absorbed via the lymph system, and medium- and short-chain fatty acids can enter into the bloodstream and be transported directly to the liver. Once in the bloodstream, fats and cholesterol are transported in conjunction with special proteins called lipoproteins. Fats that are not needed are converted to fat stores. The liver is the main processing center for fats. In the liver, fats can be used for energy and modified by shortening or lengthening fatty acids and saturating or un-saturating fatty acids. The liver cells also synthesize triglycerides, lipoproteins, cholesterol, and phospholipids. Fats are constantly broken down, resynthesized, and used for energy. But they are in equilibrium when caloric intake is in balance with energy needs. When caloric intake from fats, proteins, or carbohydrates exceeds energy needs, fat stores are increased, and body fat weight is increased.

You Are What You Eat

The type of fat you eat can affect your body's composition of fatty acids. As all cellular membranes contain fatty acids, comparisons between vegetarians and meat eaters have revealed that vegetarians have bodies made up of more unsaturated fatty acids. It also revealed that those people on high saturated fat diets have bodies made of more saturated fatty acids. Saturated fatty acids tend to be less stable than unsaturated fatty acids are and therefore more susceptible to damage from free radicals and metabolic toxic waste products. This means that a body made of more unsaturated fatty acids may be more resistant to certain cellular damage.

How Much Lipid Does an Athlete Need?

The National Research Council (NRC) recommends that total fat intake stay below 30 percent of total daily calories and that saturated fat intake stay below 10 percent of total daily calories (assuming you are only eating the recommended total daily calories for your age and body size and not more). As for the essential fatty acids, linoleic and alpha-linolenic acids, the NRC recommends 1 to 2 percent of total daily calories, roughly 3 to 6 grams. Some health professionals estimate that males may require three times this amount because of their hormonal differences.

As far as athletes are concerned, the total amount of fat intake will vary with the type of sport, body size, and personal requirements. In general, endurance athletes will need to maintain a higher level of fat intake than power athletes will. This is directly related to the energetics of a particular sport. Additionally, when we consider that an athlete's diet consists of two to three times the amount of what is considered "average" caloric intake, fat intake can become high using the high percentage of about 30 percent of total daily calories—intended as a general guideline for the population of nonathletes.

Most athletes should concentrate on reducing total fat intake and saturated fat intake and on increasing essential fatty acid intake, and EPA and DHA. Because of the total high-caloric intake athletes maintain, consumption of over 25 percent of total daily calories is not recommended during high activity periods when energy expenditure increases but when personalized sports nutrition plans may require lower total daily fat intake.

Bile: a substance secreted by the liver that is essential for the digestion and absorption of fats.

Too Much Fat in Our Diets

Most of us get too many fats in our diet. The typical American consumes 45% of their calories from fat. When you consider that each gram of fat contains more than twice the number of calories of a gram of either carbohydrate or protein, you can easily see why fats and oils are such villains.

Not only that, but the very latest scientific studies reveal that fats and oils might be even more villainous than their caloric values suggest. In direct comparisons of high-fat and low-fat diets, even when the number of calories in each is exactly the same, the high-fat diet causes much more fat to be stored.

1 tsp fat	5 grams	45 calories
1 Tbsp fat	15 grams	135 calories
	40 grams of fat	360 calories

How much fat should you get in your diet? The American Heart Association recommends 30% of your total calories as an absolute maximum. But the closer you can move to 20% (or below), the easier your fat-loss and weight-maintenance goals will be achieved:

Total caloric intake	30% fat diet	20% fat diet
2,400 calorie diet:	720 cal	480 cal
	<6 Tbs.	<4 Tbs.
3,000 calorie diet:	900 cal	600 cal
	<8 Tbs.	<5 Tbs.
(<) means less than		

Flax Oil — Nature's Essential Fatty Acid Bounty

When turning to the market place to find a product that supplies a good source of alpha-linolenic acid, flax oil stands out. Flax oil contains about 51% to 57% alpha-linolenic acid. It also contains 15% to 18% linoleic acid. Using flax as a substitute for cooking and salad oils, butter and margarine can help with nutritional efforts to increase alpha-linolenic in the diet.

Dietary Sources of Fat

It seems that plant sources of fats tend to be healthier than animal fats are because plant sources are unsaturated. However, remember that most plant sources of proteins are incomplete and low quality, while animal proteins are complete and high quality. A balance must be maintained to minimize saturated fats and high-cholesterol sources that occur in meats but to benefit from the complete proteins they contain.

As a general rule, here are some of the foods athletes should avoid or eat infrequently to keep saturated fatty acids and cholesterol intake low: kidneys, liver, excessive egg yolks, custard, fatty animal meats, coconut oil, butter, palm oil, bacon, pork sausage, cream cheese, whole milk products, hot dogs, bologna, and hamburger.

Instead, eat lean meats like fish, egg whites, skim milk products, chicken, turkey, a combination of plant proteins that make complete protein sources, and protein formulas. This is why pure supplement formulations of proteins/amino acids are beneficial to health and an athlete's high-performance nutrition program.

Regarding pure sources of fat (such as oils), intake of unsaturated fats should be substituted for food sources high in saturated fats. Some fat sources that are low in saturated fats and cholesterol are margarine, corn oil, olive oil, peanut oil, cottonseed oil, safflower oil, sunflower oil, and most nuts (which also contain protein). Fats to avoid or to keep at a very low intake include butter, bacon fat, cream, mayonnaise, and mayonnaise salad dressings.

Fats and Athletic Performance

- Excess body fat should be avoided. It only creates dead weight and slows you down.
- Keep fat intake below 30 percent of total daily calories or less, depending on your sport.
- Minimize intake of saturated fatty acids and cholesterol.
- Eat a low-fat meal before and after training and competition. Fat makes the stomach empty slowly, thus preventing nutrients from getting into the body quickly.
- Include good sources of essential fatty acids, DHA, EPA, and gamma-linolenic acid.

Conclusion

Lipids are a diverse group of macronutrients, which are vital building blocks of the human body for growth, maintenance, and repair; used to make a variety of biomolecules required for body function and structure; and also contribute a source of energy for athletic performance. Focusing on healthy types of lipid food sources is also important. Unit 17 will provide details regarding lipid nutrition guidelines for athletes, including specialty topics, such as timing nutrient intake.

Keywords

- Triglycerides
- Oils
- Saturated fatty acids
- Unsaturated fat
- Polyunsaturated fatty acids (PUFAs)
- Solid fats
- Linoleic acid (LA)
- Alpha-linolenic acid (ALA)
- High-density lipoprotein (HDL)
- Lipotropic
- Trans fatty acids
- Hydrogenation
- Low-density lipoprotein (LDL)
- Bile

Topics Covered In This Unit

UNIT 6

WATER AND OXYGEN

Learning Objectives

After completing this unit, you will be able to:

- Define and describe key terms related to hydration and oxygenation for athletes;
- Understand water balance;
- Estimate hydration requirements for athletes;
- Discuss the adverse effects of dehydration on athletic performance;
- Understand role of oxygen in the human body;
- Discuss nutrients and nutritional substances related to blood flow and oxygen in the body.

Introduction

Water and oxygen are two of the most important nutrients for health and performance. Studies have verified that even small fluctuations in the body's water balance can, and often does, adversely affect athletic performance. Similarly, the availability of oxygen is vital for top athletic performance, and research has determined that oxygen utilization can be maximized by physical training and nutritional means. However, many people take water and oxygen for granted or neglect them. This is equally true for athletes and nonathletes. In this unit, we will take an in-depth look at water and oxygen. We will review their functions and approaches to potentially optimize water intake and oxygen utilization for maximum athletic performance.

Water

Water (fluid) consumption for adequate hydration is needed every day for good health and physical and athletic performance. In spite of this, inadequate hydration is common among nonathletes and athletes, also referred to as hypohydration and dehydration. **Hypohydration** occurs when water intake does not meet the body's hydration requirements. Studies have verified that even very small fluctuations in the body's water balance can, and often do adversely affect physical and even mental performance. **Euhydration** is a term used to indicate as state of adequate hydration. **Hyperhydration** refers to excess body water.

Hypohydration: occurs when water intake does not meet the body's hydration requirements

Euhydration: a term used to indicate a state of adequate hydration.

Hyperhydration: excess body water.

A Word of Caution

Although on the surface achieving adequate hydration appears to be easily accomplished, a variety of issues can occur when working with athletes to achieve euhydration, in particular, other related nutrients, such as electrolytes. For many athletes, a challenge to achieve and maintain euhydration is related to the physiology of water balance in the body, in particular that water loss can exceed water intake capability during exercise, training, physical activity, and athletic events.

Hydration complications can and do occur with athletes, for example, during training sessions and athletic events, athletes can lose more body water than can be replenished during these physical activities. Total daily activities, climate, health status, clothing, and even food consumption can all contributed to an athlete's daily water balance. While general hydration reference information for healthy adults is contained in this unit, determining adequate hydration for each individual athlete requires one-on-one detailed evaluation and medical analysis under physician supervision and by other trained health professionals. Also, note that variation exists in the different position papers, scientific studies, and authoritative body information related to hydration guidelines, which underscores the importance of determining hydration, and other athlete nutrition requirements, on an individual athlete basis, starting with general guidelines and fine-tuning them under appropriate physician supervision, which can include the athlete's doctor and team doctor. Although examples of general hydrations guidelines are contained in this unit, be aware that additional hydration reference information and guidelines can exist published by an athlete's individual team, sports organization, team doctors, or other team health professionals or from the various health professional position papers. These team and health professional additional reference sources should also be considered when creating an athlete's hydration program.

Note that while body weight measurements, reviewed below, can be used as a type of "biomarker" for tracking general hydration status, these do not provide important insights about the body's status of other related nutrients, such as electrolytes, sodium, chloride, and potassium for example. For a comprehensive hydration evaluation to be conducted, the assessment of more involved biomarker testing can be warranted, such as determination of plasma osmolality, urine osmolality, and urine-specific gravity, which is beyond the intention of this sports nutrition fundamentals course. Osmolality is a measure of the concentration of chemicals found in the body fluids. These useful data involve medical testing and analysis by qualified health professionals.

Athletic Training for Water Conservation

An important consideration, besides fluid intake, is management of fluid losses. For example, while athletes may not have much control over the environmental conditions they will encounter during events, they are more in control of environmental conditions they are exposed to during daily training. In general, daily training conditions should be conducted during times of the day in which fluid losses during physical activity are minimized. Athletic clothing should also be selected that is appropriate for evaporation. For specific event training that anticipates high sweat losses, special training conditions may be warranted for acclimation purposes so an athlete's body can have time to adjust to the conditions, typically weeks or longer.

The past crazy and hazardous training methods that exposed athletes to extreme heat and sweating should be avoided. Examples of such practices to be avoided include "hell week" reported in some American football training programs and practicing in plastic sweats and layers of clothing in hot rooms—items associated with wrestling and other weight-class sports. In addition, excessive use of saunas and other situations that promote excess loss of body fluids should be avoided. Physical conditioning and skill training should be approached to minimize fluid loss and to compensate (replenish) fluid loss during training and athletic events.

A simple rule is to prevent fluid loss during physical activity that results in more than 2% reduction in total body weight from water loss. However, less water loss is always better. Note that for some sports, and under certain weather conditions, the rate of fluid replacement may not be able to achieve this general rule, primarily due to the body's limitation to ingest enough water during physical activity to replenish water lost from sweating. Obviously, longer duration athletic training sessions and events result in higher amounts of net body water loss. An approach can be justified for shorter training sessions each day to reduce fluid loss that cannot be replaced adequately during "marathon" training sessions, in addition to other nutrients such as electrolytes and carbohydrates.

The reality is that some sports events, ultra-endurance sports that don't allow for adequate rehydration, for example, are unhealthy and put the athlete's health at risk, even with medical supervision and before and during hydration and other nutrient-replenishment programs. It is common for athletes in these ultra-endurance events to experience mild to severe medical problems that require immediate medical attention and that often require intravenous fluid, electrolyte, and glucose treatment and, sometimes, even hospitalization for treatment. In some tragic instances, death can even occur. Adequate, healthy nutrient intake is important along with water intake for adequate hydration status.

Water and the Athlete

Water, otherwise known as H2O, consists of two hydrogen atoms and one oxygen atom. It is the aqueous medium used for transporting the body's food materials and the place where the body's biochemical reactions occur. Water is found in all parts of the body and, depending on a person's body fat content, its content can vary from about 45% in very obese individuals to 70% in lean individuals, with an average of about 60%. The different parts of the body also vary in water content. For example, approximate water content in blood is normally the highest at about 83%; in muscle tissue, water content is about 75%; bone contains about 22% water, and fat tissue may only contain about 10% water. Of course, these values vary from person to person.

Water Balance

The state of hydration that a person exhibits is affected by the current rate of water intake in relationship to the rate of water loss. At rest, water turnover is smaller than under conditions of high-intensity exercising. Water intake occurs from fluids that are ingested, fluids in food, and water produced from metabolism. The following will summarize the major types of water intake/availability and water output. This just serves as a generalized overview. It must

Water Intake/Availability	Water Output
Metabolic Water	Skin: Sweat
Liquids	Lungs: Exhalation
Food	Kidneys
Glycogen Bound Water	Digestive System: Feces

be emphasized that water intake and output varies with activity, size of the individual, age, gender, duration and intensity of the activity, clothing, and weather conditions.

Metabolic Water. **Metabolic water** is the often overlooked water that is produced as a result of energy metabolism. Metabolic water is produced in the body from oxygen and hydrogen atoms. The oxygen is derived from the atmosphere and brought into the body via the lungs during breathing. The hydrogen atoms are from catabolism of carbohydrates, fatty acids, and other carbon molecules that are broken down for energy.

Liquids. These are by far the most abundant source of the body's water, accounting for about two-thirds, or more, of water intake per day. However, on hot days, and at high-training volumes or competition events, liquid intake can be a higher proportion related to the other water sources, such as from food. Liquids can readily be taken in by the body without much digestive effort. However, pure water is generally utilized by the body the fastest. As the amount of carbohydrates and electrolytes are increased in a beverage, the length of time the stomach takes to empty is increased, which slows delivery of water and nutrients into the body for utilization. Drinking liquids with the proper concentration of carbohydrates and electrolytes depends on the sport, training program, and level of physical activity.

Food. All foods consist of water and solids. The amount of water varies with the food type. For example, fruits, vegetables, cooked cereals, and milk consist of 80% to 95% water. Meat contains about 75% water if cooked rare and 45% or lower if cooked well done. Dry cereals and pastas contain some water, about 3% to 5% water content. Generally, about 1/3 of daily water intake is derived from food.

Glycogen-Bound Water. This water is stored in the muscles along with glycogen. About 3 or 4 ounces of water are stored with 1 ounce of muscle glycogen. The availability of this water becomes important when your glycogen supply is depleted for energy use. This depletion will occur during training and endurance events lasting more than an hour and during periods of calorie restriction. This water bound to glycogen can release about 16 fluid ounces of water per hour of intense endurance activity. This will only last as long as the amount of glycogen remains stored in the body, and any hydration benefit might be offset by water loss from the skin and lungs depending on the climate conditions. Some estimates report that approximately 3 to 4 pints of glycogen-bound water can be stored in the body, but it varies from person to person. This water must be replenished when used, unlike metabolic water, which is constantly being produced. For endurance athletes and athletes performing in day-long tournaments, this **glycogen-bound water** may be an important component of hydration during physical activity. Glycogen-bound water can be maximized through carbohydrate loading, which results in more glycogen and therefore more glycogen-bound water.

Skin – Sweat. Water is lost through the skin when the body sweats. Sweating is always occurring at some rate and becomes evident when conditions such as increased activity or hot humid days cause sweat to accumulate on the skin. Sweating is the body's cooling mechanism and removes excess heat to keep the body's core temperature within a limited range to prevent it from overheating. If the body overheats from hypohydration, thermoregulatory problems can cause heat stroke, fainting, and even death. Sweat must be evaporated from the skin to result in heat removal. The mere production of sweat is just the first step in the process. Sweat that just drips off the body does not add to the cooling process. It must evaporate from the body to have a cooling effect. Heat is removed from the body only when water is converted from the liquid state to a gaseous state on the surface of the skin. Water loss from sweat becomes a major mode of water loss during exercise. A quart of water or more per hour can be lost from sweat during prolonged exercise. This loss will obviously occur in long-distance running events but is also significant in sports like basketball, football, soccer, and swimming.

Metabolic water: the water that is produced in the body as a result of energy production.

Glycogen-bound water: the water that is stored in the muscles along with glycogen.

Diuretic: a substance that increases urination.

Lungs.
A small amount of water is lost as water droplets in exhaled air and becomes increased during exercise.

Kidneys.
Water that is filtered out through the kidneys is excreted as urine. Interestingly, water loss from the kidneys is usually minimized during exercise. During exercise, the fluid loss from the kidneys is slowed down. This occurs through hormonal control, in particular, through the action of "antidiuretic hormone – ADH" (vasopressin). ADH levels are increased during exercise, which increases the amount of water reabsorbed by the kidneys, thereby decreasing water loss. Note that alcohol (ethyl alcohol) and caffeine have **diuretic** effects because they are inhibitors of ADH and therefore increase water output via the kidneys. Alcohol and caffeine beverages and other not-needed diuretic substances should be avoided during the season and several days prior to a major athletic event. For individuals consuming caffeine as part of their training and competition nutrition program, extra water intake may be required, determined on an individual basis.

Feces.
Under normal conditions, water loss through the feces is relatively small. However, when gastrointestinal disorders set in (diarrhea and vomiting), 32 to 160 fluid ounces can be lost per day. It is therefore important for any athlete with a gastrointestinal problem to make sure he or she consumes larger than normal amounts of liquids to compensate for this extra water loss.

Some Factors Affecting Rate of Water Loss Include:
Hot Weather
Intensive Exercise
Heat-Trapping Clothes
Obesity
High Rate of Sweating
Inadequate Acclimation to Heat
Disease, Illness
Alcohol/Caffeine Consumption
High Humidity
Exercise Longer than 1 Hour
Diarrhea/Vomiting
Diuretic Drugs
Diuretic Foods and Supplements

Some Hydration Information from Institutes of Medicine Reports, Such As The Daily Reference Intake Reports (Values Are for Healthy Adult and Approximate). Note That There Are Limitations for Applying to Individuals and Athletes That Need To Be Determined on a Personal Basis.

Dietary Reference Intake for total water: an AI (adequate intake) was established for different age groups and genders. Total water includes water contained in food, beverages and drinking water. Remember the AIs are not intended to be interpreted as a specific requirement.

The DRI tables are in the Appendix, but here are some examples:

The highest value AI for adult males is 3.7 liters per day. (about 125 fluid ounces, 1 gallon).

This includes about 3 liters as total beverages, including drinking water. (about 101 ounces, 13 cups).

The highest value AI for adult non-pregnant females is 2.7 liters per day. (about 91fluid ounces, 0.7 gallon).

This includes about 2.2 liters as total beverages, including drinking water. (about 74 fluid ounces, 9 cups).

Respiratory Daily Water Loss, approximate: 200–350 milliliter per day for sedentary people, 500-600 milliliter per day for active people; temperate climates at sea level.

Urinary Daily Water Loss, approximate: 1–2 liters per day.

Fecal Daily Water Loss, approximate: 100–200 milliliters per day.

Skin, Insensible Diffusion, Daily Water Loss, approximate: 450 milliliters per day.

Skin, Daily Sweet, Daily Water Loss: too variable to set an approximate value.

Active Adults: physical activity can double to triple daily fluid intake needs to make up water lost via sweating.

- People in very hot (e.g., desert) climates, who often have sweating rates of 0.3–1.2 L/hour while performing occupational activities.
- People wearing protective clothing, who often have sweating rates of 1–2 L/hour while performing light-intensity exercise in hot weather.
- Male competitive runners, who can have sweating rates of 1 to > 2 L/hour while training or racing in the heat.
- Female competitive runners may increase their sweat losses from approximately 0.7 L/hour in temperate weather to approximately 1.1 L/hour in warm weather when performing the same event.

The UL (Tolerable Upper Limit) was not established for water. However, the DRI report(s) note that acute water toxicity has been reported from the rapid consumption of large amounts of fluids that greatly exceed the kidney's maximal excretion rate of approximately 0.7–1.0 liter per hour (24–33 fluid ounces per hour). Note that sweating rate must also be considered when dealing with athletes and other people during physical activity.

According to NHANES III (1988–1994), the highest total water intake (99th percentile) reported was 8.1 L/day. No adverse intakes have been reported with chronic high intakes of water in health people consuming a normal diet, as long as fluid intake is approximately proportional to losses.

According to data from NHANES III, adults in the United States obtained total water from the following sources:

- 35–54 percent from drinking water.
- 49–63 percent from other beverages (with juice, carbonated drinks, coffee, and milk being the major sources).
- 19–25 percent from foods (such as fruits, vegetables, soups, ice cream, and meats).

Note: A liter of water weighs 1 kilogram. A kilogram converts to 2.2 pounds, so a liter of water weighs 2.2 pounds. This assumes that the weighing takes place at sea level and the water is at 4 degrees centigrade (39.2 degrees Fahrenheit).

1 liter = 33.8 fluid ounces; 1 liter = 1.06 quart; 1 cup = 8 fluid ounces, USA.

Hypohydration / Dehydration Effects on Performance and Health

Hypohydration can adversely affect physical performance, mental function, and motor control. As the body loses water, core temperature rises, affecting all metabolic pathways, interfering with cardiovascular function, and reducing total work capacity. When water losses reach just 1% to 2% of body weight, reduction in physical performance can start to occur, with significant adverse side effects observed at over 2%. Marathon runners can lose several quarts of water during a race, which represents 6% to 10% of their body weight. Without properly rehydrating during the race, this amount of water loss will significantly impair performance and put the runner's health at risk. Even "non-endurance sports" like football, basketball, hockey, or soccer can result in similar losses in body water content. In addition, during tournaments, all athletes must make sure to increase their water intake to compensate for the prolonged physical activity over the one or two days of the tournament. Moreover, major water losses can occur during everyday training, which if not adequately rehydrated day to day, will adversely affect athlete performance during events.

Other sports in which participants must meet certain weight classes (boxing and wrestling for example) are also associated with dehydration. Wrestlers typically dehydrate themselves to make a lower weight class. This type of chronic dehydration will decrease performance and adversely affect health.

Chronic dehydration will develop in any athlete who does not make an effort to keep adequately hydrated. The thirst response in humans is not as fine-tuned as it should be. This means that an athlete's body can enter into a state of dehydration, and you will not feel the sensation of thirst until hours later. If athletes solely rely on the thirst response, chances are they will have become dehydrated by the time they become thirsty. It is therefore mandatory to rehydrate all day long, based on individual needs.

While reduced body water has obvious overall expected negative effects on health and athletic performance, researchers are constantly examining the various negative effects on the body's structure and function and the mechanisms of action. For example, researchers have determined that hypohydration of 2% results in a reduction of flow-mediated dilation, which is vital for blood flow, and decreased plasma volume, both negative outcomes related to health and athletic performance.

A reduction in plasma volume is also associated with an increase in plasma osmolality, which is a measure of concentration of substances in the blood. This can make the blood thicker and harder to move through the blood vessels, further reducing the rate of blood flow. The following presents results of two studies related to the negative effects of hypohydration under experimental conditions, one focused on endothelial function related to flow-mediate dilation effects and the other study regarding negative effects of hypohydration on exercise performance.

Hypohydration Negative Effects Research Study Examples

The effect of hypohydration on endothelial function in young healthy adults.

In this research study, Arnaoutis and coworkers in 2017 examined the effects of hypohydration on body mass, plasma volume, plasma osmolality and flow-mediated dilation (FMD), versus euhydrated state. Flow-mediated dilation occurs in blood vessels in response to blood flow; as the blood flow increases, the blood vessel dilation increases to allow for increased blood flow. Impaired FMD results in poor blood flow, which reduces the rate of oxygen and other nutrients delivered to cells, and also reduces the clearance of metabolic waste products from the cells. Poor blood flow is related to reducing athletic performance and has a negative impact on health.

For this research study ten young, healthy males participated. The study design was crossover. The characteristics of the male subjects were as follows: average age was about 24.3 years; average weight was about 80.8 kg; and average BMI was about 24.3 kg m-2. Flow-mediated dilation measurements were made for each subject in the euhydrated and hypohydrated states. The measurements were separated by 24 hours. The subjects completed 100 minutes of low-intensity intermittent walking exercise to achieve hypohydration of about -2 % of individual body mass. For the rest of the day, a standardized, low water content diet was provided. The following morning, hydration markers and endothelial function were recorded.

On average, the subjects achieved levels of hypohydration of about -1.9% of body mass. This hypohydration resulted in decreased plasma volume by about -3.5% and increased plasma osmolality by about 9 mmol kg-1; and FMD as a response to hypohydration decreased by about -26.8 %. Based on the results of this study the researchers reported that a small degree of hypohydration induced by moderate exercise and fluid restriction significantly impaired endothelial function. This study did not measure impacts to physical performance. However, another research study conducted by James and coworkers in 2017 examined the adverse effects of hypohydration on endurance exercise performance.

Hypohydration impairs endurance performance: a blinded study.

In this study by James and coworkers in 2017, these researchers examined the effect of hypohydration in a single blind manner. Seven males average age 25 years were subjects in this study. The exercise test followed an exercise preload followed by a 15-minute all-out exerciser performance test on a cycle ergometer. Both states of euhydration and hypohydration of about – 2.5% body mass were examined. Work completed during the exercise performance test was lower during hypohydration. Therefore, related to exercise performance the researchers reported that exercise performance was impaired by hypohydration.

Sources:Arnaoutis G, Kavouras SA, Stratakis N, Likka M, Mitrakou A, Papamichael C, Sidossis LS, and Stamatelopoulos K., The effect of hypohydration on endothelial function in young healthy adults. Eur J Nutr. 2017 Apr;56(3):1211-1217.

James LJ, Moss J, Henry J, Papadopoulou C, Mears SA. Hypohydration impairs endurance performance: a blinded study. Physiol Rep. 2017 Jun;5(12).

Warning: Remember to Include Water Loss from Other Daily Physical Activities in Addition to Athletic Training Activities.

For example, the 2004 “Dietary Reference Intakes for Water, Potassium, Sodium, Chloride, and Sulfate” report, presents a variety of water loss data. One figure on page 130 includes approximate daily water requirements as a function of climatic temperature and activity levels based on calories per day.

Light work (2800 kcal/day) range was 2.5 to 10 quarts per day (80 to 320 fluid ounces).

Hard work (5600 kcal/day) range was 6 to 19 quarts per day (192 to 608 fluid ounces).

Other data presented from military studies reported similar ranges of approximate daily fluid requirements related to climate and physical activity.

Beware the Limitations

Similar to limitations with other sports nutrition requirements at the personal level, the same limitations apply to generalized water loss and hydration data, too. For example, researchers report a wide range of water loss from sweat among athletes, with sweating rates during exercise or sports activities ranging from 0.3 to 2.4 liter per hour. However, recent (as reported by Davis 2016) noted that American football players have mean sweating rates from 1 to 2.9 liters per hour during exercise, with some of the larger players experiencing 3 or more liter-per-hour sweat rates.

How Much Water Does an Athlete Need?

The amount of water needed will vary greatly based on initial level of hydration, the climate, the duration and intensity of exercise, and other daily activities. As a general rule, evaluate fluid intake by fluid output, namely frequency of urination, and also using body weight fluctuations. When well hydrated, a person may be urinating about once every one and a half to two hours. In addition, the color of urine can indicate hydration status, with the lighter color possibly indicating adequate hydration and darker colored urine indicating inadequate hydration. Adequate hydration is a serious medical matter, and health practitioner supervision is required to determine hydration requirements on an individual basis. If urination is only a few times per day, you probably need to increase water/fluid intake.

Because the thirst response takes longer to tell the body it needs water, athletes should get in the habit of drinking water/fluids frequently throughout the day. Daily hydration guidelines are important for all athletes to follow. Studies have shown that endurance athletes who compete for periods lasting longer than 30 minutes improve their competition performance by drinking during the activity. However, for shorter events, athletes need to be properly hydrated from the start to achieve peak performance. For all athletes, besides paying special attention for adequate hydrate related to competition, day-to-day adequate hydration during training is of utmost importance, too.

Body Weight Fluctuations for Estimating Hydration Requirements

One approach to obtain estimates regarding an athlete’s water balance is to track changes in body weight several times a day, including before, during, and after exercise, training, and athletic events. Working in kilograms can be convenient, as 1 liter of water is about 1 kilogram.

The first step is to establish a baseline of being adequately hydrated (euhydrated). This can be accomplished using body weight measurements taken in the morning before and after urination, for several days, including a two-day rest period from exercise or other physical activities, including work, along with adequate daily hydration. Body weight measurement may be taken without clothing.

For the water-loss-during-exercise evaluations, immediately before starting exercise, take a body weight measurement. Then depending on the climate and expected rate of sweating during exercise, low, medium, or high, plan for taking a body weight measurement after 30 minutes of exercise, or longer, depending on conditions. If

fluid is consumed during exercise, the weight must be factored in. Body weight measurement may be taken without clothing: have the athlete remove sweat from the body with a dry towel.

In the following example, 0.250 kilograms of body weight was lost during 30 minutes of exercise from fluid loss (sweating), during which 0.250 ml of water was consumed. Note that if water/beverage intake exceeds fluid loss by sweating/lungs, this would result in a gain in body weight. The total actual water loss from sweating is about 0.500 liters (500 milliliters) when considering the measured reduction of body weight and the additional water lost from sweating during exercise that was replaced by water consumption during exercise. The following table summarizes the measurements and calculations.

Body Weight at Start of Exercise = 70 kilograms	**Body Weight at 30 Minutes of Exercise = 69.750 kilograms**	**Sweat Rate Based on Total Water Loss:**
1 liter of water = about 1 kilogram	Fluid intake was 0.250 liters water (250 milliliters)	- 0.250 kg BW reduction - 0.250 L (or 0.250 kg) fluid intake during exercise, would be about -0.500 L total water loss per 30 minutes Estimation of – 1 liter per hour water loss
Note: Here are some water weight estimates, keeping in mind that water volume/mass varies at different temperatures. A liter of water weighs about 1 kilogram or 2.2 pounds (35.2 ounces). 1 pound is about 454 grams. 1 milliliter is about 1 gram. 1 kilogram is about 33.8 fluid ounces. About 30 milliliters per fluid ounce.		

Daily Hydration Guideline Examples

The following fluid intake examples are intended for an approach based on daily energy expenditure. Note that each individual needs to have his or her hydration requirements confirmed on an individual basis by qualified health professionals. It has been determined that relating water intake to daily energy expenditure is one approach reported in some publications. (Refer to the unit related to energy expenditure needs.)

In the following hypothetical examples, a minimum daily water intake range estimate is provided to accommodate for individual differences and climatic differences that are determined. As temperature and humidity climb over 70 degrees F and 70% humidity, water loss will be increased due to increased sweating, especially during exercise, and appropriate increase in daily water intakes should be determined, above minimum range estimation values.

Daily Energy Expenditure	Minimum Daily Water Intake
2,000 calories	64 to 80 ounces
3,000 calories	102 to 118 ounces
4,000 calories	138 to 154 ounces
5,000 calories	170 to 186 ounces
6,000 calories	204 to 220 ounces

Along with estimating calorie and macronutrient requirements with energy expenditure-based approaches, using the daily energy expenditure-based approach for hydration requirements can provide a compatible method for health professionals. However, this energy expenditure approach

can be fine-tuned using the body weight-based approach to crosscheck body loss water dynamics with the energy expenditure approach estimations. In fact, the body weight approach can be used to validate energy expenditure approach values for an athlete to fine-tune and personalize their energy expenditure based daily water intake estimates. Whichever approach or combination of approaches is used, good data collection and analysis are required to determine an athlete's daily water intake to achieve the desired euhydration and to avoid dehydration (hypohydration) and excess hydration (hyperhydration) that can have adverse health effects and adverse effects on athletic performance.

SOURCES OF WATER

Concern over the quality of water and other beverages has become a preoccupation for many people. Reports of the harmful effects of contaminants in drinking water and chemicals in beverages will certainly make the health-minded individuals think twice about looking for pure and natural products to drink. Because athletes consume far greater amounts of beverages than do nonathletes, the exposure to impurities is greater. In general, water is preferable to soda, juices, and other calorie-containing beverages. But specialty sports beverages have their place in an athlete's performance nutrition program, when used wisely on a daily basis, as needed.

NOTE that Unit 17 contains additional information related to the entire sports nutrition program.

Hydrating with Glycerol: Effective, but Proceed with Caution

Glycerol is a three-carbon-atom molecule that is the backbone of triglycerides and phospholipids. Triglycerides consist of three fatty acids attached to a glycerol molecule, and phospholipids consist of two fatty acids attached to a glycerol molecule, with a phosphate-containing compound attached to the third carbon atom. When glycerol is removed from these fats by hydrolysis, it is a clear, syrupy liquid. The liquid has been used in a variety of ways over the years, but it is especially popular as an emollient in skin-care products and cosmetics and as a sweetening agent in pharmaceuticals.

As a supplement, glycerol has been found by researchers to possibly help the body remain better hydrated. Studies have shown that athletes training for prolonged periods (more than one hour) are able to run cooler and longer when they ingest a water-glycerol mixture. Researchers report variable results, some positive and some neutral, on athletic performance enhancement.

Examples of dosages used in research that reported a benefit are high in comparison with other ergogenic supplements. The 1999 Hitchins and coworker study examined effects of glycerol hyperhydration on improving cycle time trial performance. Each time trial was preceded in a single dose, about 2 to 2.5 hours prior to time trial, by ingestion of either a glycerol solution [1 g x kg(-1) body mass (BM) in a diluted carbohydrate (CHO)-electrolyte drink] or a placebo of equal volume (the diluted CHO-electrolyte drink). The total fluid intake in each trial was 22 ml x kg(-1) BM. Glycerol ingestion expanded body water by approximately 600 ml over the placebo treatment. Glycerol treatment significantly increased performance by 5% compared with the placebo group.

In a more recent study, Patlar and coworkers (2012) consumed glycerol (1.2 g/kg body weight) followed by water (26 ml/kg body weight). The results demonstrated an athletic performance-enhancing benefit for soccer players.

A word of caution: Some side effects, including bloating, nausea, and lightheadedness, have been reported with glycerol use. If an athlete chooses to try a glycerol-containing beverage, he or she should test it out at least several times before competition to see how the body reacts to it. When taking food or supplements for the first time, under the supervision of a physician, starting with low dosages/amounts to determine allergy reaction, intolerance, or other issues is an evaluation approach used. This should befFollowed by incrementally, each few days, increasing the dosage to the effective range.

In addition, it is crucial to check legal status for use of glycerol in certain competitive sports. WADA and other sports governing organizations can have bans on the use of glycerol. So be sure to confirm the legal status before use by competitive athletes.

Oxygen

Oxygen and the Athlete

Oxygen, like water, is something that most people do not consider a nutrient but that the body cannot survive without. It is basic to human life. Oxygen not only keeps the lungs breathing and the heart pumping but also feeds every cell of the body. Knowing the dynamics of oxygen uptake and utilization can help you plan a scientific and sound athletic performance-enhancement program. The best training program not only builds muscles and increases stamina but also improves the body's ability to take in and properly utilize oxygen, which builds bigger muscles and increases stamina even further.

Oxygen takes a circuitous route through the body. It enters by the lungs and then travels via the bloodstream through the heart to the cells of the muscles, brain, and other tissues. The lungs are also the last stop for the waste products of oxygen metabolism, which are carried away from the cells through the blood vessels and eventually exhaled into the air.

The Lungs

The lungs are the first step in the operation that brings oxygen into the body system. The lungs are a pair of organs that sit in the chest on either side of the heart. They process the air that is breathed in, removing the oxygen and transferring it to the bloodstream for distribution throughout the body. The amount of air that the lungs can process varies with the condition of the person—a conditioned person can process more air than a deconditioned person can. The amount of air that the lungs can process is therefore a limiting factor.

To use an analogy, the lungs are like a dairy that processes milk. When bulk milk comes in, the cream is separated from it and then bottled and sent off for distribution. When the empty bottles come back, they are flushed out, filled with more cream, and sent out once again. The air that we breathe is like the bulk milk, and oxygen is like the cream. When bulk air comes into the lungs, the oxygen is extracted from it, "bottled" in red blood cells, and sent off in the bloodstream for distribution. When the "bottles" reach the tissues that they are to feed, they exchange their oxygen for **carbon dioxide** and water, waste products that they then carry back to the lungs to be flushed out of the

Carbon dioxide: a metabolic waste product.

body. Once emptied of these waste products, the "bottles" are again filled with oxygen and sent out once more for distribution.

The air that we breathe is approximately 21percent oxygen and 78 percent nitrogen, with negligible traces of other gasses. This ratio never varies. What does vary is the amount of air that can be processed. If the lungs cannot process enough air, they cannot extract enough oxygen to produce enough energy. Two factors limit the lungs' ability to process air.

First, the lungs have no muscles of their own. To expand and contract, they must depend completely on the muscles of the rib cage and diaphragm. Upon inhalation, the muscles surrounding the lungs increase the available space within the lung cavity. When they do this, they cause a partial vacuum, which helps suck air into the lungs. Upon exhalation, assisted somewhat by the natural elasticity of the lungs and the chest wall, the muscles contract to create greater atmospheric pressure inside the lungs than outside the body. This causes the air to be pushed out.

This normal breathing is done by the body at rest. As was already mentioned, all resting bodies consume essentially the same amount of oxygen and consequently inhale and exhale about the same amount of air. When the body is in action, however, the amount of air that the lungs can inhale and exhale becomes limited by the size of the vacuum the muscles can create for the lungs to expand into and the size of the area the lungs can squeeze back down into. A conditioned person in action obviously is able to inhale more air and for longer periods of time than a deconditioned person can. A conditioned person is also capable of exhaling more waste products because the muscles around the lungs have been trained to do more work.

The second factor that limits how much air the lungs can process is the condition inside the lungs. Lungs vary in size. A larger person naturally has proportionately larger lungs than a smaller person does. Thus, in fitness and sports, we are less concerned with the size of the lungs, or total lung capacity, than with how much of that capacity is usable. The usable portion of the lungs is called the vital lung capacity, and it is measured in the laboratory by the amount of air that can be exhaled in one deep breath. Numerous tests have shown that a conditioned person's vital lung capacity is about 75 percent of total lung capacity. Often, however, an otherwise deconditioned person can match this, so we look at one more factor—the maximum minute volume. This is the amount of air a person can process during one minute of vigorous exercise, and it usually separates the fit from the unfit. Conditioned persons can force as much as 20 times their vital capacity through the lungs in one minute, whereas deconditioned persons are often hard-pressed to force even 10 times through. Deconditioned persons simply lack the muscle and strength endurance to perform at a higher level.

The remainder of the lungs—or, more specifically, the remainder of the air in the lungs—is called the residual volume. The residual volume is fixed, and even a conditioned person cannot breathe this remaining air in or out. Because residual volume is inversely related to vital lung capacity, too much residual volume is unhealthy. If your body deteriorates from inactivity or disease, the unusable portion of your lungs increases, blocking off more and more space and allowing less space for normal breathing, let alone vigorous exercise. Ultimately, you will find yourself short of breath from even light activity, such as climbing a flight of stairs.

Thus, when athletes allow their bodies to deteriorate, they may live their lives with two handicaps in their lungs alone. When you need more oxygen in a hurry, you may have trouble getting it because the muscles controlling your lungs will not be in good enough condition to force large volumes of air through the lungs. In addition, the usable space within your lungs may be seriously reduced.

Training can reverse both these trends. Exercising the muscles surrounding the lungs can increase the muscles' strength and efficiency, allowing them to open more usable lung space. Opening more usable lung space has the net effect of increasing the vital lung capacity and reducing the residual volume. In each instance, the lungs become more efficient at processing air and extracting oxygen.

A simple way to test the breathing condition of your lungs is to take a deep breath and then see how long you can hold it. Most adults in moderately good physical condition and with healthy lungs are able to hold their breath for 60 seconds or longer.

The Blood

From the lungs, the oxygen extracted from the bulk air goes directly into the bloodstream, the body's "assembly line." This is accomplished because the lungs contain millions of tiny air sacs, called alveoli, around which the blood flows. The alveoli are like tiny balloons that are filled with air and dangle in the liquid of the bloodstream. The air was originally forced into the alveoli by atmospheric pressure, and now, obeying the law of gaseous diffusion, the oxygen transfers from the air in the sacs, in which the pressure is higher, to the red blood cells, or "empty bottles," in which the pressure is lower. The limiting factors here are the number of red blood cells that exist and the amount of hemoglobin these blood cells can carry. Even if the lungs could process more oxygen, the tissue cells would not receive more unless additional "bottles" existed to deliver it.

Training helps here, too. Training produces more hemoglobin to carry oxygen, more red blood cells to carry the hemoglobin, more **blood plasma** to carry the red blood cells, and, consequently, more total blood volume. Red blood cells, also referred to as erythrocytes, contain hemoglobin. Laboratory tests have repeatedly shown that individuals in good physical condition have a larger blood supply than do deconditioned individuals of comparable size. An average-sized person can increase his or her blood volume by nearly a quart in response to aerobic conditioning. The red blood cell count increases proportionately.

The additional "bottles" produced by training not only deliver more oxygen to the tissue cells but also carry away more metabolic waste products, such as carbon dioxide. The removal of carbon dioxide and other metabolic waste products is important for reducing fatigue and increasing athletic performance.

One process by which the "bottles" unload their oxygen into the tissue cells and pick up waste products is called osmosis. The oxygen and food substances, now in liquid form, pass through the cell membranes into the cells in one direction, while the waste products exit the cells through the cell membranes in the opposite direction. This is the life cycle—materials for nourishment and energy go in, and waste products come out. The carbon dioxide and other waste products are then carried away in the bloodstream via the veins, and when they reach the lungs, they follow the law of gaseous diffusion in reverse. The pressure of the carbon dioxide in the veins is greater than the pressure in the empty alveoli is, so the carbon dioxide passes freely into the alveoli and is exhaled with the expired air.

Blood plasma: the liquid part of the blood; the substance in the blood that carries the red blood cells.

The efficiency and capacity of this cycle are both functions of the effects of training. If you increase the system's capacity, you help increase its efficiency. If you do nothing, the system deteriorates.

The Blood Vessels

Muscular activity speeds up the rate of a normal heart, forcing it to pump more blood per minute and increasing the amount of blood returning to the heart. This increases the circulation. As the volume of blood increases, so does the blood supply to the muscles. This improved blood flow, resulting from tissue **vascularization** (creation of new blood vessels), is probably the most remarkable training effect. Capillarization is another term related to the formation and development of capillaries, which is activated by exercise and athletic training. To carry on our analogy, it is similar to a dairy's expanding its regular delivery routes by opening up new routes into many small neighborhoods that up until now had been neglected.

Vascularization: the creation of new blood vessels in the tissues.

In addition to helping create new blood vessels, training also improves the condition of the existing blood vessels, which has a beneficial effect on the blood pressure. When a blood pressure reading is taken, two figures are noted. A common reading is 120 over 80, written as 120/80. The top figure is the systolic pressure, the pressure of the blood against the walls of the arteries when the heart is in the process of ejecting blood into the system. The lower figure is the diastolic pressure, the pressure during the relaxed phase of the pumping cycle. In other words, the two figures represent the maximum and minimum pressures inside the blood vessels. In a conditioned person, these figures are usually lower because the blood vessels are more pliable, and the resistance to blood flow is at a minimum. In a deconditioned person, the figures are higher because the arteries tend to lose elasticity with disuse (inactivity), and the resistance to blood flow is increased.

Heart rate: the rate at which the heart pumps the blood through the body.

When physical activity or emotional stress is added, trouble can result. The **heart rate** is increased, which raises the blood pressure because the heart is pumping more blood into the system at a faster rate. In a treadmill test, a conditioned man might start with a diastolic pressure of 70 and experience only a slight increase during his run. After the test, his blood pressure returns to normal within a few minutes. A deconditioned person, however, and especially an overweight deconditioned person, might start with a diastolic pressure of 90 and have it shoot up to 105 during the test and then take 10 minutes or more to recover.

Almost everyone, especially people with clinical conditions, may reduce their blood pressure significantly by adhering to an appropriate medically supervised exercise program for even just a few weeks. First, blood vessels tend to make compensatory adjustments to handle increased exercise capacity, something that almost all body systems do in response to increased stress. Once again, this is an effect of training. Second, conditioning the blood vessels causes the creation of an augmented blood supply, the new routes that are opened up into the small "neighborhoods," as discussed above.

One of the most famous, and amusing, tests done in this area was reported by a researcher who lifted a weight with a finger. The researcher set the weight on the floor, tied a rope to it, ran the rope over a pulley fastened to the edge of a table, and then sat on the other side of the table and looped the end of the rope over the middle finger of his right hand. In time to a metronome, he repeatedly lifted the weight with his finger. The first time, and for many weeks thereafter, the best he could do was 25 lifts before his finger became fatigued. To expand the experiment, he occasionally had a mechanic in his building lift the weight with a finger. The mechanic always beat him. Then one day, about two months into the test, the researcher did his usual routine but found that his finger was not tired at 25 lifts. He kept going and ultimately reached 100 lifts. He suspected what had happened and brought the experiment to a rather unorthodox conclusion. He invited the mechanic in again and made a small bet that he could beat the man. The mechanic accepted the bet and lost.

What the researcher had suspected was that his finger muscles had undergone vascularization in response to the stress of the lifting exercise. More blood vessels had opened up/developed, creating new routes for delivering more oxygen. However, the new blood vessels apparently did not open up one at a time but an entire network at a time. Many people practicing conditioning programs recount how they agonized for months and then, boom! Almost overnight, the exercise became relatively effortless. Athletes report similar "plateaus of progress," improving not only day by day but also in quantum leaps.

Vascularization is an essential factor in building endurance and reducing fatigue in the skeletal muscles, in saturating the tissues with oxygen, and in carrying away more waste products. It is also an extremely vital factor in the heart's health and in other parts of the body's health.

EPO and Blood Building

One of the hottest topics capturing the attention of athletes, coaches, and other people in sports focuses on the illegal use of the drug rhEPO (recombinant erythropoietin) by some athletes. EPO (erythropoietin) is a hormone that is naturally produced in the body and primarily functions to stimulate the production of new red blood cells. Increasing the number of red blood cells increases the oxygen-carrying capacity of the blood to deliver more oxygen to exercising muscles. The extra oxygen significantly increases the muscles' energy production and can therefore help improve athletic performance output ability; higher intensity and longer duration. These benefits of the body's natural EPO has led to the illegal use of synthetic rhEPO drug doping by some athletes.

Due to the increase in oxygen-carrying capacity and other vasoactive effects of interest, EPO has also gained interest among athletes outside of the endurance crowd: strength athletes, including bodybuilders, who are looking to increase exercise intensity, training session volume, and quality of their workouts, and those who are equally interested in achieving the "perpetual pump." But there are even more interesting aspects to the EPO blood-boosting story, including combating the fatigue-causing drop in pH levels, a synergistic Nitric Oxide connection, and enhancing nutrient delivery to stimulate muscle growth.

Keep in mind that this information about EPO and rhEPO is for awareness, not for use of rhEPO.

EPO—Red Blood Cells—Oxygen

From a straightforward athletic performance bio-energetic perspective, oxygen is required for the body to make energy (aerobically) to produce muscle contractions in addition to anaerobic-produced energy. Within muscle cells are energy-producing structures called mitochondria. Oxygen is used inside the mitochondria to drive the biochemical reactions that break down carbohydrates, fats, and certain amino acids to produce energy in the form of ATP (adenosine tri-phosphate). This enables the body to convert the energy stored in foods to a form that the body can use—in the form of ATP.

These high-energy ATP molecules are then used by the muscles as an energy source to power muscle contractions. Thus, more oxygen in the body/muscles yields more ATP generation, increasing muscle contractions, which results in improving athletic performance. This benefit of increasing oxygen in the body has led to the reported use or suspected use of rhEPO by top endurance athletes.

Now, with the sports authorities cracking down on illegal rhEPO used in sports and the additional risk of potential harmful side effects of using rhEPO unsupervised, athletes are seeking alternative ways to boost their own EPO levels and red blood cells in addition to boosting their nitric oxide (NO) levels.

Sports Performance Benefits of EPO

Medically, rhEPO is used to increase red blood cell count. Logically, because EPO accelerates red blood cell production, it also increases the oxygen-carrying capacity of the blood and more oxygen to muscles and to other body tissues. This primary benefit of rhEPO attracted the attention of the athletic community and led to the use (or alleged) of rhEPO by elite athletes.

Endurance Athletes and rhEPO

The use of rhEPO is reported by the athletic community to help increase oxygen-carrying capacity of the blood by building more red blood cells, thereby improving athletic performance and reducing exercise fatigue. This enables performance improvements in endurance type and other sports because of the extra oxygen-carrying capacity. It is also believed that rhEPO and naturally produced EPO increase the metabolism and the healing process of muscles because the extra red cells carry more oxygen and nutrients, improving recovery ability. This review of rhEPO is meant to present information about this topic to explain what is going on with some athletes and the science behind this drug and is not intended to encourage the illegal use of rhEPO by athlete.

Natural/Nutritional Epo Boosting

The current trend among some athletes is to use legal specialized sports nutrition supplements designed to naturally boost production of EPO, taking the legal sports supplement route to boost the body's ability to maximize EPO, red cell building, and oxygen uptake. The natural/nutritional approach may offer ways for all athletes to perhaps improve their oxygen-carrying capacity.

Red Blood Cell (Erythrocytes) Building

Red blood cells, also known as erythrocytes or red corpuscles, primarily function in the transport of oxygen and carbon dioxide in the body. The red blood cells are specialized types of cells that are loaded with a substance called hemoglobin. Naturally produced EPO in the body stimulates the production of red blood cells from stem cells that originate in bone marrow.

Because blood cells have a short life in the bloodstream (only a few to several weeks), it is important to optimize this blood-building process to maintain an optimum level of red blood cells. This is vital to people who are more physically active, such as athletes, because intensive exercise will increase the breakdown of red blood cells. Furthermore, it is additionally beneficial to maintain optimum levels of nutrients and substances that increase the red blood cell-building stem cell populations and to protect red blood cells once they are produced and delivered into the bloodstream.

Major Function of Hemoglobin

The major function of the hemoglobin molecules found densely packed in red blood cells is the transport of oxygen from the lungs through the bloodstream to the tissues and trillions of cells in the body. During hemoglobin's functioning in the body, hemoglobin will alternate between two physiological states based on whether it is carrying oxygen molecules or not: oxyhemoglobin and deoxyhemaglobin. In the oxyhemoglobin state, hemoglobin is loaded up with oxygen. In the deoxyhemoglobin state, hemoglobin is devoid of oxygen, which is also known as empty hemoglobin.

Biochemically, hemoglobin is a specialized protein molecule, a conjugated globular protein, which consists of heme groups containing iron. The iron components of hemoglobin function to "lock on" to oxygen and also onto carbon dioxide molecules. Therefore, adequate dietary/supplement intake of iron is vital for the development and functioning of red blood cells. Forms such as ferrous fumarate are used in supplements as an "organic" alternative to iron oxide and other inorganic forms.

Carbon Dioxide Transport and Hemoglobin

In addition to carrying molecules of oxygen, hemoglobin also transports the metabolic waste product carbon dioxide from cells through the bloodstream and to the lungs where it is exhaled into the atmosphere. (Yes, humans are a source of CO_2.)

During exercise, CO_2 tissue levels build up during exercise, which contributes to the onset of fatigue, reducing the ability to maintain high-normal levels of exercise/athletic performance. It is therefore of paramount importance to have high levels of red blood cells, plus good blood circulation, to create the conditions in the bloodstream that will rapidly clear away CO_2 from exercising muscles and eliminate it from the body.

Natural EPO and Red Blood Boosters

In a quest to find natural alternatives to rhEPO, that is, substances to naturally enhance EPO levels and boost red blood cell production in the body, there is a growing list of research-backed ingredients being reported about in the scientific and medical literature and appearing in sports nutrition products. The following are some nutrients/ingredients found in sports supplements that are reported to boost EPO and red blood cell production along with other benefits of interest to athletes. Note that this is an emerging area of sports nutrition, and examples are intended for providing some preliminary background to the ingredients found in the natural EPO-boosting sports nutrition products you or your clients may encounter.

Arachidonic Acid: The EPO production stimulating effects of arachidonic acid are attributed to its involvement in the biochemical process leading to the actual production of EPO in the body and phospholipase activation in erythroid progenitor cell proliferation. Arachidonic acid is abundant in the body and involved in many structural and biochemical functions. Regarding EPO production, arachidonic acid is the precursor molecule in the production of eicosanoids, which are substances in the body found to be involved in stimulating EPO production. Additionally, recent research has reported anabolic muscle-building effects of arachidonic acid.

Cobalt: Cobalt is another vital research-based EPO/red blood cell production stimulator, which is needed by humans in small amounts. It is also a necessary component of vitamin B12. In the research report titled "Blood Doping by Cobalt," researchers reported that cobalt is a naturally occurring element that enhances erythropoiesis and angiogenesis (growth of new blood vessels), resulting in increasing red blood cell concentration and circulation. The proposed mechanisms of action include more efficient transcription of the erythropoietin gene.

Echinacea: More recent research has demonstrated that Echinacea stimulates production of erythroid (red blood cell) growth factors, induces erythropoiesis, and increases the oxygen-transport capacity of the blood, in addition to its well-known role for beneficially stimulating the immune system. The blood-building and improved oxygen-carrying capacity effects of taking standardized Echinacea supplements was reported in a recent study using male subjects. This research, along with other research studies, has found that the use of Echinacea-containing supplements increased EPO levels, interleukin-3 (IL-3) levels, red blood cell count, the number and size of red blood cells, and maximal oxygen consumption $\dot{V}O_2$ max.

Niacin: This essential vital vitamin that is required by the body for the formation of coenzymes NAD and NADP. Niacin also has vasodilation properties, especially for dilating the micro-circulatory system that is responsible for the delivery of oxygen, nutrients, and hormones to the muscle cells and for clearance of metabolic waste products.

Portulaca oleracea: This botanical contains high concentration flavones that scientific research reports may improve the expression level of EPO and accelerate the generation of erythrocytes and hemoglobin.

Vitamin B-6 (As Pyridoxine HCl and Pyridoxine 5-Phosphate): An essential vitamin needed for red blood cell production. Vitamin B-6 also helps increase the amount of oxygen carried by hemoglobin (the iron-containing oxygen transport metallo-protein in red blood cells). Note that a vitamin B-6 deficiency can result in some health problems.

Vitamin B-12 (Methylcobalamin, Cyanocobalamin, Dibencozide): This essential vitamin is vital for red blood cell production. Deficiency in vitamin B-12 is responsible for a reduction in red blood cells and can lead to muscle fatigue and weakness.

EPO Blood Building and the Synergistic Effects of Nitric Oxide

Although EPO and NO boosting have well-known distinct benefits, the question arises whether boosting both EPO and NO will produce synergistic effects. Let's examine how these two performance agents work in tandem to give athletes a new competitive edge.

Here's a short recap of the science of NO. Major attention was first directed to NO when the Nobel Prize in Physiology or Medicine in 1998 was awarded to Robert F. Furchgott, Louis J. Ignarro, and Ferid Murad for their discoveries concerning “the nitric oxide as a signaling molecule in the cardiovascular system.” One of the main functions performed by NO in the cardiovascular system is dilating blood vessels. This function helps increase blood flow to muscle and other tissues in the body. As more research has been focused on NO, more functions have been identified, such as NO’s role as an important signaling molecule outside the cardiovascular system, signaling between nerve cells in the brain, and enhancing the olfactory sense and immune system functioning.

Chief among NO’s many functions in the sports nutrition product industry is its role in vasodilation – leading to achieving the resistance exercise-induced PUMP. Vasodilating during exercise is vital to accommodate increasing blood volume and to enhance blood flow rate for maximum delivery of oxygen, nutrients, and anabolic hormones to muscle tissue and to improve metabolic waste clearance, such as fatigue-causing carbon dioxide.

Therefore, although EPO boosting provides a means to stimulate more red blood cells and higher nutrient and oxygen-carrying capacity, NO provides the means to widen the blood vessels to promote greater blood flow. In this way, EPO and NO working together are the vasoactive cart and horse of maximizing performance-enhancing enriched blood and blood vessel super-pumps.

Nitric oxide stimulates the blood vessel dilating effects to create a wider circulatory system conduit for the EPO-stimulated red blood cell-enriched volumized bloodstream to deliver more oxygen and nutrients to the muscles and other tissues, with a new level of performance expected from these synergistic effects.

Hundreds of products now feature ingredients for promoting NO-mediated vasodilation, primarily by two modes of action: precursors that are involved in NO production and stimulators that are involved in the production of NO. Here is a summary of some of the ingredients being used in NO-stimulating products and that are also contained in the newest class of dual-action EPO–NO-stimulating products.

NO-Boosting Ingredients Summary

Arginine: Arginine is a crucial amino acid used to make nitric oxide in your body. NO products found on the shelves usually contain arginine as a single ingredient or in other forms, for example, Arginine Alpha Keto Glutarate and Arginine Ethyl Ester. Some products contain a multisource arginine blend claiming to ensure fast, complete, and sustained absorption of the arginine molecule provided in free form and special organic complexes, such as with Alpha Keto Glutarate and Ethyl Ester for dynamic physiological action.

Citrulline: Citrulline is another amino acid found in NO-stimulating supplements, primarily for its purported function of boosting the body’s arginine levels, thereby supporting the NO production pathway. Citrulline can be used on its own as a supplement, but it is typically included along with arginine and other NO-stimulating ingredients as a way of saturating the nitric oxide production pathways to ensure that peak nitric oxide production is achieved because arginine has a variety of other functions in the body in addition to NO production.

Cnidium monnier: This botanical ingredient is reported to be traditionally used to support already normal male sexual performance. However, modern research determined that a primary physiological function of this botanical is to increase the release of nitric oxide by cells lining the circulatory system, thereby promoting vasodilation. This NO-boosting effect reveals a viable reason for its traditional use of promoting normal male sexual function and as an ingredient used in NO-boosting sports nutrition products.

Folate: This essential vitamin is involved in the hematopoietic system and is required for red blood cell production. Folate also has beneficial effects on endothelial function, as measured with the use of flow-mediated dilatation (FMD). A study reported that folic acid improved endothelial function and increased flow-mediated dilation. Folate also lowers homocysteine levels, which is beneficial because a high level of homocysteine impairs cardiovascular function and blood flow. Furthermore, research revealed that folic acid is involved in the regeneration of tetrahydrobiopterin, which enhances nitric oxide synthase function and maximizes nitric oxide production.

Gynostemma pentaphyllum: Gypenosides extracted from Gynostemma pentaphyllum have been shown to elicit vasorelaxation and vasodilation through the direct release of endothelium-derived nitric oxide. In this way, Gynostemma serves to directly stimulate NO levels in the cardiovascular system and plays a synergistic role with NO precursor substances, like arginine.

Norvaline: Norvaline is related to the branched-chain amino acid valine. Norvaline is reported to inhibit the arginase enzyme, thus increasing arginine levels available for NO production. Norvaline can in this way optimize the NO-boosting effects of a multi-ingredient NO-boosting formula, in formulas containing arginine and/or citrulline, by optimizing the NO-synthesizing biochemical pathway.

Pycnogenol®: Pycnogenol® is brand name of a dietary ingredient used in dietary supplements. Compositionally, it is a well-researched and highly standardized botanical, referred to as French maritime bark extract, with multiple health benefits. Regarding NO, it may play an important role with physical activity because it was shown to aid the body in producing nitric oxide (NO), thus enhancing blood microcirculation and improving blood flow to the muscles. This can help achieve peak muscle performance and speed recovery after exercise. It is reported that Pycnogenol® helps relax blood vessels and improves blood flow. Pycnogenol® stimulates the enzyme “endothelial nitric oxide synthase” (eNOS) for enhanced generation of NO from the precursor molecule L-arginine. Two clinical studies have shown that Pycnogenol® causes vasodilatation and consequently improves blood micro-circulation. An increased presence of oxygen and decreased carbon dioxide after consumption of Pycnogenol® was shown. Pycnogenol® contributes to better blood flow and oxygenation of muscle. Pycnogenol® has other benefits related to exercise and sports performance that will be elaborated on in Unit 9.

Conclusion

An athlete's personalized adequate water intake (hydration) and oxygen consumption is a major factor for achieving and maintaining peak athletic performance and good health. Determining hydration requirements for each athlete is an involved process that needs to be established prior to events to increase hydration success. The suitability of using glycerol and other hydration sports nutrition products needs to be evaluated on an individual basis should use be justified.

Keywords

Hypohydration	Diuretic
Euhydration	Carbon dioxide
Hyperhydration	Blood plasma
Glycogen-bound water	Vascularization
Metabolic water	Heart rate

Topics Covered In This Unit

UNIT 7

VITAMINS

Unit Outline

- **I. Introduction**
- **II. The lipid-soluble vitamins- A, D, E, and K**
  - a. Vitamin A- retinol and pro-vitamin A (beta-carotene)
    - i. Vitamin A and beta-carotene in food and supplements
  - b. Vitamin D
    - ii. Vitamin D in food and supplements
  - c. Vitamin E
    - i. Vitamin E in food and supplements
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    - i. Vitamin k in food and supplements
- **III. The water-soluble vitamins**
  - a. Vitamin C
    - i. Vitamin C in food and supplements
  - b. Thiamin
    - i. Thiamin in food and supplements
  - c. Riboflavin
    - i. Riboflavin in food and supplements
  - d. Niacin
    - i. Niacin in food and supplements
  - e. Vitamin B6
    - i. Vitamin B6 in food and supplements
  - f. Folate
    - i. Folate in food and supplements
  - g. Vitamin B12
    - i. Vitamin B12 in food and supplements
  - h. Biotin
    - i. Biotin in food and supplements
  - i. Pantothenic acid
    - i. Pantothenic acid in food and supplements
  - j. Choline
    - i. Choline in food and supplements
  - k. Inositol
    - i. Inositol in food and supplements
- **IV. Daily Vitamin Intake Reference Summary**
- **V. Conclusion**

Learning Objectives

After completing this unit, you will be able to:

- Define and discuss terms related to vitamins;
- Discuss the main functions of vitamins;
- Determine benefits of vitamins for health and performance of athletes;
- List food sources of vitamins.

INTRODUCTION

Vitamins are a group of naturally occurring nutrients found in food and supplements that are required in the diet for maintenance of good health, normal metabolic functioning, growth, recovery, and performance. They are organic compounds, which means they are biologically produced and contain carbon atoms as part of their chemical structure. By definition, vitamins are necessary in trace amounts for health (micrograms to milligrams) and are essential in the diet because the human body either does not make them at all or does not make them in adequate quantities. If any one of these nutrients is lacking in the diet, metabolism will be affected, and essential vitamin deficiency symptoms can arise.

Athletic Significance of Vitamins

- Vitamins are needed for normal metabolism, growth, and maintenance of tissue.
- Adequate vitamin intake is essential for performance and health.
- When vitamin intake is low (deficient) health and athletic performance are compromised.
- Health and athletic performance improvements may be experienced with vitamin supplementation.
- Dietary surveys show that athletes can be deficient in one or several vitamins.
- Optimum vitamin intake is attained from food and supplements.

Traditional nutrition views have focused primarily on providing minimum amounts of vitamins to prevent deficiency symptoms. As mentioned earlier, this is the “nutrition for survival” approach. New research has determined that greater amounts of vitamins can offer other benefits for health and performance. However, although more is indeed better, there is an upper limit of safety and efficacy. This unit will present information about the “essential” vitamins and present information about their form, function, and recommended daily amounts. Data on estimated safe intakes of vitamins were derived from several reputable sources, including the National Research Council and the Council for Responsible Nutrition.

Note that reference intake data from multiple sources is provided in a summary table at the end of this Unit for vitamins for educational purposes only. While a variety of useful scientific information about vitamins is contained in this unit, it is important to realize that personalization of vitamin intake for each athlete requires doctor supervision and testing to determine whether vitamin deficiencies or excesses are present and need to be corrected.

Vitamins are classified into two groups based on their solubility characteristics. There are the fat-soluble and water-soluble vitamins. This categorical grouping was devised back when researchers were first working on isolating nutrition factors that prevented nutritional diseases. Scientists called the fat-soluble fraction “fraction A” and the water-soluble fraction “fraction B.” Vitamin A was the first vitamin identified in the fat-soluble fraction, thus the name. Similarly, the B vitamins were the first identified in the water-soluble fraction. As research progressed, other vitamins were found in each fraction, and the letter system was used to name the vitamins.

The Lipid-Soluble Vitamins – A, D, E, and K

The fat-soluble vitamins are vitamin A, vitamin D, vitamin E, and vitamin K. These vitamins are soluble in lipid and organic solvents. This fat-soluble property allows them to be stored in the body in large amounts along with body fat stores in the liver. Water-soluble vitamins can also be stored, but usually in much smaller amounts, as they have the tendency to be flushed out of the body easily.

Vitamin toxicity: vitamin poisoning.

The fat-soluble vitamins, especially vitamin A, have been posted with a warning sign because their levels can be built up in the body. There is a concern that this build-up may reach harmful levels, even though very few **vitamin toxicity** cases have been reported. However, this concern has grown during recent years and peaked with the emerging use of supplements and the popularized practice of mega-dosing vitamins to combat and prevent diseases and aging. Although vitamin toxicity is rarely seen, you should be aware of its potential occurrence, especially when striving for peak performance. Even though you may not develop a clear case of vitamin toxicity, overdoing it may impair performance. When it comes to nutrition, more is not always better.

Additionally, proper digestion and absorption of the fat-soluble vitamins may require the presence of fat in the diet. Athletes on low-fat and low-calorie diets should be cautioned that deficiency of these vitamins is possible due to absorption malfunctions. Those taking supplements as a source of fat-soluble vitamins should look toward the ones in an oil base or take them with a meal. The following will review the basics on the fat-soluble vitamins.

Vitamin A – Retinol and Pro-Vitamin A (Beta-Carotene)

Vitamin A and its function in vision make it one of the most widely known vitamins. As children, we were all forced to eat carrots, like the cartoon character Bugs Bunny, so our vision would be improved and we wouldn't need glasses. Night blindness is a well-recognized disease, accounts of which can be traced back to ancient Egypt. The cure practiced then was to squeeze the liquid out of cooked liver onto the eyes. Later, other civilizations included liver in the diet to combat night blindness. As we know today, liver is very high in vitamin A content, which lends credibility to this ancient health practice.

Vitamin A actually designates a group of compounds that display vitamin A activity. The principal vitamin A compound is retinol and belongs to a class of chemicals called retinoids, which have varying degrees of vitamin A activity. Retinol is the standard to which the other compounds that display vitamin A activity can be rated against. The retinoids occur in animals.

The carotenoids are another class of chemicals that display vitamin A activity. They are made by plants and function as pigments, but can also be stored in animal fat. They occur in the precursor form of vitamin A. The body converts some carotenoids to vitamin A, to mostly retinol, and referred to as provitamin A. The carotenoids can build up in the body, but do not appear to develop signs of toxicity. Persons desiring to maintain high vitamin A intake will usually combine a moderate amount of vitamin A with a higher intake of Beta-carotene. Beta-carotene is the most popular carotenoid and has about one-sixth the biological vitamin activity of retinol. Other carotenoids with vitamin A activity include alpha-carotene and beta-cryptoxanthin. Carotenoids may have additional benefits beyond vitamin A activity, especially due to their antioxidant activity. Other dietary carotenoids of interest include lycopene, zeaxanthin, and lutein.

The carotenoids are yellow-red plant pigments, and taking high amounts of them may affect a person's skin color with a yellow tint due to accumulation in subcutaneous fat. This condition is called carotenemia. Coloration disappears when the high dosages are discontinued. If carotenemia develops, just cut back on your dosage of Beta-carotene. Beta-carotene also displays antioxidant activity, which is important for protecting the body against free radical damage.

Vitamin A has many functions and is essential for vision as a component of rhodopsin; cellular growth and development; reproduction (involved in testicular and ovarian function); integrity of the immune system; formation and maintenance of healthy skin, hair, and mucous membranes; promotion of bone growth and tooth development; and anti-cancer functions. In addition to these important functions of vitamin A, beta-carotene functions as an antioxidant, with the ability to quench the free radicals, particularly singlet oxygen. This antioxidant function will help reduce cellular, molecular, and tissue damage of free radicals, which are greatly increased by exercise and increased oxygen uptake.

Deficiency signs of vitamin A include development of night blindness; glare blindness; rough, dry skin; dry mucous membranes; loss of appetite; increased susceptibility to infections; and slow growth. Deficiency is found mostly with children under the age of five and is usually due to an insufficient dietary intake. Deficiency also occurs as a result of chronic fat **malabsorption**. The primary signs of vitamin A deficiency are indicated by eye disorders.

Malabsorption: incorrect absorption.

International unit (IU): a measure of potency based on an accepted international standard. It is usually used with beta-carotene and vitamins A, D, and E. Because this unit is a measure of potency, not weight or volume, the number of milligrams in an IU varies, depending on the substance being measured.

Excess intake of vitamin A can occur acutely or chronically. Toxic effects include headaches, vomiting, dryness of mucous membranes, bone abnormalities, and liver damage. Signs of toxicity in adults seem to appear after prolonged daily intakes of 15,000 micrograms (50,000 **IU**) of retinol and 6,000 micrograms (20,000 IU) of retinol in children and infants. These dosages are well above the RDA and are difficult to obtain from food unless large amounts of liver are eaten every day for long time periods or unless supplements are taken in enormous quantities. In women, ingestion of high therapeutic doses of vitamin A has been reported to cause spontaneous abortions and birth defects. Women who are pregnant, or planning on becoming pregnant, should consult their doctors to determine the proper dosage of vitamin A or any other supplements, but note some authorities caution not to exceed amounts of 10,000 IU of retinol per day. Beta-carotene ingested in high amounts is not known to be toxic and is preferred to retinol in higher amounts to derive the benefits of vitamin A and simultaneously gain the benefits of antioxidant activity. However, as mentioned above, discoloration of the skin may occur at high levels of intake due to the accumulation of carotenoids in subcutaneous fat.

Athletic Performance Considerations of Vitamin A or Beta-Carotene. Studies support the adequate intake of vitamin A and beta-carotene for maintenance of overall health and performance. Studies have not supported the use of megadoses for immediate improvements in athletic performance. As determined by a physician, maintain intake within PDI guidelines from dietary and supplement sources. Beta-carotene may be increased proportionally to activity levels to derive the antioxidant benefits.

Vitamin A and Beta-Carotene in Food and Supplements

The vitamin A that is most commonly used in supplements is vitamin A acetate and palmitate. These are effective and economical synthetic forms of retinol. Natural vitamin A retinol forms are available but are more expensive because they are concentrated and extracted from natural animal sources, such as fish liver oil. Beta-carotene, though of plant origin, comes in a synthetic form used mostly in supplements. Beta-carotene is several more times expensive than vitamin A is. Both vitamin A and beta-carotene are found in gel caps, capsules, and tablets. The dry forms tend to be more stable than are those suspended in oils.

Antioxidants Overview

During progressive research on the possible metabolic roles that nutrients may play in addition to prevention of nutrient-deficiency disorders, a group of vitamins, minerals, and enzymes called antioxidants have been identified that protect the body from chemical damage. Because "free radicals" damage biomolecules, they are responsible for aging and for causing diseases like cancer, degenerative diseases, and environmental-reactive contaminants. Oxygen itself also causes damage. Because athletes are overexposed to more free radicals, it is crucial that every athlete's diet contain the antioxidant nutrients for protection. Specifically, antioxidants protect against free radical damage and oxidation. The antioxidant group of nutrients is growing, and the following are examples of antioxidants or antioxidant cofactors: beta-carotene and other carotenoids, vitamin C, vitamin E, cysteine, glutathione, selenium, bioflavonoids, polyphenols, proanthocyanidins, and SOD (super oxide dismutase).

Taking a combination of vitamin A and beta-carotene is a common approach, along with eating a diet rich in vegetables that are high in beta-carotene.

Dietary sources of Vitamin A and Beta-carotene. Vitamin A sources: liver and fish liver oils, egg yolk, crab, halibut, whole milk products, butter, cream, margarine, vitamin A-fortified milk. Beta-carotene sources: carrots and green leafy vegetables, spinach, broccoli, squash, apricots, sweet potatoes, and cantaloupes.

Note that ingestion of over 25,000 IU of beta-carotene may lead to yellow or orange coloration of the subcutaneous fat. However, the coloration is reported to be harmless. Additionally, a note of caution to women who are pregnant or planning on becoming pregnant: high amounts of vitamin A have been associated with the incidence of certain birth defects. Consult a physician about supplementation before and during pregnancy.

Vitamin D

Vitamin D was originally revealed as the active nutrient in cod liver oil that was used for the treatment of rickets and other disorders. Later, researchers also determined that ultraviolet light from sunlight or lamps could cure rickets. We know that vitamin D occurs in high amounts in cod liver oil and that the body can make vitamin D when exposed to ultraviolet light.

Several compounds that exert vitamin D activity. The most commonly encountered are calciferol, cholecalciferol, and ergocalciferol. Cholecalciferol is the major form of vitamin D that is formed in the body. Ultraviolet light induces the conversion of a compound called 7-dehydrocholesterol into vitamin D3 (cholecalciferol). Vitamin D2, ergocalciferol, may be produced commercially by ultraviolet irradiation of the plant sterol, ergosterol. The body can use these forms of vitamin D in the body by converting them to the biologically active form, 25-hydroxycholcalciferol.

Vitamin D has several important functions and is essential for normal growth and development. Its main function is the absorption and metabolism of calcium and phosphorus to support normal mineralization (hardening) of bones and teeth. Vitamin D is involved in many aspects of calcium and phosphorus metabolism, including mediating intestinal absorption and use. Maintenance of the appropriate level of serum calcium is also necessary to promote proper functioning of the neuromuscular system and heart action. There is also some evidence that vitamin D functions to improve muscle strength, helps maintain immune function, helps reduce osteoporosis, and is involved in the cell division process. There appear to be no added benefits for athletes from ingesting megadoses of vitamin D.

The signs of vitamin D deficiency are characterized by inadequate mineralization of bone and associated abnormalities such as soft bones, bowed legs, poor teeth, and various skeletal deformities. In children, this deficiency can result in severe deformation of the skeleton (rickets). In adults, bone loss and an increased susceptibility to fractures can occur. Although vitamin D deficiencies are rarely seen due to fortification of milk and other foods with vitamin D, the condition is of concern for some infants who are breastfed without supplemental vitamin D or adequate exposure to sunlight. Characteristic biochemical changes include low blood calcium and phosphorus levels. For the growing child, normal adults, and athletes, vitamin D is a crucial nutrient. Elderly people and persons who spend most of their time indoors should make an effort to get at least the RDA amount from dietary sources.

However, excess vitamin D intake is potentially harmful, especially for young children. The effects of excessive vitamin D intake can lead to calcium buildup in soft tissues and irreversible kidney and cardiovascular damage. Harmful levels have not been clearly established; however, consumption of as little as 45 micrograms (1,800 IU) of cholecalciferol per day has caused hypervitaminosis (overdose toxicity) in children. Because exposure to sun forms vitamin D, intake of this nutrient should be closely monitored. In some cases, only five times the RDA has produced side effects. Although greater intake than the RDA may be beneficial for athletes, megadosing of this vitamin should be avoided unless under the prescription and supervision of a doctor.

Athletic Performance Considerations of vitamin D. Studies support the adequate intake of vitamin D for maintenance of overall health and performance. Studies have not supported benefits for using megadose amounts of vitamin D for immediate improvements in athletic performance. As determined by a physician, maintain intake within PDI guidelines from dietary and supplement sources.

Vitamin D in Food and Supplements

The types of vitamin D generally used in supplements are vitamin D2 (ergocalciferol) and vitamin D3 (cholecalciferol). These occur mostly in dry tablet form, and supplements containing both vitamin D3 and D2 should be sought.

Dietary sources of vitamin D include fish liver oil, eggs, butter, cream, halibut, herring, liver, mackerel, salmon, sardines, and shrimp. In the United States, foods fortified with vitamin D are a major dietary source, especially milk. Sunlight-produced vitamin D can also be a major contributing factor, making precise dietary guidelines difficult. Persons who do not get frequent sun exposure need more vitamin D from dietary sources.

Vitamin E

Identification of vitamin E's role in reproduction is widely recognized, which has led to the popular supplemental use practiced by many in the hopes of enhancing sexual performance. Recent research has proven other potential benefits of vitamin E supplementation that are of interest to athletes and the population at large, including antioxidant activity, which helps protect the body's substances, cells, and tissues from oxidative/free radical damage.

Two major groups of compounds are found in foods that display vitamin E biological activity: tocopherol and tocotrienols. The tocopherols display a much higher activity than the tocotrienols do and are therefore the primary source of vitamin E. There are several major tocopherols. Natural d-Alpha tocopherol is the most active form of vitamin E.

Vitamin E's major function is as a chain-breaking antioxidant that prevents the spread of free-radical reactions and that scavenges radicals to protect fatty acids within membrane phospholipids and plasma lipoproteins. Other vitamin E functions include normal red blood cell formation and prostanoid synthesis modulation. These compounds are important in the reproductive process, blood platelet aggregation, energy metabolism, synthesis of DNA and RNA, and aging and heart disease retardation. Vitamin E therefore protects cell membranes against oxidation, inhibits coagulation of blood by preventing blood clots, retards oxidation of the other fat-soluble vitamins, participates in cellular respiration, and treats and prevents vitamin deficiency in premature or low-birth-weight infants. Of interest to athletes, vitamin E supplementation has been shown to lower blood lactate levels, decrease lipid peroxidation products formed during exercise, reduce oxidative cell damage, maintain muscle tissue, and play a possible role in testosterone production. High experimental intakes of vitamin E have been reported to benefit athletes by improving energy functioning, reducing cellular damage, and stabilizing cell membranes. Supplementation has also had noticeably beneficial effects on physical performance and tissue protection at high altitudes.

Vitamin E deficiencies have been observed in animals but are less clear in humans. Newborn infants have a low tissue concentration of vitamin E. Hemolytic anemia and dermatitis have been noticed in infants, especially premature ones. A common instance of what appears to be vitamin E deficiency is muscle weakness. Increased destruction of cellular membranes is also suspected, as are abnormal disposition of fat in muscles and rupture of red blood cells. Clear determination of vitamin E deficiencies in humans is complicated by the additional factor that the mineral selenium plays a role in vitamin E's metabolism and that symptoms in animals sometimes disappear by the addition of selenium or the sulfur-containing amino acids. Vitamin E is clearly an important essential nutrient whose amounts should be ingested above the RDA amount.

Compared with the other fat-soluble vitamins, vitamin E is relatively nontoxic when orally ingested, but individual tolerance will vary. This is fortunate considering the large number of people who self-prescribe megadoses of vitamin E in the hopes of curing or preventing many disorders. However, high levels of vitamin E may interfere with the activity of vitamin K, leading to anticoagulant effects and prolonged blood clotting time.

Athletic Performance Considerations of Vitamin E. Studies support the higher than average intake of vitamin E by athletes. As determined by a physician, maintain intake within PDI guidelines from dietary and supplement sources. For athletes in high altitudes (over 5,000 feet above sea level), maintaining vitamin E intake at the upper end of the PDI range during training and competition may be warranted. Higher than normal intakes of vitamin E are also indicated for those recovering from an injury or surgery. Natural vitamin supplement may be preferred over synthetic vitamin E containing supplements depending on the total daily dosages and individual requirements.

Vitamin E in Food and Supplements

Both natural and synthetic forms of vitamin E are found in supplements. The natural form, D-Alpha tocopheryl succinate is generally preferred due to its reported higher rate of absorption. Other bioactive forms include alpha-tocopherol and alpha-tocopheryl acetate. The DL-alpha tocopheryl appears to be less bioactive. A combination of the two forms is also recommended (mixed tocopherols). Other forms of vitamin E also exist. Vitamin E is found in gel caps, in oil, or as a solid. Both delivery systems are OK, but the dry form is likely to be more stable.

Dietary sources of vitamin E vary greatly depending on their storage and preparation. The richest sources are vegetable oils, such as soybean, corn, cottonseed, peanut, and safflower. Products containing vitamin E include margarine, wheat germ, and nuts. Meat, fish, animal fats, and fruit are mostly low in vitamin E.

Vitamin K

The need for vitamin K was suspected in about 1929, when researchers observed that newly hatched chickens on diets containing only the known essential nutrients developed a hemorrhagic disease. Later in 1939, vitamin K was isolated, and its role in blood clotting was established.

Several compounds display vitamin K activity. Phylloquinone (K1) is the principal one. Other forms of vitamin K include the menaquinones (K2), which are produced by intestinal bacteria, and menadione (K3), which is a synthetically produced form of vitamin K. Phylloquinone occurs naturally in green plants. Menaquinone is formed in the human intestines from bacterial metabolism. The synthetic form of vitamin K, menadione, is fat soluble and about twice as potent as the naturally occurring phylloquinone form is. Menadione is also synthesized in water-soluble forms.

Vitamin K's major function as a coenzyme is the formation of prothrombin and procoagulants, which is vital for blood clotting/coagulation, by converting these proteins into their biologically active forms. It is therefore essential for maintenance of prothrombin levels and blood clotting. Vitamin K is also involved in bone metabolism and helps maintain bone tissue. As athletes undergoing strenuous training are constantly damaging tissue, a supplemental amount of vitamin K is warranted to ensure adequate vitamin K daily intake.

Deficiency of vitamin K is rarely encountered in healthy individuals eating a balanced diet. However, deficiency can develop if green vegetables are restricted from the diet or drugs are taken that inhibit the formation of vitamin K by intestinal bacteria. Most instances of vitamin K deficiency are encountered with infants. Ingestion of too much aspirin can interfere with the metabolic pathways vitamin K is involved in and prevent normal blood clotting. A deficiency of vitamin K would decrease the amount of prothrombin made by the body and increase the tendency for **hemorrhage**. It is sometimes given to patients before surgery to aid in blood clotting.

Hemorrhage: bleed excessively.

Excessive intake of vitamin K, even over long periods, has not readily yielded toxic side effects. However, excessive dosages in experimental animals and in infants have been shown to cause **hemolytic anemia** (separation of the hemoglobin from red blood cells). The synthetic water-soluble forms may have a wider margin of safety.

Hemolytic anemia: a condition in which the hemoglobin becomes separated from the red blood cells.

Athletic Performance Considerations of Vitamin K. Few studies have been conducted on vitamin K's direct effects on performance. As determined by a physician, maintain intake within PDI guidelines from dietary and supplement sources. Megadosing Vitamin K is not supported by current research.

Vitamin K in Food and Supplements

Phylloquinone (K1) and menadione (K3) are commonly used in supplements, primarily tablets and powders. Taking a supplement that combines the two forms is recommended. Dietary sources primarily include green leafy vegetables. Small amounts are found in milk and dairy products, eggs, cereals, fruits, and vegetables. Another important source is the vitamin K made in your intestines by bacteria. However, this supply is difficult to evaluate and may or may not be responsible as a major source.

The Water-Soluble Vitamins

The water-soluble vitamins include vitamins C, B1 (Thiamin), B2 (Riboflavin), B3 (Niacin), B6, folate, vitamin B12, biotin, and pantothenic acid. These vitamins are not normally stored in the body in any great amount. Therefore, a constant daily intake is needed to avoid depletion and interference with normal metabolic functions. The B vitamins basically act as coenzymes and are involved in the metabolism of fats, proteins, and carbohydrates. Vitamin C has been in the spotlight for many years and is best known for combating colds and functioning as an antioxidant. Because the water-soluble vitamins are not stored by the body in significant amounts, it is critical to maintain an adequate daily intake of these vitamins.

Vitamin C

Scurvy is the dreaded disease that sailors, explorers, and other travelers used to develop when deprived of fresh fruit and vegetables for prolonged periods. It has been written about in scientific literature and novels time and time again. Doctors discovered that eating limes, lemons, and oranges prevented and reversed scurvy. In fact, the English sailors were nicknamed "Limeys" because of their frequent ingestion of lemons, limes, and other citrus fruit during voyages. Later, it was determined that citrus fruit contained vitamin C, and in the 1930s, scientists isolated and identified vitamin C from citrus fruit.

Vitamin C, also called ascorbic acid, is primarily a water-soluble antioxidant that cannot be synthesized by humans and is essential. There is also a slightly altered form of ascorbic acid present in the diet, called dehydroascorbic acid. This oxidized form also displays some vitamin C activity. There is extremely little storage of vitamin C in the body.

Vitamin C has multiple functions as a cofactor or coenzyme. It is involved in the formation and maintenance of collagen, which is an important constituent of connective tissues and intercellular substances. Collagen is a protein and an important component of skin, ligaments, and bones. Vitamin C promotes healthy capillaries, gums, and teeth; aids in intestinal iron absorption, transport, and storage; prevents the oxidation of folacin; helps heal wounds; may provide resistance against infections; aids in the metabolism of tyrosine and phenylalanine; increases immune function; and protects cells from free radical damage.

Vitamin C has been touted as a general cure all by many. It gained great attention when the esteemed Nobel prize-winning biochemist, Dr. Linus Pauling, advocated its use to help prevent the onset of the common cold. As with the other antioxidants, vitamin C may play an important role in the prevention and correction of many dietary-borne diseases. For athletes, these functions of vitamin C are crucial, especially as an antioxidant. Studies have also indicated vitamin C's role in increasing muscular strength, reducing lactate blood levels, and sparing glycogen.

A deficiency in vitamin C can lead to scurvy, which is a serious disease characterized by weakening of collagenous tissues and structures that results in widespread capillary hemorrhaging. Scurvy is rarely seen in adults in the United States but is sometimes observed in infants and the elderly.

Excessive intake of vitamin C (usually more than 3 to 5 grams per day or more) has been associated with several potential side effects: headache, increased urination, diarrhea, and nausea. Megadosing vitamin C is commonly practiced by those wishing to derive the proven and speculative health benefits. As with all vitamins, megadosing many times above the RDA for long periods is not recommended.

Athletic Performance Considerations of Vitamin C. As determined by a physician, maintain intake within PDI guidelines from dietary and supplement sources. There could be benefits for increasing levels of intake as activity increases for some athletes. Endurance athletes may need higher amounts of this and other antioxidants. Megadosing vitamin C above the PDI is not reported to cause any improvements in athletic performance. However, some individuals find that taking higher amounts vitamin C a day when they feel a cold or flu developing may help reduce the duration, along with other physician-supervised treatment.

Vitamin C in Food and Supplements

The primary form of vitamin C used in supplements is synthetic ascorbic acid. Other forms include buffered vitamin C and mineral ascorbates, such as calcium and magnesium ascorbate. Natural supplemental form of vitamin C is supplied by rose hips and is a very expensive ingredient when compared with the synthetic form. Supplements that contain a combination of ascorbic acid and vitamin C from rose hips are preferred. Also, bioflavonoids may increase the vitamin C absorption. There is also a patented form of vitamin C, called Ester C™. The company that manufactures it ran independent studies that indicate that it may have a higher bioavailability than do other forms of vitamin C.

Dietary sources of vitamin C include fruits and vegetables, especially citrus fruits, green and red peppers, collard greens, broccoli, spinach, tomatoes, potatoes, and strawberries.

Thiamin

Thiamin (as thiamin pyrophosphate or TPP), also called vitamin B1. In the body, thiamin joins with phosphate to form thiamin pyrophosphate (TPP), also known as thiamin diphosphate (TDP), and functions as a coenzyme required in carbohydrate and branched-chain amino acid metabolism. Thiamin is water soluble and not readily absorbed by the body. Thiamin, along with other B vitamins, is converted into coenzymes that aid in the complete breakdown of carbohydrates. Other functions of thiamin include the production of ribose, which is needed for the synthesis of nucleic acids (RNA and DNA), the promotion of normal growth and function, and for appetite simulation. As athletes eat more carbohydrates, more thiamin is needed. Additionally, performance improvements have been reported in endurance athletes ingesting higher amounts of thiamin.

Signs of deficiency include abnormalities of carbohydrate metabolism, fatigue, loss of appetite, constipation, depression, confusion, poor coordination, and a disease called Beri Beri or beriberi. Beri Beri is the disease associated with prolonged intake of a diet low in thiamin. Primary symptoms involve the cardiovascular system and nervous system. Symptoms include muscular weakness, atrophy, heart failure, and depression. The cells of the nervous system are sensitive to carbohydrate metabolism, which may be why this system is the first to show signs of thiamine deficiency. Thiamin deficiency is also observed in individuals who drink alcohol excessively.

Excessive intakes of thiamine are cleared by the kidneys. Thiamine toxicity is rarely reported in healthy adults.

Athletic Performance Considerations of Vitamin Thiamin. As determined by a physician, maintain intake within PDI guidelines from dietary and supplement sources. Increase levels of intake as activity increases. Some research indicates that endurance athletes may derive acute performance enhancing effects by ingesting megadoses of thiamin for three to five days prior to competition. However, more research is needed to conclusively verify these effects and determine the exact range of thiamin intake for this purpose. Additional research reports that supplemental thiamine may significantly improve firing accuracy in marksmen.

Thiamin in Food and Supplements

Thiamin HCl (hydrochloride) and thiamin mononitrate are two forms commonly used in supplements in various amounts. Both forms seem to perform equally well.

Dietary sources of thiamin include brewer's yeast, peas, pork, wheat germ, whole grain pasta, peanuts, beans, organ meats, and enriched and fortified grains and cereals.

Riboflavin

Riboflavin (Vitamin B2) functions as a coenzyme involved in energy production and cellular respiration. In the body, riboflavin functions primarily as part of two coenzymes: flavin mononucleotide (FMN) and flavin adenine dinucleotide (FAD). These coenzymes are involved in many oxidation-reduction reactions, which produce energy from carbohydrates, fatty acids, and some amino acids. Because of riboflavin's role in energy-producing reactions, it is a vital nutrient for the health of all tissues, in particular the skin, eyes, and nerves. Riboflavin therefore helps in energy production, tissue formation, to maintain red blood cells, to maintain normal metabolism of iron, and to maintain the body's ability to metabolize nutrients.

Apart from these essential functions, riboflavin taken in 10 mg/per day amounts was reported to produce a lowering of neuromuscular irritability after electrical stimulation of muscles. This indicates that riboflavin taken in higher amounts may improve muscular excitability and result in better overall performance, but this needs to be confirmed with further research.

Deficiency symptoms of riboflavin include inflamed lips, cracks in skin, growth reduction, hair loss, cataracts, generalized seborrheic dermatitis, and behavioral changes such as depression, moodiness, nervousness, and irritability. Riboflavin is also essential to the functioning of vitamins B6 and niacin. Some symptoms often attributed to riboflavin deficiency are actually caused by the failure of these other nutrients to operate effectively. Excessive intake of riboflavin does not appear to produce toxic effects. This vitamin is considered nontoxic even in quantities many times above the RDA value.

Athletic Performance Considerations of Vitamin Riboflavin. As determined by a physician, maintain intake within PDI guidelines from dietary and supplement sources. Additional performance effects of megadosing riboflavin above the PDI are not supported by the research and therefore not recommended.

Riboflavin in Food and Supplements

Pure riboflavin is used in supplements.

Dietary sources of riboflavin include brewer's yeast, meats, poultry, fish, dairy products, nuts, enriched grain products, green vegetables, broccoli, asparagus, spinach, turnip greens, wheat germ, kidney, and liver.

Niacin

Niacin, vitamin B3, is a water-soluble vitamin of the B complex family that is used in a general sense for both nicotinic acid and niacinamide (nicotinamide). Niacin is functionally active in the body as two very important coenzymes: NAD (nicotinamide adenine dinucleotide) and NADP (nicotinamide adenine dinucleotide phosphate). NAD and NADP are present in all cells and function in many vital metabolic processes, such as energy production, glycolysis, carbohydrate and protein metabolism, fatty acid synthesis, and steroid synthesis. Niacin is also known for its ability to reduce both cholesterol and fatty acids in the blood. Thus, niacin plays many important roles in the body, including in normal growth and development, energy metabolism, tissue formation, and in helping maintain the body's ability to metabolize nutrients.

Niacin can also be synthesized by the body from the amino acid tryptophan to form some nicotinamide, which can contribute to meeting niacin requirements. However, as discussed in the unit on protein, tryptophan is often a limiting amino acid, and its function as a niacin producer should be minimized by ensuring a daily intake of supplemental niacin.

Niacin's role as a cholesterol-controlling nutrient brought it major acclaim as a miracle nutrient and resulted in its widespread use in megadose quantities. Nicotinic acid seems to perform better than niacinamide does for lowering cholesterol and fatty acid blood levels. However, nicotinic acid in amounts over 50 milligrams causes the blood capillaries to dilate, resulting in what has become known as the niacin flush. This flushing produces red skin, itching, and heating of the skin. This response is not observed with the niacinamide form of niacin.

Caution: Excessive Niacin Intake May Impair Performance. It is interesting to note that although niacin is critical for cellular respiration, energy-production research conducted with athletes clearly shows that niacin reduces performance in some instances. The higher amounts of niacin administered before exercise caused glycogen to deplete at a faster rate and caused earlier onset of fatigue. Niacin apparently blocks the release of fatty acids from adipose tissue, thus making this source of energy less available during exercise. Thus, niacin megadosing should be avoided by endurance athletes. However, there is some evidence that high dosages of niacinamide given before anaerobic exercise may improve performance because these athletes get more energy from stored glycogen, and faster glycogen liberation may result in better anaerobic energy. More research is warranted.

Deficiency symptoms of niacin include depression, confusion, headaches, elevated body fats, fatigue, and development of pellagra. Pellagra is a disease characterized by dermatitis, inflammation of mucus membranes, dementia, and inflamed and discolored skin.

Athletic Performance Considerations of Niacin. As determined by a physician, maintain intake within PDI guidelines from dietary and supplement sources. Current research does not support megadosing niacin above the PDI. In fact, as noted above, endurance athletes may need to keep niacin intake on the low end of the healthy range, especially before events.

Niacin in Food and Supplements

Both forms of niacin should be taken as supplements and are commonly found individually in many nutrition formulas.

Dietary sources of niacin include liver, brewer's yeast, lean meats, whole grains, nuts, legumes, and potatoes.

Vitamin B6

Transamination reaction: the process in which an amino group is transferred from an amino acid to a molecule, usually to produce another amino acid.

Vitamin B6, also known as pyridoxine, is an essential vitamin that functions as a coenzyme, has become most noted by athletes for its role in amino acid metabolism, and is also involved in the metabolism of glycogen and sphingoid bases. Vitamin B6 actually occurs in nature as pyridoxine, pyridoxal, and pyridoxamine. In the body, B6 is converted to its active forms, pyridoxal phosphate (PLP) and pyridoxamine phosphate (PMP), and serves primarily in many of the same types of **transamination reactions** that take place in amino acid metabolism. Due to vitamin B6's role in protein/amino acid metabolism, the requirement for vitamin B6 increases as the intake of protein increases. Vitamin B6 in also involved in conversion of the essential fatty linoleic acid to arachidonic acid and in glycogen breakdown, energy production, tissue formation, and synthesis of red blood cells.

Studies with athletes indicate similar results as with niacin, due to B6's tendency to increase utilization of glycogen stores and decrease fatty acid energy substrate use. Thus, for endurance athletes, high dosages of vitamin B6 should be avoided. However, short-term anaerobic activity may benefit from extra B6 due to the glycogen-liberating action. In sports such as weight lifting, sprinting, shot put, and so on. The primary energy source is glycogen. It is possible that extra B6 will promote greater glycogen utilization and result in greater power output. Coincidentally, strength-power athletes are on higher protein diets, and their B6 requirements therefore increase. Athletes undergoing glycogen depletion as part of a carbohydrate-loading program may expect more rapid depletion of glycogen stores with as little as 8 milligrams of B6 per day, but individual requirements and responses need to be determined. This effect can be useful during the first glycogen depletion days of a carbohydrate-loading cycle. Vitamin B6 intake has also been reported to increase the exercise-induced rise in growth hormone, which is another potential benefit for strength athletes.

Deficiency symptoms associated with low intakes of vitamin B6 include depression, skin problems, poor wound healing, anemia, fatigue, and convulsive seizures. High dosages taken over several months have been reported to be linked to nervous system disorders. Symptoms included tingling and numbness of arms and legs.

Athletic Performance Considerations of Vitamin B6. As determined by a physician, maintain intake within PDI guidelines from dietary and supplement sources. Megadosing of vitamin B above PDI guidelines is not recommended.

Vitamin B6 in Food and Supplements

Vitamin B6 is most commonly used in supplements as pyridoxine hydrochloride.

Dietary sources of vitamin B6 include chicken, fish, kidney, liver, eggs, rice, soybeans, banana, lima beans, peanuts, and walnuts.

Folate

Folate, also referred to as folacin, is a water-soluble B vitamin naturally occurring in foods. The folic acid form is generally used in supplements and fortified foods. Folate compounds function metabolically as coenzymes that transport carbon molecules from one compound to another in amino acid metabolism and nucleic acid synthesis, making it involved as a coenzyme in the metabolism of amino acids and nucleic acids. In this way, folate is very important as a cofactor in DNA (deoxynucleic acid) and RNA (ribonucleic acid) formation, protein synthesis, and cell division. Folate also stimulates the formation of red blood cells and vitamin B12. In particular, folate affects tissues that grow rapidly, such as the skin, lining of the gastrointestinal tract, bone marrow where blood cells are formed, and regenerating muscle tissue. Studies have also indicated that increasing the intake of folate during pregnancy has reduced the incidence of premature births and birth defects, such as neural tube defects, by supporting normal early development of the fetal brain and spinal cord.

Deficiency of folate can result in anemia, birth defects, sore tongue, digestive problems, growth problems, fatigue, poor memory, and megoblastic anemia. Excessive folate intake may stimulate convulsions in persons with epilepsy, kidney damage, and lower zinc levels.

Athletic Performance Considerations of Folate. As determined by a physician, maintain intake within PDI guidelines from dietary and supplement sources. Megadosing of folate is not indicated.

Folate in Food and Supplements

Folate is found in supplement formulations as folic acid.

Dietary sources of folate include beef, lamb, pork, chicken liver, eggs, asparagus, whole wheat, deep-green leafy vegetables, salmon, and yeast.

Vitamin B12

Vitamin B12 (cyanocobalamin, methylcobalamin and other biologically active cobalamins) has been regarded in athletic circles as the primary energy vitamin. In fact, it is a common practice for athletes to get vitamin B12 shots during the season. Vitamin B12 is only part of the nutrition picture but does play an essential role in maintaining performance. Vitamin B12 and cobalamins are terms used to describe a group of cobalt-containing compounds that display vitamin B12 activity.

Vitamin B12 forms essential coenzymes that are necessary for neural tissue development and function, folate metabolism, DNA synthesis along with folacin, energy metabolism, new cell growth, conversion of homocysteine to methionine, immune system function, and red blood cell synthesis. Studies conducted on nonathletes experiencing tiredness are credited with prompting widespread megadosing and B12 injections among athletes. These studies used injections of B12. However, studies show that megadosing of B12 by athletes may not be indicated or required. Various studies examining strength and endurance effects of B12 have not demonstrated apparent immediate increases in performance. Thus far, B12's role is in promoting its essential metabolic functions and red blood cell formation.

Some attention has focused on a coenzyme form of B12 called cobamamide, or Dibencozide. This has recently been touted as an anabolic nutrient form of B12 comparable to anabolic steroids. In a study conducted on children with growth deficiency disorders, cobamamide improved growth. Direct comparison to anabolic steroids and an anabolic growth effect in healthy adults has not been proven. However, cobamamide has been reported by athletes to increase perceived energy levels and increase appetite. Use of coenzyme B12 by athletes may be warranted, along with B12.

Deficiency symptoms of B12 include a disease called pernicious anemia, fatigue, irritability, loss of appetite, constipation, headache, and sore tongue. B12 deficiency in the diet is rarely seen, and most deficiencies are attributed to poor B12 absorption. Pernicious anemia is actually a disease that develops from inhibited absorption of B12. Vitamin B12 must be activated before it can be absorbed. This is the job of a substance that is secreted by the stomach called intrinsic factor. Vitamin B12 injections are needed in treatment of pernicious anemia because increasing the amount of B12 taken orally still needs intrinsic factor for activation and absorption. Excessive intakes of B12 do not appear to exhibit side effects. This does not mean that you should megadose this vitamin, as there may be unidentified performance-inhibiting effects yet to be discovered.

Athletic Performance Considerations of Vitamin B12. As determined by a physician, maintain intake within PDI guidelines from dietary and supplement sources. Megadosing Vitamin B12 above the PDI is not indicated.

Vitamin B12 in Food and Supplements

Vitamin B12 is found in supplements such as cyanocobalamin. Other forms are not recommended. Vitamin B12 and cobamamide are unstable when exposed to light, so make sure your supplements with B12 are in light-protected bottles. Be sure to look for light-protected forms of cobamamide (Dibencozide).

Dietary sources of vitamin B12 occur primarily in animal products, such as lamb, beef, herring, mackerel, pork livers, oysters, poultry, clams, eggs, and tofu.

Biotin

Biotin is water-soluble vitamin of the B vitamin family. It is a sulfur-containing vitamin that functions as a coenzyme. Biotin functions as a coenzyme in bicarbonate-dependent carboxylation reactions. It is involved in energy metabolism, urea formation, protein synthesis, and in the metabolism of amino acids, glucose, and fatty acids. Biotin plays an important role in energy production and fat metabolism. It functions in the biosynthesis of fatty acids, replenishment of tricarboxylic acid cycle, amino acid metabolism, gluconeogenesis, and as a coenzyme for a number of carboxylase enzymes. Biotin helps maintain cognitive function and helps maintain healthy nail, hair, skin, and mucous membranes. Biotin is manufactured by intestinal bacteria.

Deficiency symptoms can be produced from insufficient dietary sources of biotin being low or from ingestion of large amounts of a biotin-binding glycoprotein found in raw egg whites. Biotin deficiency is characterized by nausea, vomiting, mental depression, pallor, dry scaly dermatitis, increased serum cholesterol, and loss of muscle tone.

Athletic Performance Considerations of Biotin. As determined by a physician, maintain intake within PDI guidelines from dietary and supplement sources.

Biotin in Food and Supplements

Biotin is a common ingredient in multiple vitamin formulas and is not frequently found in single dosage form. Dietary sources of biotin include liver, egg yolk, soy flour, cereals, yeast, nuts, cauliflower, milk, and legumes.

Pantothenic Acid

Pantothenic acid plays many important metabolic roles, primarily as a component of coenzyme A (CoA). These metabolic reactions are important in the release of energy from carbohydrates and fatty acids, helping in energy metabolism. Pantothenic acid is also involved in steroid and cholesterol synthesis and in tissue formation, membrane phospholipids, amino acids, and neurotransmitters. Studies on athletes have yielded results that indicate pantothenic acid may have performance-enhancing effects when taken by endurance athletes in higher amounts for short periods.

Deficiency symptoms of pantothenic acid include weakness, irritability, burning feet, vomiting, and insomnia. Excessive pantothenic acid intakes may be related to causing diarrhea or water retention.

Athletic Performance Considerations of Pantothenic Acid. As determined by a physician, maintain intake within PDI guidelines from dietary and supplement sources. Note that megadosing pantothenic acid above the PDI guidelines may be beneficial for endurance athletes for short time periods (seven to fourteen days) before athletic competition, which can be determined on an individual basis under physician supervision.

Pantothenic Acid in Food and Supplements

Pantothenic acid is found in supplements as d-calcium pantothenate.

Dietary sources of pantothenic acid include potatoes, eggs, pork, beef, fish, milk, whole wheat, whole grain cereals, fruits, and vegetables.

Choline

Choline is involved in fatty acid metabolism, liver function, and structural integrity of cell membranes. The term "lipotropic" is used to describe the effects of choline and other substances that prevent deposition of fat in the liver. Choline is a component of the phospholipid phosphatidylcholine (lecithin) and a part of all cell membranes and lipoproteins. Choline is also used by the body to make the neurotransmitter acetylcholine, which is critical for optimum nervous system functioning. Exercise can deplete the supply of choline, and this may theoretically impair acetylcholine amounts in the nervous system.

Choline deficiency can have major consequences on the liver, memory, nerve functioning, and normal growth. Deficiencies in humans are rarely observed. Excess intakes of choline, 2 or more grams per day, can result in diarrhea, depression, and dizziness.

Athletic Performance Considerations of Choline. As determined by a physician, maintain intake within PDI guidelines from dietary and supplement sources.

Choline in Food and Supplements

Choline is commonly found in multiple vitamin mineral formulations, lipotropic fat-burner supplements, and lecithin. Choline is available as choline bitartrate, choline dihydrogen citrate, and phosphatidyl choline. Dietary sources of choline include lecithin, egg yolk, liver, soybeans, most fatty foods, meat, whole grains, asparagus, green beans, spinach, and wheat germ.

Inositol

Like choline, inositol is a lipotropic agent. A biologically active form of inositol found in foods is myo-inositol. It is involved in fatty acid metabolism, carbohydrate metabolism, and intracellular calcium mobilization. There is no RDA for inositol, nor have there been reports on the effects of megadosing on athletic performance. It is included here because inositol is used in sports nutrition products and other supplements, and while the body can make inositol, similar to other metabolites, there may be benefits for increasing inositol in the diet from foods and dietary supplements. The FDA has acknowledged in its regulations (21 CFR, Section 184.1370) that inositol, or myo-inositol, is generally recognized as safe for use in supplements and for specialty dietary foods and infant formulas.

Deficiency of inositol results in build-up of fat in the liver and may affect nervous system function. Inositol appears to be relatively nontoxic in healthy individuals. The average adult diet contains about 1 gram of inositol per day.

Athletic Performance Considerations of Inositol. As determined by a physician, maintain intake within PDI guidelines from dietary and supplement sources.

Inositol in Food and Supplements

Inositol is commonly found in multiple vitamin mineral formulations and fat-metabolizing enhancement supplements. Dietary sources of inositol include heart, organ meat, whole grains, fruit, milk, nuts, meats, and vegetables.

Daily Vitamin Intake Reference Information Summary (For Educational Purposes Only)

	USA Minimum and Upper Vitamin Reference Intakes (total intake from food and supplements)				Vitamin Reference Intakes (intake from supplements) Council for Responsible Nutrition and Canadian Health		Performance Daily Intake (PDI), 2017
	Daily Values Total Intake	**DRI* Men Total Intake**	**DRI* Women Total Intake**	**Tolerable Upper Intake Total Intake**	**CRN's Upper Level for Supplements 3rd Edition, 2014**	**Canadian For Supplements (maximum)**	**PDI (Performance Daily Intake range, including all nutrient sources; foods and supplements).**
Vitamin A (retinol and its esters)	5,000 IU	900 mcg (3,000 IU)	700 mcg (2,330 IU)	3,000 mcg 10,000 IU	3,000 mcg, 10,000 IU with low dietary retinol. 1,500 mcg, 5,000 IU with high dietary retinol.	10,000 IU	5,000 to 15,000 IU (not for pregnant women).
Beta-Carotene	Not Established	Not Established	Not Established	Not Established	25 mg nonsmokers. Smokers should not use.	Not Established	5 to 30 mg
Vitamin C	60 mg	90 mg	75 mg	2,000 mg	2,000 mg	1,500 mg	500 to 3,000 mg
Vitamin D	400 IU	15 mcg 600 IU	15 mcg 600 IU	100 mcg 4,000 IU	250 mcg 10,000 IU	l,000 IU	400 to 4,000 IU
Vitamin E	30 IU	15 mg	15 mg	1,000 mg	1,600 IU (1,000 mg)	1,000 IU	200 IU to 1,000 IU
Vitamin K	80 mcg	120 mcg	90 mcg	Not Established	10,000 mcg (10 mg)	Not Established	80 to 180 mcg
Thiamin	1.5 mg	1.2 mg	1.1 mg	Not Established	100 mg	100 mg	15 to 135 mg
Riboflavin	1.7 mg	1.3 mg	1.1 mg	Not Established	200 mg	100 mg	15 to 135 mg
Niacin	20 mg	16 mg	14 mg	35 mg		500 mg	20 to 100 mg
(Nicotinic Acid)					500 mg / 250 mg SR		
(Nicotinamide)					1,500 mg		
Vitamin B6	2 mg	1.7 mg	1.5 mg	100 mg	100 mg	250 mg	10 to 100 mg
Folate	400 mcg	400 mcg	400 mcg	1,000 mcg	1,000 mcg	1,000 mcg	400 to 1,200 mcg
Vitamin B12	6 mcg	2.4 mcg	2.4 mcg	Not Established	3,000 mcg	1,000 mcg	12 to 200 mcg
Pantothenic Acid	10 mg	5 mg	5 mg	Not Established	1,000 mg	500 mg	20 to 200 mg
Biotin	300 mcg	30 mcg	30 mcg	Not Established	2,500 mcg	500 mcg	300 to 600 mcg
Choline	Not Established	550 mg	425 mg	3.5 g	Not Established	1,000 mg	600 to 3,500 mg
Inositol	Not Established	Not Established	Not Established	Not Established	Not Established	650 mg	600 to 1,200 mg

Vitamin intake reference information is for total per day nutrient intake from conventional foods and dietary supplement sources, unless otherwise noted.

mg = milligrams, mcg = micrograms, g = grams.

Note: This information is for educational purposes only. The example guidelines are for model healthy adult athletes, for short-term use during periods of athletic training. Typically, the exact nutrition requirements for each person can differ, and for best results should be determined working with a health care professional.

* = highest DRI reported on a gender basis, excluding pregnant or lactating women.

DRI (Dietary Reference Intakes) includes Recommended Dietary Allowances (RDA) and Adequate Intakes (AI).

References: Office of Dietary Supplements, NIH, Dietary Supplement Fact Sheets, 2017.; Institute of Medicine, Dietary Reference Intakes for vitamin D and Calcium, 2011.; Institute of Medicine, Dietary Reference Intakes: The Essential Guide to Nutrient Requirements, 2006.; Vitamin and Mineral Safety, 3rd Edition, Council for Responsible Nutrition, Washington, D.C., 2014.; Health Canada 2017.

Conclusion

Vitamins represent essential nutrients vital for health and athletic performance. Food and supplements play a role in providing athlete's with essential substances. Vitamin deficiencies or excess requires doctor testing and supervision to determine and resolve. In general, healthy adult athletes, as their physical activity increases with athletic training and competition seasons, may require an increase of daily amounts of vitamins compared to the DRI and DV intakes for non-athletes and during off season, when activity levels are lower. In addition, vitamin intake requirements can be body weight depend, with increasing daily intake amounts being require. However, while reference information is useful, doctor supervised metabolic testing is required to determine an athlete's vitamin status and personal requirement.

Key Words

Vitamin toxicity

Malabsorption

International unit (IU)

Hemorrhage

Hemolytic anemia

Transamination reaction

Topics Covered In This Unit

UNIT 8

MINERALS

Unit Outline

After completing this unit, you will be able to:

- **Define and discuss terms related to minerals;**
- **Discuss the main functions of minerals;**
- **Determine benefits of minerals for health and performance of athletes;**
- **List food sources of minerals.**

Introduction

Minerals have long been regarded as essential nutrients for proper health and vigor. With the invention of more sophisticated scientific equipment, scientists keep discovering more minerals essential to our health. Trace minerals, which are required only in very small microgram amounts, are an example of this growing category of nutritionally important minerals. Minerals are inorganic elements that are required by the body. They are commonly referred to as minerals (or macrominerals), trace minerals, ultra-trace minerals, and electrolytes. The minerals covered in this unit include calcium, magnesium, and phosphorus. Minerals (macrominerals) are required in larger amounts. The trace minerals, which are required in smaller amounts, are boron, chromium, copper, fluoride, iodine, iron, manganese, selenium, and zinc. The ultra-trace minerals include boron, germanium, and vanadium. The electrolytes discussed in this unit are chloride, potassium, and sodium; however, take note that calcium and magnesium also have electrolyte activity and other essential roles. Recall that all the minerals fall into the general "micronutrient" category, as do the vitamins.

Food and supplement sources of minerals are supplied either as part of mineral-organic compounds (like copper lysinate) or in inorganic forms (like potassium chloride). Although minerals are found throughout the body, they are estimated to make up only about 4 to 6 percent of the body. They are, however, important in many structural and metabolic roles. Minerals occur in the body as components of tissues, such as calcium in bone. They also are found as part of organic molecules, such as iodine in thyroxine and iron in hemoglobin. Some minerals, such as electrolytes, also occur in their free **ionic form** in body fluids in blood, cells, and so on.

Ionic form: in the form of ions, which are atoms or groups of atoms that have either a positive or a negative charge from having lost or gained one or more electrons.

For enhanced athletic performance, minerals are just as essential as vitamins and other metabolite factors are. However, current research indicates that although athletes generally require higher mineral intake than nonathletes do, there are no clear benefits for mega-dosing minerals as with some of the vitamins and other nutrients. Most minerals are not immediately lethal if overdosed, with the exception of iron for children (see iron section). However, special care must be exercised when supplementing with minerals not to overdo it. The increased amounts required by athletes is due to greater metabolic demands created from increased physical activity and replenishment needs of minerals lost through sweat and excretion and also due to larger body size and more lean body mass, including muscle and bone.

Athletic Significance of Minerals

- Minerals are needed for normal metabolism, growth, and health of the body.
- Adequate mineral intake is essential for athletic performance and health.
- Dietary surveys have discovered that many athletes' diets are deficient in one or more minerals.
- Optimum mineral intake is best attained from a combination of food and supplements.

Inadequate intake of minerals is associated with decreased athletic performance and negative effects on health, so you want to make sure that you are getting the amounts you need. Additionally, inadequate intake of important structural minerals, like calcium, can result in weakening of the skeleton and connective tissues, making the athlete more susceptible to injury. Mineral intake should be attained from dietary and supplement sources for best results. Although food offers variable amounts of minerals, supplements can be relied on to supply precise amounts of minerals in highly bioavailable forms to supplement the diet with.

Note that reference intake data from multiple sources are provided in a summary table at the end of this unit for minerals for educational purposes only. While a variety of useful scientific information about minerals is contained in this unit, it is important to realize that personalization of mineral intake for each athlete requires doctor supervision and testing to determine whether mineral deficiencies or excesses are present and need to be corrected.

Calcium

The average adult body contains approximately 1,200 grams of calcium, 99 percent of which is present in the skeleton. Calcium is found in the skeleton primarily as calcium phosphate. This is why calcium and phosphate intake are important to the integrity of bone tissue. Calcium also occurs in the body in its free ionic state and as calcium carbonate. The role calcium plays in bone formation is well known, but calcium also has other vital functions as well. Calcium plays essential roles in nerve conduction, transmission of nerve impulses, normal heartbeat, muscle contraction, increased membrane permeability, and blood clotting. Calcium also functions as an enzyme cofactor. Calcium has been connected to controlling blood pressure in some individuals. While calcium is a primary nutrient in bone formation and maintenance, other nutrients are also important in bone formation and the proper utilization of calcium. These include vitamin D, copper, zinc, manganese, and boron.

Mineralization of bone requires a positive calcium balance; that is, more calcium being absorbed than being excreted. This balance is important to maintain during growth years and during adulthood. Until recently, most medical authorities believed that once an individual attained the ripe old age of 30, it was not possible to build more bone tissue. But research has finally proven what many sports fitness scientists already knew. Exercise and proper dietary intake of calcium will result in increased bone mass in adults. The benefits are obvious for everyone who wants to maintain a healthy body. High-intensity exercise appears to stimulate increase in bone mass more than aerobic-type exercise does. From an athlete's standpoint, adequate calcium must be maintained all year long, and from childhood through adulthood. This means eating a diet adequate in calcium based on the individual athlete's extra requirements in addition to taking a comprehensive supplement with the other nutrients, good sources of calcium, and the calcium cofactors as required.

Deficiency/Excess Symptoms. Researchers have determined that deficiency of calcium is more common than previously thought. Dietary surveys have determined that both athletes and nonathletes exhibit inadequate calcium intake. This results in poor bone formation or onset of a bone disease, such as osteoporosis. Poor calcium intake also results in muscle cramping and reduced energy levels. Rickets and stunted growth are also potential disorders related to a calcium-deficient diet. Besides most diets being low in total calcium, the calcium in many diets is in a form that is poorly absorbed. Like other minerals, different forms of calcium will be absorbed by the body better than others will. In fact, the 1989 RDA book estimates that young adults absorb only 20 percent to 40 percent of their ingested calcium. This is another reason for taking a good-quality calcium supplement every.

Excess calcium taken during short or long periods normally does not cause major side effects in adults aside from constipation and possible increased risk of urinary stone formation for people susceptible to forming stones due to calcium. A high calcium intake can also interfere with the absorption of iron, zinc, magnesium, and other minerals. Very high calcium intake for long periods can lead to renal function problems.

Athletic Performance Considerations of Calcium. Studies support the adequate daily intake of calcium for maintenance of overall health and performance. The research does not report benefits of mega-dosing calcium for increased performance. Maintain calcium intake within the PDI guidelines from dietary and supplement sources, as determined by doctor evaluation and supervision.

Calcium in Food and Supplements. Good sources of calcium include the following: dairy products, milk, cheese, ice cream, sour cream, cottage cheese, yogurt, broccoli, kale, collards, oysters, shrimp, salmon, clams, calcium-precipitated tortillas, and calcium-fortified foods. Some supplement sources of calcium include calcium carbonate, calcium citrate, calcium malate, calcium glycinate, and certain antacids, of which some are labeled with Supplement Facts and Drug Facts panels.

Phosphorus

Like calcium, phosphorus is an important part of bone and plays several other important roles in the body. Phosphorus occurs in bone at approximately a 1:2 ratio with calcium. Phosphorus is present in bone, in cellular fluids as phosphate ion, and in lipids, proteins, nucleic acids, ATP, creatine phosphate, and so on. Phosphorus is also involved in cell permeability, metabolism of fats and carbohydrates, formation of ATP and high-energy storage, modulation of enzyme activity, and phospholipid transport of fatty acid. The chemical energy of the body is stored in high-energy phosphate compounds, such as ATP and CP. Phosphorus also plays a role in collagen synthesis. Most diets normally supply adequate amounts of phosphorus, about 1,500 milligrams per day. Even so, some supplement intake is recommended for athletes, along with a full profile of the other essential vitamins and minerals.

Athletic Performance Considerations of Phosphorus. Studies support the adequate daily intake of phosphorus for maintenance of overall health and performance. Maintain phosphorus intake within the PDI guidelines from dietary and supplement sources, as determined by doctor evaluation and supervision.

Deficiency/Excess Symptoms. Because phosphorus is readily available in most foods, deficiency is rarely seen in adults, although it has been observed in cases of malnutrition and in clinical settings among the ill. Deficiency symptoms over long periods include poor bone formation, poor growth, weakness, anorexia, and malaise. Excessive intake of phosphorus has been reported to adversely affect calcium metabolism and to stimulate bone loss.

Phosphorus in Food and Supplements. Phosphorus is found in most foods, but protein-rich foods and cereal grains contain especially high amounts. Good sources also include milk, fish, eggs, and asparagus.

Some multi-nutrient supplements contain phosphorus as part of a complete multivitamin/mineral formula, when required.

Magnesium

The majority of magnesium (about 24 grams) in the body occurs in the bones, muscles, and soft tissues. Magnesium has many metabolic and structural roles. It constitutes part of bone and teeth, plays a role in muscle and nervous system function, activates enzymes, assists calcium and potassium uptake, assists glycolysis, and aids many biosynthetic processes. Of particular interest to athletes are the several studies that show that supplementing the diet with moderate amounts of magnesium (200 mg to 400 mg) improves several athletic performance factors, including, for example, enhanced physical endurance and increased strength. Maintenance of bone tissue is also an important function of magnesium that should not be overlooked. In addition, magnesium plays a role in the proper functioning of smooth muscle tissue. When physical activity is increased, depletion of magnesium is observed, especially among athletes involved in long-distance sports.

Athletic Performance Considerations of Magnesium.
Studies support the adequate daily intake of magnesium for maintenance of overall health and performance. The research does not currently report benefits of megadosing magnesium for increased performance. Maintain magnesium intake within the PDI guidelines from dietary and supplement sources, as determined by doctor evaluation and supervision.

Deficiency/Excess Symptoms. Deficiency of magnesium is rarely seen, but symptoms include muscle weakness, irritability, nausea, and depression. Of interest to female athletes, studies show that suboptimum intake of magnesium can cause or increase premenstrual tension and discomfort, which may be corrected with magnesium supplementation. Excess intake of magnesium to the point of causing side effects is rare. Healthy individuals seem to be able to tolerate magnesium intake well. Large amounts have a laxative effect, and several laxative products contain magnesium compounds for this express purpose. Individuals with abnormal renal function can be subject to hypermagnesemia, symptoms of which include depression, nausea, vomiting, and hypotension.

Whole grains: grains and grain products made from the entire grain seed, usually called the kernel, which consists of the bran, germ, and endosperm. If the kernel has been cracked, crushed, or flaked, it must retain the same relative proportions of bran, germ, and endosperm as the original grain to be called whole grain. Many but not all whole grains are also sources of dietary fiber.

Magnesium in Food and Supplements. Food sources of magnesium include green vegetables, **whole grains**, nuts, legumes, oats, and fruit. Examples of supplement forms of magnesium are magnesium oxide, magnesium glycinate, and magnesium carbonate.

Iron

Iron's well-known function is its role as a part of hemoglobin, which is a carrier of oxygen in the body. Iron also is a constituent of myoglobin and a number of enzymes. Iron stores primarily occur in the body in bone marrow, the spleen, and the liver. When iron intake is low, these stores are depleted so that individuals can sustain for a while on a diet low in iron without developing anemia. However, when anemia does occur due to severe depletion, it takes a long time to reverse the condition. For the athlete, this can be extremely detrimental. Dietary surveys have reported many athletes' diets being low in iron. Women athletes, long-distance athletes, and athletes on low-calorie diets are more commonly iron deficient than others.

Athletic Performance Considerations of Iron. Studies support the adequate daily intake of iron for maintenance of overall health and performance. The research does not currently report benefits of megadosing iron for increased performance. In fact, high dosages of iron can have detrimental effects. Maintain iron intake within the PDI guidelines from dietary and supplement sources, as determined by doctor evaluation and supervision.

Deficiency/Excess Symptoms. The most commonly seen deficiency symptom of inadequate iron intake is the development of anemia. Anemia causes a reduction in the oxygen-carrying capacity of the blood, resulting in decreased performance. Additionally, iron deficiency has been linked to lower immune system function, which will make individuals more susceptible to disease. However, excess iron intake can result in death if the amount is large enough. Each year, a few thousand cases of iron poisoning are reported in the United States. Several of these cases a year result in death. Deaths have been reported in very small children who eat large quantities of iron-containing supplements. High dosages can cause abdominal cramping, constipation or diarrhea, and nausea. Excessive iron intake may also cause certain liver disorders. An additional note of caution is directed at some individuals who may have the rare hereditary condition called idiopathic hemochromatosis. When this inherited condition exists, individuals will absorb iron at a higher rate than normal and slowly accumulate high iron content in their bodies, which may lead to problems with liver and other organ function.

Iron in Food and Supplements. Foods high in iron include red meats, poultry, fish, iron-fortified foods, liver, molasses, nuts, clams, chocolate, legumes, and bread. Supplements have become a primary source of iron for most people concerned with iron intake. However, the right source of iron supplement is required for safety, absorption, and efficacy. Choose multivitamin/mineral supplements with iron as part of the total nutrient profile. Look for supplements that provide iron as iron fumarate (ferrous fumarate) and iron glycinate.

Zinc

In athletic circles, zinc has developed a reputation as one of the primary "healing" nutrients and one of the prime contributors to male fertility. Zinc has many important metabolic roles in the body and is part of various **metalloenzymes** that play roles in growth, testosterone production, DNA synthesis, cell replication, fertility, reproduction, and prostate gland function. Zinc functions as a free ion in cells, as a part of the synthesis of biomolecules, and as a part of enzymes. For the athlete, maintaining proper zinc intake is vital, especially for growth and repair of muscle tissue to meet training's recovery demands. Dietary surveys on athletes report that low zinc intake is common. This occurs especially in endurance athletes, athletes on low-calorie diets, strength athletes, bodybuilding athletes, and female athletes. Very few studies have examined the actual effects of zinc supplementation on performance, but one study did show increased muscle endurance with zinc-supplemented athletes. Further research will reveal more beneficial effects on performance. However, be advised that too much zinc may impair performance. The role zinc plays in healing and testosterone production should not lead you to think that more is better. Stick to the PDI guidelines for zinc intake and don't megadose, as determined by doctor evaluation and supervision.

Metalloenzyme: a mineral-containing enzyme.

Athletic Performance Considerations of Zinc. Studies support the adequate daily intake of zinc for maintenance of overall health and performance. The research does not currently report benefits of megadosing zinc for increased performance. Maintain zinc intake within the PDI guidelines from dietary and supplement sources, as determined by doctor evaluation and supervision. As with the other essential nutrients, take supplemental zinc as part of a complete multivitamin/mineral formulation.

Deficiency/Excess Symptoms. A deficiency in zinc can cause growth retardation, loss of appetite, skin changes, disrupted immune system, delayed sexual maturation, night blindness, and impaired healing. These conditions of inadequate zinc intake are obviously detrimental to athletic performance. Excessive zinc intake can result in adverse effects, such as lowering of high-density lipoproteins, inhibition of copper absorption, nausea, gastric distress, headaches, dizziness, and other metabolic disturbances. Diets high in protein and fiber can impair zinc absorption. Because athletes are normally on such diets (either high in protein, fiber, or both), supplementation can be a way to ensure that adequate zinc intake is achieved.

Zinc in Food and Supplements. Some food sources of zinc include meat, whole grain products, liver, eggs, seafood, herring, oysters, oatmeal, maple syrup, and dry yeast. Supplemental zinc can be found in many forms, such as zinc citrate and zinc arginate.

Iodine

The form and function of iodine in the body is the simplest of the minerals. Iodine occurs in two thyroid gland hormones: thyroxin and **triiodothyronine**. Iodine is therefore required for the proper function of the thyroid gland, which is essential for normal metabolism, energy production, growth, and overall physical performance.

Triiodothyronine: a thyroid hormone that affects almost every physiological process in the body, including growth and development, metabolism, body temperature, and heart rate

Athletic Performance Considerations of Iodine. Studies support the adequate daily intake of iodine for maintenance of overall health and performance. The research does not currently support megadosing iodine for increased performance. Maintain iodine intake within the PDI guidelines from dietary and supplement sources, as determined by doctor evaluation and supervision.

Deficiency/Excess Symptoms. Because iodine is only essential for thyroid gland function, a deficiency of iodine is associated with thyroid gland disorders. The classic iodine deficiency is goiter. Goiter is a condition that is manifested by enlargement of the thyroid gland. A mental disorder known as cretinism also develops from iodine-deficient diets. Excess iodine intake will promote various side effects, including rash, headache, metallic taste in the mouth, and thyroid gland dysfunction.

Iodine in Food and Supplements. Iodine food sources include iodized salt, seafood, cod, cod liver oil, halibut, oysters, kelp, spinach, meat, and dairy products. Iodine in supplements is provided as iodine from kelp concentrate and should be part of your daily multivitamin/mineral supplement. Iodized salt can also be considered a supplemental source of iodine, and sodium.

Selenium

Selenium's role in influencing antioxidant activity in the body is well known. Selenium is a vital component of an antioxidant enzyme called glutathione peroxidase. Glutathione peroxidase protects the body from free radical damage, in particular, hydroperoxides. In this role as an antioxidant, selenium helps prevent damage to the body's tissues, cells, and molecules, which can lead to reduced risk of degenerative diseases such as coronary heart disease, arthritis, and certain cancers. For athletes, protection against free radicals is important for protection of tissues, shortened recovery times, and protection from the extra added free radical load that exercise causes. The few studies on athletes' taking selenium supplements report encouraging findings that indicate a reduction in lipid peroxidation, which translates into less tissue damage.

Athletic Performance Considerations of Selenium. Studies support the adequate daily intake of selenium for maintenance of overall health and performance. The research does not currently support megadosing of selenium for increased performance. Maintain selenium intake within the PDI guidelines from dietary and supplement sources.

Deficiency/Excess Symptoms. Low selenium intakes have widespread adverse effects on the body due to lowering the body's defense against hydroperoxide free radicals. Deficiency symptoms include hair loss, growth retardation, pancreatic problems, Keshan disease, muscular discomfort, and weakness. Excessive intake of selenium results in fingernail changes, hair loss, fatigue, abdominal pain, nausea, increased dental caries, diarrhea, and irritability. Some studies report side effects due to excessive selenium intake starting at 5 milligrams per day and as little as 1 milligram per day (1,000 micrograms) may cause fragility in finger nails. Therefore, although selenium is essential for good health and performance, stay within PDI guidelines, as determined by doctor evaluation and supervision.

Selenium in Food and Supplements. Some food sources of selenium include brazil nuts, meat, seafood, kidney, liver, and some whole grain products. Selenium content of food is extremely dependent on the selenium content of the soil in which crops are grown and on the food eaten by animals. Selenium content of foods is therefore highly variable. For a reliable supply of dietary selenium, take supplements containing selenium. Look for multivitamin/mineral complete formulations; a selenium source example is selenomethionine.

Copper

Copper is another trace mineral with several important functions. Copper is present in many enzymes. It is part of the antioxidant SOD, it is important in formation of collagen, and it is involved in energy production, melanin pigment synthesis, myelin formation, immune function, glucose metabolism, and cholesterol metabolism. Some attention was directed toward copper by athletic researchers as a result of copper's role in energy production. Copper is part of cytochrome oxidase, an enzyme that is found in the electron transport system. Because dietary surveys indicate that many athletes, especially endurance athletes, have inadequate copper intake, additional supplemental amounts of copper have been researched. The role copper plays as a component of antioxidant SOD is again vital for the protection of the body at the cellular level, for improved performance, and for shorter recovery times after exercise.

Athletic Performance Considerations of Copper. Studies support the adequate daily intake of copper for maintenance of overall health and performance. The research does not currently support megadosing of copper for increased performance. Maintain copper intake within the PDI guidelines from dietary and supplement sources, as determined by doctor evaluation and supervision.

Deficiency/Excess Symptoms. Deficiency symptoms of inadequate copper intake include anemia, bone abnormalities, defects in skin pigmentation, reproductive failure, decreased arterial elasticity, low SOD activity, and defective formation of connective tissues. Excessive copper intake can cause nausea, vomiting, hepatic necrosis, and abdominal pain. Furthermore, excessive copper intake can be fatal, especially for individuals with a hereditary disorder called Wilson's disease. Wilson's disease is characterized by the accumulation of copper in the body, leading to toxic effects on the liver, kidney, eyes, and nervous system.

Copper in Food and Supplements. Rich sources of copper in the diet include organ meats (especially liver), nuts, seafood, cocoa, chocolate, meat, and mushrooms. When selecting a supplement containing copper, look for products supplying a full profile of vitamins and minerals and copper sources that include copper lysinate or copper gluconate.

Manganese

Manganese is a trace mineral with several important functions. It is required for energy production, is part of enzymes, aids in bone and connective tissue formation, is part of the antioxidant superoxide dismutase (SOD), aids in collagen synthesis, and facilitates carbohydrate metabolism. The role manganese plays in bone and connective tissue formation and in antioxidant activity are of particular importance to athletes. The strength and maintenance of bone and connective tissues is essential for performance. Adequate manganese intake is therefore required. Injury prevention and recovery can be benefited by manganese. Maintaining the body's proper supply of SOD is also an important function linked to manganese. SOD is a powerful antioxidant and helps protect the body from free radical damage.

Athletic Performance Considerations of Manganese. Studies support the adequate daily intake of manganese for maintenance of overall health and performance. The research does not currently support megadosing of manganese for increased performance. Maintain manganese intake within the PDI guidelines from dietary and supplement sources, as determined by doctor evaluation and supervision.

Deficiency/Excess Symptoms. Although manganese deficiency is rarely observed, symptoms include growth retardation, poor bone and connective tissue formation/maintenance, low superoxide dismutase production, and disturbance of energy metabolism. Because of manganese's essential role in bone and cartilage formation, and because of its role as a part of antioxidant SOD, certain degenerative diseases may be caused from inadequate manganese intake, such as osteoporosis and arthritis. Excessive manganese intake exhibits a relatively low level of toxicity under normal circumstances. Not many cases of nutritional manganese overdosing are currently reported.

Manganese in Food and Supplements. Food sources of manganese are Brussels sprouts, spinach, peas, turnip greens, wheat germ, meat, buckwheat, barley seed, beets, bananas, corn, lettuce, oatmeal, and other whole grain and cereal products. Look for supplements that contain manganese as part of a complete multivitamin/mineral formulation. Supplement sources of manganese include manganese arginate, manganese glycinate, and manganese gluconate.

Chromium

Chromium is another nutrient that has received a vast amount of attention in the media and is touted as a muscle-building anabolic steroid alternative and as the 1990s miracle fat-loss aid. Chromium is merely another essential nutrient that the body requires for proper health and functioning. Chromium's major role is in the functioning of insulin; it is needed as a cofactor. Chromium also plays a role in the metabolism of nucleic acids (DNA and RNA) and helps maintain their structure and gene expression. Chromium aids in fatty acid and cholesterol formation in the liver, and some studies have shown a lowering of cholesterol with chromium supplementation. Furthermore, chromium-deficient diets are linked to higher incidence of diabetes and heart disease.

It is chromium's role as an insulin cofactor that has brought it so much recent media attention. Early researchers found that chromium exhibited a lowering of blood glucose levels. Because of this characteristic, chromium is referred to as a glucose tolerance factor. The glucose tolerance test is used to determine how well a person can remove high levels of glucose from the bloodstream. The subject being tested is fed high amounts of glucose, and the blood levels are tested over several hours. The test is used to determine diabetes and hypoglycemia. It is also used to measure the efficacy of nutrients and drugs that possess blood glucose-removal properties, like chromium. Due to chromium's role with insulin function, glucose and amino acids that circulate in the bloodstream after ingestion will have a higher rate of uptake by the cells. This does not necessarily mean that the levels of insulin are increased. And it does not mean that chromium has a direct effect on muscle building (as testosterone does) or on fat loss (as growth hormone does). It just means that increasing dietary chromium levels will improve the functioning of insulin, which should result in a higher rate of **cellular uptake** of glucose and amino acids into the cells. The cells then use these nutrients for energy and growth. If insulin is not working 100 percent, then glucose and amino acids will circulate back to the liver and most likely be converted to fat. Moreover, insulin malfunction can also lead to the development of diabetes, heart disease, and other metabolic disorders.

Cellular uptake: absorption by the cells.

This does not make chromium itself an anabolic agent but an important cofactor for energy production and tissue growth and repair. For the athlete, adequate chromium intake is essential. Several studies have shown that individuals taking supplemental amounts of chromium in association with training and a good diet has been reported to increase the rate of muscle gains and increase the rate of fat loss. However, other studies have not reported significant improvements in muscle building and fat loss. As with most nutrient interventions, the rate of effectiveness will depend on the research subject's nutritional status; if a research subject is deficient in chromium, improvements can be greater and significant, compared with research subjects who may have adequate chromium status, and taking extra chromium may not then cause significant improvements.

Deficiency/Excess Symptoms. Researchers in the 1950s first discovered chromium's essential role in nutrition when they fed chromium-deficient diets to laboratory animals and noticed the development of glucose intolerance. Further experiments caused health demographers to link impaired glucose tolerance, certain forms of diabetes, poor appetite control, and heart disease with low amounts of chromium in the diet. Because of chromium's low occurrence in food, toxic encounters are rarely reported.

Athletic Performance Considerations of Chromium. Studies support the adequate daily intake of chromium for maintenance of overall health and performance. The research doesn't report benefits of megadosing chromium for increased performance. Maintain chromium intake within the PDI guidelines, as determined by doctor evaluation and supervision.

Chromium in Food and Supplements. Food sources of chromium include meats, mushrooms, liver, bread, brewer's yeast, black pepper, cheese, beer, brown rice, and potatoes. Supplement forms of chromium include chromium dinicotinate glycinate, chromium picolinate, and chromium polynicotinate.

Molybdenum

Molybdenum is a trace mineral whose content in the body is extremely low but is recognized as an essential nutrient and required by the body for maintenance of good health. Molybdenum is present in enzymes, such as xanthine oxidase, sulfite oxidase, and aldehyde oxidase. These compounds are involved in energy production, nitrogen metabolism, and uric acid formation.

Athletic Performance Goals of Molybdenum. Studies support the adequate daily intake of molybdenum for maintenance of overall health and performance. The research does not report benefits of megadosing molybdenum for increased performance. Maintain molybdenum intake within the PDI guidelines from dietary and supplement sources, as determined by doctor evaluation and supervision.

Deficiency/Excess Symptoms. No deficiency of molybdenum in humans has been reported. Because molybdenum is required in such small quantities, adequate amounts of it can be found in most diets. Ingestion of large amounts of molybdenum may cause gout (15 milligrams daily for several months), retarded growth, and loss of copper.

Occurrence in Supplements and Foods. Molybdenum is found in milk, beans, breads, cereals, and organ meats. Amounts vary considerably in regional food supplies. Molybdenum is found in many supplements in different forms, such as molybdenum chelate and sodium molybdate. Choose supplements that contain molybdenum as part of a complete multivitamin/mineral formulation.

Fluoride

The role of fluoride in prevention of tooth decay is well known. Fluoride is also found in bone and in soft body tissues in very small amounts as calcium fluoride. Fluoride's role in increasing resistance to tooth decay is most notably seen in children. Fluoride intake has also been associated with increased bone integrity. There is some evidence that maintaining good fluoride intake may help reduce osteoporosis. For the athlete, however, fluoride intake is not related to any increase in athletic performance. Its importance lies in the maintenance of good teeth for proper eating and the maintenance of a healthy skeleton. Additionally, fluoride supplements are only available by prescription. The primary intake of fluoride is from the water supply and the diet. A link of low fluoride in water with increased tooth decay has led to the practice of adding fluoride to water supplies in areas without naturally occurring fluoride.

Deficiency/Excess Symptoms. A deficiency of fluoride has been linked to increased tooth decay and possibly to osteoporosis. Excess fluoride intake causes mottling of teeth and affects bone health, kidney function, and possibly muscle and nerve function. Intake of high amounts of fluoride (5 to 10 grams of sodium fluoride) has been reported to cause death. This amount is far above the normal range of fluoride ingestion, 1 to 4 mg per day.

Fluoride in Food. Fluoride occurs in most foods in extremely low amounts. It does occur in tea in moderate amounts. In fact, a dietary survey conducted in the United Kingdom found that tea was the main source of fluoride in adult diets and accounted for 1.3 milligrams of a total daily intake of 1.8 milligrams.

The Electrolytes (Sodium, Chloride, and Potassium)

Sodium, chloride, and potassium are collectively referred to as the electrolytes. Although the other minerals may have electrolyte activity, these three are generally considered the main electrolytes in the body.

Magnesium is sometimes grouped with these three electrolytes by some authorities but is treated separately here due to its unique functions and supplement requirements. The primary function of these electrolytes is maintenance of the balance of fluids in the body between cells and the bloodstream. Other functions of these electrolyte minerals are summarized in the following table.

Electrolyte	Main Functions
Sodium	• Extracellular cation • Regulation of osmolality • Regulation of body fluid balance • Active transport across cell membranes • Uptake of some nutrients in intestines • Muscle contraction and nerve impulse transmission
Chloride	• Extracellular anion • Control of fluid balance
Potassium	• Intracellular cation • Fluid balance • Nerve transmission and muscle contraction • Glycogen formation

Deficiency/Excess Symptoms. Deficiency of the electrolytes is not normally observed except under conditions of severe dehydration, during prolonged periods of exercise without proper hydration or electrolyte replenishment, and in conditions of renal disease. Side effects include dizziness, fainting, and reduced performance. Excessive intake of sodium and chloride (because they occur together in food) causes hypertension, fluid balance problems, and edema. High potassium intake, 18 grams or more, will lead to acute hyperkalemia, which can cause cardiac arrest and prove fatal.

Dietary sodium: also called "salt," sodium helps your nerves and muscles work properly. Table salt is composed of sodium and chloride. Your kidneys control how much sodium is in your blood, releasing it when needed and flushing out any excess. Too much sodium building up in the blood may raise blood pressure. High blood pressure is linked to serious health problems.

Electrolytes in Food and Supplements. These three electrolytes occur in all foods. Sodium and chloride are supplied by food mostly as sodium chloride. Sodium bicarbonate and monosodium glutamate also contribute to **dietary sodium** intake. Table salt (sodium chloride) and processed foods are by far the largest contributors. Potassium is present in all foods but is particularly high in fruits and vegetables. Most individuals want to maintain moderate sodium and chloride intake and maintain higher potassium intake. Athletes in particular have higher demands of these minerals due to excessive sweating and increased physical activity. But do not think you have to load up on table salt. The higher food intake of athletes usually compensates for higher electrolyte demands.

Many sports drinks on the market contain water, carbohydrates, and electrolytes. Use of these drinks is recommended for active athletes. Drink them during and after exercise. Long-distance and ultra long-distance athletes need to make sure they are first maintaining adequate water and carbohydrate intake and then maintaining *appropriate* levels of electrolytes. Drinks lower in electrolytes are best during exercise because higher electrolyte concentrations will delay gastric emptying and impair hydration and carbohydrate supply during physical activity.

Supplement intake of sodium and chloride are not usually required. There is typically more than enough in most diets. Athletes wishing to add more sodium or chloride to their diets can do so with the addition of table salt to their foods. However, excess intake of sodium chloride is usually the condition with most diets. Potassium, however, can range quite considerably in the diet. Individuals concerned with possible low potassium intakes should look for multivitamin/mineral supplements that contain some potassium, such as potassium chloride.

Boron

Boron is an ultra-trace mineral that occurs in the body in small amounts. It has been established as an essential mineral in humans. Boron appears to have several functions, including influencing calcium, phosphorus, and magnesium metabolism; parathormone action; functionality of membranes; and bone formation. Attention by athletes has been directed toward boron because of its alleged role in increased testosterone production. It all began in 1987 when a study was published reporting increased testosterone levels in postmenopausal women as a result of born supplementation. Translating this effect to younger adult males and females is speculative at best. One study in 1992 was conducted with bodybuilders taking 2.5 milligrams of boron per day for seven weeks. The subjects did not report any increases in testosterone levels or significant increases in lean body mass and strength over that of the placebo group.

Boron intake is required daily for health and performance, but like the other minerals, side effects can occur if too much boron is taken. The estimated safe intake range for boron in healthy adults is daily amounts up to 20 milligrams. Side effects of overconsumption have been observed with amounts ranging from 5 to 10 grams and include nausea, vomiting, diarrhea, dermatitis, lethargy, nervous system irritability, renal failure, and shock. Boron intake should be kept within the PDI guidelines from food and supplement sources. Boron tri-chelate is a preferred boron supplement form, as determined by doctor evaluation and supervision.

Conclusion

Minerals represent essential nutrients vital for health and athletic performance. Food and supplements play a role in providing athletes with these essential substances. Adequate mineral intake should be determined by doctor evaluation and supervision to determine whether mineral deficiency or excess is present and to resolve these issues if so. In general, healthy adult athletes, as their physical activity increases with athletic training and competition seasons, may require an increase of daily amounts of minerals compared with the DRI and DV intakes for nonathletes and during off-season, when activity levels are lower. In addition, mineral intake requirements can be body-weight dependent, with increasing daily intake amounts being required. However, while reference information is useful, doctor-supervised metabolic testing is required to determine an athlete's mineral status and personal requirement.

Daily Mineral Intake Reference Information Summary (For Educational Purposes Only)							
USA Minimum and Upper Vitamin Reference Intakes (total intake from food and supplements)					Vitamin Reference Intakes (intake from supplements) Council for Responsible Nutrition and Canadian Health		Performance Daily Intake (PDI)
	Daily Values Total Intake	**DRI* Men Total Intake**	**DRI* Women Total Intake**	**Tolerable Upper Intake Total Intake**	**CRN's Upper Level for Supplements 3rd Edition, 2014**	**Canadian For Supplements (maximum)**	**PDI (Performance Daily Intake range, including all nutrient sources; foods and supplements).**
Calcium	1,000 mg	1,300 mg	1,300 mg	2,500 mg	1,500 mg	1,500 mg	1,200 to 2,600 mg
Chromium	120 mcg	35 mcg	25 mcg	Not Established	1,000 mcg Any form of Cr III	500 mcg	200 mcg to 600 mcg
Copper	2 mg	0.9 mg	0.9 mg	10 mg	9 mg	8 mg	3 to 10 mg
Iodine	150 mcg	150 mcg	150 mcg	1,100 mcg	500 mcg	800 mcg	150 to 1,100 mcg
Iron	18 mg	11 mg	18 mg	45 mg	60 mg (full stomach)	45 mg	18 to 60 mg
Magnesium	400 mg	420 mg	320 mg	350 mg	400 mg	500 mg	400 to 800 mg
Manganese	2 mg	2.3 mg	1.8 mg	11 mg	10 mg	9 mg	4 to 30 mg
Molybdenum	75 mcg	45 mcg	45 mcg	2,000 mcg	350 mcg	2,000 mcg	100 to 300 mcg
Phosphorus	1,000 mg	1,250 mg	1,250 mg	4,000 mg	1,500 mg	2,000 mg	1,000 to 4,000 mg
Selenium	70 mcg	55 mcg	55 mcg	400 mcg	200 mcg	200 mcg	100 to 400 mcg
Zinc	15 mg	11 mg	8 mg	40 mg	30 mg	50 mg	15 to 60 mg
Potassium	3,500 mg	4,700 mg	4,700 mg	Not Established	1,500 mg (500 mg, 3x per day)	200 mg	3,500 to 4,700 mg
Sodium	2,400 mg	1,500 mg	1,500 mg	2,300 mg	Not Established	Not Established	1,500 to 4,500 mg +
Chloride	3,400 mg	2,300 mg	2,300 mg	3,600 mg	Not Established	Not Established	2,300 to 4,500 mg +
Boron	Not Established	Not Established	Not Established	20 mg	6 mg	0.7 mg (700 mcg)	0.7 to 20 mg
Fluoride	Not Established	4 mg	3 mg	10 mg	6 mg (UL)	Not Established	3 to 10 mg

Mineral intake reference information is for total per day nutrient intake from conventional foods and dietary supplement sources, unless otherwise noted.

mg = milligrams, mcg = micrograms, g = grams. Note: This information is for educational purposes only. The example guidelines are for model healthy adult athletes, for short-term use during periods of athletic training. Typically, the exact nutrition requirements for each person differ and for best results should be determined working with a health-care professional.

* indicates the highest DRI was included as reported on a gender basis, excluding pregnant or lactating women.

+ indicates that dietary intake requirement for sodium and chloride can be periodically higher for individuals who lose sodium and chloride in excess or when in extremely hot or prolonged strenuous conditions. Extra sodium and or chloride intake may be required, estimated to be several or more additional grams for replenishment of these minerals lost from sweating and excretion. Also, note that some individuals can be sensitive to high sodium chloride intake levels, and high sodium chloride intake may cause high blood pressure in these sensitive individuals.

DRI (Dietary Reference Intakes) includes Recommended Dietary Allowances (RDA) and Adequate Intakes (AI).

References: Office of Dietary Supplements, NIH, Dietary Supplement Fact Sheets, 2017.; Institute of Medicine, Dietary Reference Intakes for vitamin D and Calcium, 2011.; Institute of Medicine, Dietary Reference Intakes: The Essential Guide to Nutrient Requirements, 2006.; Vitamin and Mineral Safety, 3rd Edition, Council for Responsible Nutrition, Washington, DC, 2014.; Health Canada 2017.

Keywords

Ionic form

Whole grains

Cellular uptake

Metalloenzyme

Triiodothyronine

Dietary sodium

Topics Covered In This Unit

UNIT 9

METABOLITES AND BOTANICAL SUPPLEMENTS

Unit Outline

I. **Introduction**

II. **Metabolites**

III. **Botanicals**

a. Standardizing botanical supplements for consistency

b. Variability with efficacy and safety

c. Dosages

d. Ingredient entries included in this unit

IV. **Alkalinizers, blood buffers**

V. **Beta-hydroxy beta-methylbutyrate (BHMB or HMB)**

VI. **Caffeine**

VII. **Carnitine/Acetyl-L-carnitine**

VIII. **Coenzyme Q10 (ubiquinone)**

IX. **Creatine**

X. **Gamma oryzanol and ferulic acid**

XI. **Ginsengs**

XII. **Glucosamine and chondroitin sulfate (CS)**

a. Benefits for athletes are actually old news

b. Research reports more benefits from taking G&CS supplements

XIII. **Melatonin**

XIV. **Nitrates**

XV. **Pycnogenol**

XVI. **Summary of commonly available botanicals, standardization, and use examples**

XVII. **Conclusion**

Learning Objectives

After completing this unit, you will be able to:

- Define and describe core terms related to metabolite and botanical supplements;
- Understand some of the different types of metabolite and botanical supplements and their major functions; and
- Discuss how metabolite and botanical supplements may affect athletic and exercise performance, and heath.

Introduction

In addition to the macronutrients and traditional micronutrients, a variety of other substances are in foods and supplements. These substances fall into the general categories of botanicals, metabolites, and other nutritional health and performance enhancers. The following information in this unit will review some of these topics and substances of particular interest for athletic performance, noting that most of these substances have a variety of useful and health promotion effects.

Although these various nutritional substances have a history of use backed by clinical research studies, evaluation and supervision by a doctor, coach, trainer, and other health professionals involved with the adult athletes is mandatory. Companies manufacturing the various products can be contacted for proper use instructions. Any known adverse health effects or any other issues may be reported to these companies.

As with the other parts of an athlete performance diet program, upon doctor approval, start slowly with metabolite and botanical supplement use, usually using dosages lower than recommended in the product instructions so the athlete can determine whether he or she has any sensitivities. Adding one new substance at a time for several weeks to a few months to adequately determine the safety and effectiveness on an athlete's health and performance can be useful for comprehensive evaluation, in the content of the entire training and nutrition program. Keep good records to determine if there are any significant benefits to training and athletic performance, and general health, or if there are not measurable benefits, or

any adverse side effects, which may range from mild temporary stomach upset to something more severe, such as allergic reaction. For example, gastrointestinal upset is a common complaint by some users of creatine, which may be resolved using lower dosages for a few weeks to get the body used to the creatine, taking creatine with protein and or carbohydrates, trying different brands of creatine, and making sure the creatine is completely dissolved. As with any nutritional substance, some people can experience allergic reactions, which require immediate medical attention.

Metabolites

Metabolites are substances that take part in metabolism and are made by the body. Some are produced in the body as part of the metabolic process, while others are derived from food sources. Some are also available in supplemental form, for example, creatine, carnitine, and Co-Q10 are metabolites.

Even though the body can make many of these substances, loading up on them allows athletes to prevent shortages during exercise and to have an immediately available supply in reserve. Much of the pioneering research to determine which metabolites are important to athletes was conducted in clinical settings using both individuals with metabolic disorders and patients recovering from injuries or surgery, in addition to athletes. The researchers discovered that the subjects not only overcame their disorders but also often went on to attain a state of health better than what they had started with. Studies conducted with athletes demonstrated that certain metabolites improve factors important to athletic performance such as strength, agility, speed, and aerobic capacity, in addition to promoting and maintaining good health. Metabolites, similar to other ingredients used in sports nutritionals, are available as single-ingredient formulations or as part of multiple ingredient formulations. They come in a variety of dosage forms like other food and supplement products.

Botanicals

Botanicals is a catchall term for plants. When you start reading about plants used in supplements and medicine, you will see the term herb commonly used. Technically, the term herb refers to the general characteristic of a certain plant form that is typically non-woody plants. However, in the botanical world, wood and non-woody plants, and their parts, are used in foods and supplements. Therefore, when you read about botanicals, you will encounter a variety of terms, all relating to the fact that the ingredient(s) are from plants. On dietary supplement product labels that contain botanical dietary ingredients, the part of the plant used must be listed next to the name of the plant.

The study and the practice of prescribing plants for health and athletic performance is one of the oldest health sciences. Many plants have powerful components that can be of great benefit. In fact, the pharmaceutical industry got its start when druggists began isolating these components and making them available in their purer forms. Historically, humans have used botanicals for a variety of health-related uses. Some plants offer many health and performance benefits, but they must be used with care. Some plants should be used for only short periods: to help heal the body of an illness or to treat a certain symptom. Some should not be combined with certain medications or other plants, as their primary components may interact negatively. Some plants should be avoided by competitive athletes because they may contain a substance(s) banned by sports-governing organizations. Experts knowledgeable about botanicals should be consulted, and athletes should be under physician supervision if they decide to use this diverse and beneficial category of health products. The legal status also needs to be determined for competitive athletes.

Standardizing Botanical Supplements for Consistency (Quality)

It is often the concern of athletes that not all herbs or herbal products are created equal. The reason: the chemical composition of plants varies greatly depending on where the plants were grown, the soil in which they were grown, the weather conditions during their growing season, and how they were harvested. To provide products with consistent bioactive content, the processes of concentration and extraction are examined. Standardized botanical ingredients will typically list the amount of the bioactive as a percentage of the total plant ingredient, and sometimes the amount of botanical bioactives are listed. Standardizing botanical ingredients also makes it easier to duplicate research studies.

Quality of ingredients is one of the important factors; however, equally important is the quality of the manufacturing processes. This is where current good manufacturing practices come in, which are required by law and are mandated through comprehensive FDA regulations in the United States and by Health Canada. Sports nutrition product food and supplement companies actually are inspected by the regulators to ensure the quality of products consumers use. Misconceptions proffered by the media and other parties that dietary supplements are not regulated are completely wrong: the opposite is true—foods and dietary supplement products are both well regulated for safety. However, as with even the most clinically studied and regulated of products, drugs, 100 percent safety may not be possible for botanicals and metabolites.

Variability with Efficacy and Safety

When it comes to botanicals and metabolites and athlete responsiveness, variability is expected—versus a higher responsiveness rates to the essential nutrients. Why? With metabolites like creatine or carnitine, because there are metabolites being made by the body, people with low levels may display significant measurable effects, whereas people with high natural levels might not display significant measurable effects. Regarding botanicals, due to the complexity of human physiology and metabolic processes, some people can be expected to respond better to some botanicals versus other people who may have metabolic differences that reduce or prevent responsiveness.

When it comes to safety of botanicals and metabolites, variability is again expected due to various individual differences between people. Independent researchers; expert reviewers; health practitioners; private and public organizations, such as Council For Responsible Nutrition, the Food and Drug Administration, the National Institutes of Health, and Health Canada; and scientific and medical experts working for ingredient and finished product sports nutrition product companies determine the safety of these substances.

Additionally, any person with a heath disorder should avoid use of these substances, unless use is approved and supervised by a doctor. And women who are planning to become pregnant, are pregnant, or are lactating and breastfeeding should avoid use of these and other metabolites and botanicals, unless use is approved and supervised by a doctor.

Dosages

Similar to the essential nutrients, daily dosages of most metabolite and botanical products are taken in divided dosages, taken two, three, or more times per day. In this way, effective levels of the bioactives can be sustained in the body for longer periods. Some companies even offer sustained release formulas, which are usually taken once or twice a day. Some products may also be enteric coated as to avoid digestion in the stomach to protect the often delicate natural plant bioactives and metabolites. Moreover, when taking a metabolite or botanical supplement for the first time, you can test smaller dosages than what is recommended on the labels to determine the level of tolerance. This test period can be followed by slowly increasing the dosage over a few to several days to what is directed on the labels and deemed appropriate for a particular athlete by health experts.

Another interesting point regarding dosages for these substances is opportunity to personalize daily intake and duration of use—under close medical supervision. For example, although the results of clinical research studies using a range of dosage amounts might result in beneficial effects, sometimes lower amounts may be suitable to achieve the same benefit as the greater researched amounts, whereas higher than the research amounts for some larger athletes may provide additional benefits. Metabolic differences that occur will also play a role in determining the optimum daily dosage and duration of safe and effective usage for each athlete.

Ingredient Entries Included in This Unit

The list of ingredients being used in sports nutrition products and other health products used by athletes has grown substantially since the first edition of this course book. With this in mind, the following main ingredient entries were chosen by their widespread use in various products and based on clinical research evidence. And in some instances, Health Canada has published monographs for ingredients, based on its independent review of the scientific evidence. Part of your ongoing work in this area of sports nutrition should include adding additional safe and effective evidence-based ingredients to your personal list and contacting the ISSA to evaluate ingredients of interest for new editions of this course book and or for continuing education courses.

Alkalinizers, Blood Buffers

Most of the research on blood buffers has centered around Sodium Bicarbonate (baking soda). Many studies have reported ergogenic effects for individuals undergoing repeated maximum workloads ranging from seconds to several minutes; short-term sprint type performance; physical activity that would be limited by acidosis from exercising muscles' fast metabolism; may also include benefits for sprint bursts during endurance exercise or athletic events. It is crucial to note that sodium bicarbonate is ingested as a fluid after mixing with water and completely dissolved (hydrated).

Studies performed on sprinters, 800-meter runners, and world-class rowers have documented, for example, the ergogenic effects of sodium bicarbonate. Large amounts are needed, however, which are typically associated with gastrointestinal upset/distress side effects. For example, from some research-based approaches, about 0.1 gram is required for every pound of lean body mass, and some studies even used higher dosages. For an individual with 150 pounds of lean body mass, the amount of sodium bicarbonate would be approximately 150 times 0.1 grams = 15 grams. From the body of research that has evolved over the decades reporting dozens of bicarbonate exercise-related research studies, 0.3 grams per kilogram of body mass/weight

A Lesson from Dr. Albert Szent-Gyorgyi's Research

Dr. Albert Szent-Gyorgyi, a famed Nobel Prize-winning researcher, discovered a "bioflavonoid effect" during his pioneering work on vitamin C in the early 1900s. He found that vitamin C from lemon juice extract was the most effective treatment for the fragile blood vessels caused by the vitamin C deficiency disease, scurvy, versus solely vitamin C alone, which was also beneficial. He observed an improvement in **capillary** permeability, which appeared to reduce the bleeding he was trying to alleviate. This discovery led him to conclude that another "vitamin factor" was present in the lemon-juice extract, which he called "vitamin P."

As Dr. Szent-Gyorgyi's research continued, it was determined that the vitamin P factors were chemically related substances derived from a group of natural chemicals called phenols. Upon further investigation, he determined that the vitamin P factors belong to a category of phenols called bioflavonoids, noting that chemical analysis techniques were also in develop this time. Shortly thereafter, the term vitamin P was discontinued because further research failed to establish that bioflavonoids are essential nutrients—meaning that they were not proven to be necessary for survival or required by the body to prevent nutrient-deficiency diseases. Despite their "nonessential" (but important) nutrient status, the many bioflavonoids play an essential role in health maintenance and disease prevention and in the structure and function of the human body, too.

Contemporary researchers believe that bioflavonoids play vital roles in the promotion of health and longevity. Since the early nutrition research by Dr. Szent-Gyorgyi, many researchers have turned their attention to the so-called nonessential, many now recognized to be "conditionally essential" or "semi-essential" substances in the human diet nutrients that serve to enhance the structure, function, and health of the human body but that are not absolutely required for existence. Carnitine, a metabolite, is such a substance that has been referred to as conditionally essential by some experts. Then there are the Dietary Guidelines that include recommendations to eat several servings of fruits and vegetables each day for essential nutrients, but also for the many beneficial bioactives they too contain which are important to health.

It is interesting to note that Dr. Szent-Gyorgyi's research over his lifetime also included pioneering breakthroughs in muscle anatomy, physiology, muscle contraction, biochemistry of muscle movement, actin, myosin, and energy production, in addition to health benefits vitamin C, bioflavonoids and other substances. His research at the final chapter of his career also included understanding and treating cancer, which included using vitamin C and bioflavonoids. In the United States during the 1940s, he founded the Szent-Gyorgyi Foundation for muscle research, according to the National Library of Medicine. Dr. Albert Szent-Gyorgyi and his work is admired by and was influential to the authors of this course, among other distinguished scientists around the world.

A point about this pioneering scientist's work is the determination of health benefits of these "other substances" like bioflavonoids, caffeine, creatine, Pycnogenol, nitrate, HMB, sodium bicarbonate, and carnitine, aside from essential nutrient function like with vitamin C and the other essential micronutrients.

Capillary: a tiny blood vessel through which nutrients and waste products travel between the bloodstream and the body's cells.

of sodium bicarbonate is a typical effective dosage reported being used in some research studies. Therefore, for a 70-kilogram athlete (154 pounds), $70 \times 0.3 = 21$ grams per day of sodium bicarbonate, which is very high compared with antacid sodium bicarbonate drugs. Use of sodium bicarbonate for athletic performance uses, while effective, is obviously experimental and requires close medical supervision by experienced health professionals. There are also lower dosages-per-day options taken for several days that may offer athletes alternatives. The higher dosages may be beneficial used in short-term use of one to five days.

Dosage administration depends on whether the individual is subject to possible side effects, such as diarrhea, nausea, cramps, or flatulence. Note that sodium bicarbonate antacid drug products recommend about a maximum daily dosage of 4 grams per day, so the ergogenic dosages used in athletic research studies are much higher and can have adverse effects.

Hydrated dosages can be taken on an empty stomach, one hour before strenuous activity for example. If gastrointestinal side effects occur, start two hours before the activity and take one-quarter dosage with water every 15 minutes. Sodium bicarbonate loading will also load the body up with a few grams of sodium, thus caution should be used by individuals with blood pressure problems, hypertension, and other sodium concerns. To avoid injury to the gastrointestinal system, make sure the powder is completely dissolved and do not take sodium bicarbonate when you are overly full. Do not take sodium bicarbonate for more than a few days at a time. Sodium bicarbonate is also considered an antacid, which may interact with other drugs. Consult your doctor immediately if gastrointestinal pain and discomfort persist and for proper use. Some side effects noted on sodium bicarbonate Drug Facts labeling include the following: Ask a doctor before use if on a sodium restricted diet; ask a doctor before use if taking a prescription drug; STOMACH WARNING: to avoid serious injury, do not take until powder is completely dissolved. It is crucial not to take this product when overly full from food or drink. Consult a doctor if severe stomach pain occurs after taking this product.

A 2014 study examining effects of sodium bicarbonate on high-intensity endurance performance in cyclists (Egger and coworkers) is also worth mentioning, as this is a growing area of research. This study examined the effects of oral ingestion of sodium bicarbonate at the dosage rate of 0.3 grams per kilogram of body mass versus placebo of 4 grams of sodium chloride, dissolved in 0.7 liters of water. Subjects were males and females who were well-trained cyclists. One hour after ingestion. the exercise test was conducted, consisting of 30 minutes at 95 percent of the individual anaerobic threshold (IAT), followed by 110 percent IAT to exhaustion. Cycling time to exhaustion was improved by the sodium bicarbonate-taking subjects, 49.5 minute versus 45 minutes for the placebo group. An increase in body pH and bicarbonate was also reported. Although this was an exercise test, the researchers note in their conclusions that ingestion of sodium bicarbonate might improve prolonged, high-intensity cycling performance.

Another interesting related topic involves dietary control over body alkalinity or acidity. For example, S. L. Caciano and coworkers reported in their 2015 research study on how food composition that promotes body alkalinity resulted in improvement in exercise performance, versus acid-causing diets. Unit 17 contains more details about this study and important topic.

Beta-Hydroxy Beta-Methylbutyrate (BHMB or HMB)

BHMB is metabolite supplement that gained immediate popularity and use in weightlifting and bodybuilding circles from initial research that reported increased strength and lean body mass when taken as part of a resistance-training program. BHMB is made in the body from the amino acid leucine. During BHMB's evolution of research and usage benefits, it is now found in a variety of products for athletes and the general public to help to build, rebuild, and maintain muscle. BHMB is an example of a metabolite with a primary benefit for some people of helping to significantly increase the rate of muscle mass gain, strength, and other related benefits, which may result in increasing athletic performance. Most measurable benefits are reported in the research among untrained subjects and older adults. Mixed benefits are reported for elite athletes.

Functionally, BHMB is reported to work biochemically in a few primary ways as noted by J. M. Wilson and coworkers (2013), which include anti-catabolic (role in reducing muscle protein breakdown) and anabolic (role in muscle protein synthesis). The research additionally reports a very interesting and beneficial BHMB function related to activation of skeletal muscle satellite cells, vital for muscle cell regeneration and growth. It is easy to understand how these multiple functions can result in increasing and/or maintaining lean body mass, which is of interest to athletes and nonathletes alike.

An interesting research review worth mentioning was conducted in 2003 (Crowe and coworkers) examining the effects of BHMB and creatine. It was reported that creatine was most effective in producing significant gains in lean body mass and strength with resistance training. However, the research review also reported that BHMB produced gains lean body mass and net strength gains that were less than those that were produced by creatine but that were also significant when compared to with a placebo. Another study reported that an additive effect when creatine and BHMB were taken together. Benefits for aerobic athletes are possible too from the anti-catabolic and anabolic metabolic effects. In 2015, researchers K. Durkalec-Michalski and J. Jeszka reported benefits for elite rowers taking 3 grams of BHMB for 12 weeks. The benefits observed included reduction of body fat mass, increase in aerobic capacity, and an increase in peak anaerobic power. In 2016, L. P. Lowery and coworkers examined the effects on muscle mass, strength, and power on resistance-trained individuals who received a combination of 3 grams per day BHMB and 400 milligrams per day of ATP supplementation. After the 12-week study period, the researchers observed benefits of the supplementation with resistance training, such as increasing lean body mass, power, and strength. In addition, during an overreaching training cycle, the supplement-taking subjects were still able to experience gains in strength, whereas the placebo group experienced a decline in strength and power. The 12-week study

included three resistance training phases: 8-week periodized resistance training program (phase 1), followed by a 2-week overreaching cycle (phase 2), and a 2-week taper (phase 3).

According to most studies, 3 grams per day is a common effective dosage producing measurable improvements. Health Canada has established a minimum and maximum daily intake range of 3 to 6 grams per day. BHMB can be taken in divided dosages, for example 1.5 to 3 grams twice a day. While related to leucine, note that BHMB is not a replacement for leucine, as leucine is an indispensable amino acid with many important essential functions, including making BHMB in the body. Expect a few weeks of use or longer to experience measurable benefits among people who have the capacity to respond to BHMB supplementation. BHMB is also found used in multi-ingredient formulas.

Caffeine

Increasing mental (cognitive) and physical performance, including athletic performance, is well established for adequate caffeine dosages and under safe use and certain conditions. However, a major issue with caffeine supplements, caffeine drugs, and caffeine-containing foods is misuse and abuse because caffeine can cause unhealthy side effects. The FDA notes side effects related to caffeine use, including the following:

- Causes nervousness or jitteriness
- Makes it hard to fall asleep, stay asleep, or get a good night's sleep
- Makes the heart beat faster
- Causes an uneven heart rhythm
- Raises blood pressure
- Causes headaches, nervousness, and/or dizziness
- Raises health concerns for pregnant and lactating women

The FDA noted in the May 2013 Consumer Health Information article "FDA to Investigate Added Caffeine," up to 400 milligrams per day intake for healthy non-pregnant adults to be safe, which is about four to five cups of coffee. The European Food Safety Authority established that habitual caffeine consumption up to 400 mg per day does not give rise to safety concerns for non-pregnant adults. The FDA and other expert groups have reported single dosages of 100 to

200 milligrams as safe for healthy adults, non-pregnant. Health Canada notes that 100–400 mg, per day is safe, not to exceed 200 mg per single dose (HC 2012).

Why this general review of some of the safety information about caffeine at the start? It's to make a point that although there is perhaps a safe daily caffeine dosage range for healthy non-pregnant adults, and upper daily intake is recognized at 400 milligrams, use by athletes can typically be more than 400 milligrams per day. Thus, when higher per day dosages are reported in the research and by organizations, make note that these higher dosages may come with some unwanted side effects and are not intended for prolonged usage. In addition, competitive athletes need to check with their coach, team doctor, and/or athletic organization to determine whether there is a caffeine limit or ban for their individual sports.

Caffeine is a naturally occurring compound that belongs to a group of substances called methylxanthines. It is found in coffee, tea, chocolate, cola, and botanical supplement ingredients, such as, guarana, yerba mate, and green tea, or just as a synthetic or naturally purified isolate of caffeine. Although caffeine is naturally occurring, it is also synthesized, and sold as nonprescription drug, as an alertness aid and stimulant. (Refer to box below titled "Over-the-Counter Caffeine Drug Regulation from FDA.")

Caffeine has several main effects that are desirable: it increases alertness by stimulating the nervous system, acts as a mild diuretic, simulates cardiac muscle tissue, increases lipolysis, increases physical activity, and it stimulates thermogenic activity. Almost the entire world relies on a daily caffeinated beverage to get the day started. However, for the athlete, caffeine may offer much more than a good morning drink. Studies report that intakes of caffeine can have beneficial effects on performance, in particular for endurance athletes, such as exercising for longer periods, a decrease in glycogen utilization, an increase fat oxidation, enhanced motor performance, and a reduction in the perception of fatigue. Cognitive performance effects can be of interest to athletes for whom reaction time is important. It can also foster mental alertness and help athletes combat sleepiness. Caffeine tends to increase the use of fatty acids for energy, which in turn has a glycogen sparing effect. Caffeine as a nervous system stimulant provides a mental boost to help the athlete through rigorous training sessions. Research even shows that caffeine can increase the rate of fat loss. The military is a big proponent of the use of caffeine for enhancing or sustaining physical and cognitive performance. Use of caffeine was even reported to increase the time to exercise exhaustion at high altitudes, at 4,300 meters. (Refer to box below titled "Military and Caffeine.")

Due to the combination of effects that caffeine has on the body, it is also used as a weight-loss aid. Caffeine has thermogenics effects, increasing the calorie expenditure rate, and promotes the use of fatty acids for energy. The mild diuretic effect may help reduce water retention. The stimulatory effects provide a mental energy boost that some dieters find useful in offsetting the mental energy drain that may occur while on a reduced calorie diet plan.

Caffeine primarily works by stimulating the nervous system to increase production of excitatory neurotransmitters. If an individual takes too much caffeine, or takes it for prolonged periods, the precursor nutrients that produce these excitatory neurotransmitters become depleted and cause a mentally burned out feeling. Caffeine's diuretic affects are most detrimental to endurance athletes.

Caffeine should be used sparingly by athletes until the individual athlete, under doctor supervision, determines the exact performance-enhancing effects it has for him or her. Caffeine can be used periodically to provide a mental boost to enhance workouts. In addition, some studies indicate that heavy caffeine intake, for long periods, may deplete the body of calcium; therefore, adequate calcium intake is mandatory, and heavy caffeine use should be avoided for this and other reasons. As an ergogenic aid taken before competition, you first have to check on the legality of caffeine in your sport.

Though individual dosage will vary, researchers recommend 200 to 600 milligrams (about three to five cups of coffee) about one hour before competition, but make certain that you are well hydrated to offset any diuretic effects of caffeine. However, the synthetic form of caffeine or purified natural caffeine may be a more reliable source, such as the caffeine contained in nonprescription caffeine products sold in drugs stores, which is also inexpensive Also, note that studies indicate that caffeine may reduce the strength-improving effectiveness of creatine. In strength athletes, caffeine may slow down the muscle contraction cycle and may reduce strength potential, which still needs to be resolved with more research. However, such strength athletes working with their team doctors can try experimenting for themselves to determine whether there is an ergogenic effect from caffeine, neutral effect, or a negative ergolytic effect during training or athletic events. All competitive athletes must make an effort to evaluate the health and athletic performance effects caffeine has on an individual basis and under doctor supervision.

The European Foods Safety Authority published its scientific opinion in 2011 on health claims related to caffeine and physical performance. Based on its scientific review, 3 milligrams per kilogram of body dosages were associated with improvements in endurance performance and increased endurance capacity, such as improved time. A higher dosage of 4 milligrams per kilogram of body weight one hour prior to exercise is required for a reduction in the perceived exertion/effort during exercise. Dosages are taken 60 minutes prior to physical activity. Note that dosages on a per kilogram of body weight must be crosschecked with maximum safe dosages. It is also important to note that use should be limited to bouts of exercise in which a boost in physical and mental performance is needed, and day-to-day use should be avoided due to unwanted side effects, including a reduction in the positive effects of caffeine use. These dosages are within the ranges reported in the scientific literature and in position papers.

The nonprescription drug use of caffeine is 100 to 200 milligrams, every three to four hours, for occasional use. Common side effects are nervousness, irritability, sleeplessness, and rapid heartbeat. In addition to the various side effects that people may experience from caffeine

use, hypersensitivity or allergy may occur and caffeine should be discontinued and avoided in these cases. Caffeine intake of less than 300 milligrams per day, from ingestion of a few to several cups of coffee or tea, spread out over the day, may reduce or eliminate the potential dehydrating effects. In addition to being aware of all food, supplement, and drug caffeine sources to determine total daily intake, you should identify the use of other stimulants, too, as an additive effect may occur from these, such as synephrine and other stimulant drugs of food substances. And be sure to be aware of other drugs or health conditions that may cause health problems with caffeine use.

Caution: The potential down side of caffeine is that it may cause dependency and alter physiology. Also, caffeine can be lethal at high acute dosages, over 10 grams for adults and a lower acute dose for children. (Also refer to box below titled "FDA Consumer Advice on Pure Powdered Caffeine (FDA Safety Alert.") Make sure you keep your caffeine-containing products away from children and from pets, too. Significant mild side effects in adults are reported to be observed with acute dosages starting at about 1 gram. A daily maximum dosage of 1 gram (1,000 milligrams) per day is reported by some authorities for short-term usage—for example, days. Note that the extent of side effects will depend on an individual's metabolism and ability to metabolize caffeine. Therefore, complete safe use of caffeine cannot be guaranteed, following product directions and determination of each person's caffeine safe use limits as determined by a doctor.

Over-the-Counter Caffeine Drug Regulation from the FDA PART 340

STIMULANT DRUG PRODUCTS FOR OVER-THE-COUNTER HUMAN USE

Subpart A--General Provisions

Sec. 340.1 Scope.

(a) An over-the-counter stimulant drug product in a form suitable for oral administration is generally recognized as safe and effective and is not misbranded if it meets each of the conditions in this part and each of the general conditions established in 330.1.

(b) References in this part to regulatory sections of the Code of Federal Regulations are to chapter I of title 21 unless otherwise noted.

Sec. 340.3 Definition.

As used in this part:

Stimulant. A drug which helps restore mental alertness or wakefulness during fatigue or drowsiness.

Subpart B--Active Ingredient

Sec. 340.10 Stimulant active ingredient.

The active ingredient of the product consists of caffeine when used within the dosage limits established in 340.50(d).

Subpart C – Labeling

Sec. 340.50 Labeling of stimulant drug products.

(a) Statement of identity. The labeling of the product contains the established name of the drug, if any, and identifies the product as an "alertness aid" or a "stimulant."

(b) Indications. The labeling of the product states, under the heading "Indications," the following: "Helps restore mental alertness or wakefulness when experiencing fatigue or drowsiness." Other truthful and nonmisleading statements, describing only the indications for use that have been established and listed in this paragraph, (b) may also be used, as provided in 330.1(c)(2), subject to the provisions of section 502 of the Act relating to misbranding and the prohibition in section 301(d) of the Act against the introduction or delivery for introduction into interstate commerce of unapproved new drugs in violation of section 505(a) of the Act.

(c) Warnings. The labeling of the product contains the following warnings under the heading "Warnings":

(1) "The recommended dose of this product contains about as much caffeine as a cup of coffee. Limit the use of caffeine-containing medications, foods, or beverages while taking this product because too much caffeine may cause nervousness, irritability, sleeplessness, and, occasionally, rapid heartbeat."

(2) "For occasional use only. Not intended for use as a substitute for sleep. If fatigue or drowsiness persists or continues to recur, consult a" (select one of the following: "physician" or "doctor").

(3) "Do not give to children under 12 years of age."

(d) Directions. The labeling of the product contains the following information under the heading "Directions": Adults and children 12 years of age and over: Oral dosage is 100 to 200 milligrams not more often than every 3 to 4 hours.

Military and Caffeine

Based on a report by the National Academy Sciences funded by the military, the following is a summary of some of the key recommendations of interest for use by military personnel.

- Caffeine in amounts of 100 to 600 mg can be effective in maintaining cognitive performance particularly in situations of sleep deprivation. Specifically it can be used in maintaining speed of reactions and visual and auditory vigilance, which in military operations could be a life or death situation.
- A similar amount (200 to 600 mg) of caffeine is also effective in enhancing physical endurance and may be especially useful in restoring some of the physical endurance lost at high altitude.
- Use of caffeine under conditions of sustained military operations would not appear to pose any serious, irreversible acute or chronic health risks for military personnel in situations where increased doses might be recommended.
- Caffeine use increases the risk of dehydration, so fluid and food intake of personnel should be closely monitored in these situations.
- A caffeine delivery vehicle that provides caffeine in 100-mg increments with a total content not exceeding approximately 600 mg would appear to be the most appropriate dose for use in sustained military operations.
- An in-depth training program on the benefits, directions for use, and potential side effects of caffeine should be designed for command personnel. Military personnel should be given adequate training to ensure the benefits of caffeine supplementation and avoid any potential side effects.
- Such training should include the use of caffeine during periods of sleep deprivation and altered work–rest cycles in non-operational situations.
- The military should have in place a doctrine related to the importance of sleep prior to extended missions and the importance of naps whenever possible during operations.
- At this time, caffeine should be the compound of choice for counteracting cognitive deficits since many personnel have personal experience with the compound, it is not a restricted substance, it does not interfere with recovery sleep following periods of sleep deprivation, and it has very low abuse potential.
- Military women should be informed that very high doses of caffeine may slightly increase risk of spontaneous abortion in the first trimester of pregnancy.

Source: Caffeine for the Sustainment of Mental Task Performance: Formulations for Military Operations. Committee on Military Nutrition Research, National Academy of Sciences 2001

FDA Consumer Advice on Pure Powdered Caffeine (FDA Safety Alert)

Key Advice

The FDA is warning about pure powdered caffeine being marketed directly to consumers and recommends avoiding these products. In particular, the FDA is concerned about pure powdered caffeine sold in bulk bags over the Internet.

The FDA is aware of at least two deaths of young men who used these products.

These products are essentially 100 percent caffeine. A single teaspoon of pure caffeine is roughly equivalent to the amount in 28 cups of coffee.

Pure caffeine is a powerful stimulant and very small amounts may cause accidental overdose. Parents should be aware that these products may be attractive to young people.

Symptoms of caffeine overdose can include rapid or dangerously erratic heartbeat, seizures and death. Vomiting, diarrhea, stupor and disorientation are also symptoms of caffeine toxicity. These symptoms are likely to be much more severe than those resulting from drinking too much coffee, tea or other caffeinated beverages.

Who should know

All consumers seeking caffeinated products should be aware of the potentially high potency of these pure powdered caffeine products. Parents should recognize that teenagers and young adults may be drawn to these products for their perceived benefits.

What to do

The FDA advises consumers to avoid pure powdered caffeine.

It is nearly impossible to accurately measure pure powdered caffeine with common kitchen measuring tools and you can easily consume a lethal amount.

If you believe that you are having an adverse event related to caffeine, stop using it and seek immediate medical care or advice.

The FDA wants to know about adverse events associated with pure powdered caffeine and other highly caffeinated products. You or your health care provider can help by reporting these adverse events to FDA in the following ways:

By phone at 240-402-2405

By email at CAERS@cfsan.fda.gov

Why this advice is important

Pure powdered caffeine products are potentially dangerous, and serious adverse events can result, including death. People with pre-existing heart conditions should not use them.

Additional information

FDA Voice: A blog by Mike Landa, Director of the FDA's Center for Food Safety and Applied Nutrition, addresses how two tragic deaths highlight the dangers of pure powdered caffeine.

Source: http://www.fda.gov/food/recallsoutbreaksemergencies/safetyalertsadvisories/ucm405787.htm

Carnitine / Acetyl-L-Carnitine

Carnitine is made by the body and has a primary role is the transportation of fatty acids into mitochondria. The effectiveness of carnitine in various studies has been so impressive that it is now considered a conditionally essential nutrient, meaning that the body can benefit from supplemental intake, as the body's intake may not be adequate for optimal health and function. Carntine's primary role is in the mitochondria of cells, where it moves fatty acids into the mitochondria to be used for energy.

Research has demonstrated certain athletic performance improvements with carnitine supplementation, with some mixed results similar to those from other metabolites. Athletic benefits could include increased endurance, improved $\dot{V}O_2$ max, reduced lactate levels during exercise, and improved anaerobic strength output along with antioxidant protection effects. Studies support the use of carnitine supplementation for intensively training, competitive athletes involved in primarily endurance activities lasting over several minutes. However, benefits for strength athletes have been reported, in particular during weightlifting exercise. In addition to lactate reduction, improved recovery potential after resistance training from carnitine supplementation has been reported.

Carnitine is also useful in increasing the rate of fat loss by increasing the rate of fat used for energy; carnitine encourages the body to use more fat for energy. Thus as part of a reduced-calorie diet, carnitine may increase the rate of fat loss in some people. There is also a variety of health-promoting effects derived from taking carnitine supplements, including heart health, mental wellness, healthy aging, and increased male fertility.

With all of the reported research-proven health, healing, and performance benefits carnitine has to offer, the decision to declare carnitine a conditionally essential nutrient was a good one. Carnitine supplementation of 2 to 4 grams per day is reported to yield performance-enhancing results, taken starting at least several weeks before competition. Carnitine loading 2 to 5 grams per day, one to two weeks before events can also be evaluated, especially for larger athletes. Divided dosages is also used, two to three times per day for example. Both endurance and strength athletes may benefit from using carnitine supplementation; the L-carnitine form is the bioactive form used in supplements.

In 2014, researchers G. E. Orer and N. A. Guzel reported the results of their study examining carnitine supplementation on endurance performance in professional male footballers. Footballers took 3 grams or 4 grams of carnitine prior to exercise testing, running. Running speed was increased during the test until subjects chose to quit. The test was repeated after one week as a group of placebos. The carnitine groups showed that running speeds were increased, and beneficial lactate concentration and heart rate responses were decreased in both carnitine groups versus placebo testing. The researchers concluded that the results of this short-term carnitine-use study show that taking carnitine before physical exercise prolonged exhaustion.

Carnitine occurs in supplements in a few forms: L-Carnitine Fumarate and Acetyl-L-Carnitine are high-quality forms used in supplements. Adding the “acetyl” compound to L-Carnitine improves its ability to be taken up and used in various tissues, such as the brain. Using the combination of these two forms may result in greater distribution to all the tissues in the body.

Health Canada has issued a monograph for carnitine (2013) that includes various purposes (benefits) for using carnitine supplements and dosage ranges. Some of the purposes include:

- Aids in the muscle recovery process by reducing muscle tissue damage associated with a resistance-training regimen;
- Helps support muscle tissue repair in individuals involved in resistance training;
- Helps improve physical performance when used in conjunction with a training regimen;
- Helps delay fatigue during physical activity;
- Helps support fat metabolism and fat oxidation; and
- Serves as an antioxidant.

In Canada, the carnitine daily dosage range is from 1 to 4 grams per day and should not exceed 2 grams per single dosage. Additionally, for muscle recovery, muscle tissue repair, workout supplement, physical performance, and anti-fatigue, take a dosage of up to 2 grams two to four hours prior to exercise. It is best to refer to carnitine product directions for adequate usage under doctor supervision.

Another study of interest by K. Parandak and coworkers 2014 examined the effects of 2 milligrams L-carnitine taken for two weeks on exercise-induced oxidative stress and muscle damage measurements. After two weeks of carnitine supplementation, the male test subjects performed a 14 km run on the track at their highest ability. The researchers found that carnitine supplementation increased total antioxidant capacity and had positive alleviating effects on biomarkers of muscle damage and lipid peroxidation.

Then there is the 2001 research study by Y. S. Cha and coworkers that examined the effects of carnitine, caffeine, and carnitine coingested with caffeine on metabolism and endurance capacity in a small group of healthy rugby players. High dosages were used in this study compared with other studies, and not recommended for general use, but it is worth mentioning due to the interesting improvement results. This research study used the following drinks: caffeine at 5 mg/kg body mass in 250 ml water; carnitine 15 grams in 250 ml water; caffeine 5 mg/kg body mass plus 15 grams carnitine in 250 ml water; and 250 ml water. The subjects were first provided a 640 kcal meal 150 minutes prior to exercise, followed by ingestion of one of the experimental drinks. The exercise testing was performed on a bicycle ergometer, and metabolic testing was performed. Same-day benefits were observed, such as prolonged exercise to exhaustion in which all treatments were better than placebo, carnitine was better than caffeine, and carnitine plus caffeine was better than placebo, caffeine, or carnitine. The researchers concluded that their study showed carnitine ingestion could promote fat oxidation and enhance performance in athletes, and carnitine plus caffeine yielded greater improvements under the experimental conditions. Caffeine and carnitine have different roles in fat metabolism; for example, caffeine can increase release of fatty acids and increase fatty acids in the blood and spare glycogen, and carnitine functions by transporting fatty acids in to the mitochondria for energy production. As such, the study results support that although both functions are important for fatty acid metabolism and exercise endurance benefits, carnitine's function may be more of a limiting step in the chain of metabolic events.

Coenzyme Q10 (Ubiquinone)

CoQ10 has a history of use in clinical application for people suffering from cardiovascular disorders. Its safety and effectiveness are well established for most people, under doctor supervision. Some research studies with athletes report ergogenic effects, such as improved physical performance in endurance events. CoQ10 is a coenzyme found in every cell's mitochondria and plays a role in oxidative energy production of the high-energy molecule ATP. CoQ10 is also reported to have antioxidant abilities and free-radical scavenging abilities to protect body cells, tissues, and so on. Much research has also been conducted using CoQ10 supplementation to improve heart function

There have been a number of studies reporting benefits of CoQ10 supplement use for endurance-type exercise and athletic performance. However, similar to research results on some of the other metabolites, the results of these studies have reported either a significant benefit or neutral results when compared with a placebo, which means CoQ10 may or may not work the same way for everybody to produce significant improvements in athletic performance. Thus for long-distance athletes, CoQ10 may provide an added boost in athletic performance.

Athletes choosing to test CoQ10 supplements for athletic performance should keep detailed records of their athletic performance to determine whether measurable benefits are occurring. Depending on the person's natural CoQ10 status, it may take a few to several weeks for performance-enhancing benefits to occur. Endurance ergogenic dosages may range from 60 milligrams to 300 milligrams per day. Other benefits reported include improved aerobic power, anaerobic threshold, exercise performance, and/or recovery after exercise. Lower dosages are typically used in multiple ingredient supplements, primarily for CoQ10's antioxidant properties for promoting health.

Note that ubiquinol is a reduced form of CoQ10 with similar benefits. For example, Alf and coworkers (2013) found that 300 milligrams per day of ubiquinol for six weeks significantly enhanced physical performance measured as power output among male and female German Olympic athletes. Gokbel and coworkers (2010) found a benefit of 100 milligrams per day of CoQ10 supplementation after their eight-week study period and concluded in their research study that according to these results, CoQ10 may show performance-enhancing effects during the repeated bouts of supramaximal exercises and that CoQ10 might be used as ergogenic aid. Armanfar and coworkers (2015) examined effects of CoQ10 supplement use on male distance runners. After subjects spent 14 days taking CoQ10 at a body weight-based dosage of 5 milligrams per kilogram of body weight per day, the researchers reported that, based on current results, it can be concluded that the

14-day coenzyme Q10 supplementation is more effective than is the acute supplementation to overcome the exercise-induced adverse responses in some oxidative, inflammatory, and biochemical parameters. Therefore, short-term coenzyme Q10 supplementation is recommended to reduce exercise-induced adverse consequences.

Health Canada in its monographs for Coenzyme Q10 and Ubiquinol report the following purposes and dosage ranges: helps maintain and/or support cardiovascular health; antioxidant for the maintenance of good health, (CoQ10 daily dosage is 30 to 100 milligrams, one to three times per day, and Ubiquinol daily dosage is 15 to 300 milligrams); and as a medical use, helps reduce the frequency of migraine headaches and associated symptoms such as nausea and vomiting, when taken as a prophylactic (CoQ10 and Ubiquinol daily dosage range is 75 to 100 milligrams, 2 to 3 times per day.) Refer to the Canadian monographs and product for more details, such as additional directions.

Creatine

Creatine has been used nutritionally to increase the amount of creatine and high-energy creatine phosphate in muscle tissue. Creatine is present in food and is manufactured in the body. It occurs in animal products, such as meat and fish. One pound of raw steak contains about 2 grams of creatine. But it should be noted that cooking will convert the creatine into its **creatinine**, which is quickly excreted from the kidneys. Creatine monohydrate is the form used most in clinical studies and proven over and over again to promote significant muscle-building and strength performance benefits.

Creatinine: a waste product of creatine metabolism.

In the body, creatine is made from the amino acids glycine, arginine, and methionine. Normal daily dietary creatine requirements are estimated at 2 grams per day in nonathletic individuals. ATP (adenosine triphosphate) and CP (creatine phosphate or phosocreatine) are stored in muscle cells and function as a pool of immediate energy. The bigger the amounts in the muscles, the more the muscle can lift and perform short-term maximum strength performance. CP is used to quickly replenish ATP in fast-twitch glycolytic muscle fibers. This process takes only a fraction of a second. Continued high-intensity levels of performance cause fatigue to set in from metabolic waste products.

Creatine loading can therefore result in improving training intensity and recovery in anaerobic sports by loading up the muscles' resting reserve of creatine phosphate. In other words, the more creatine and creatine phosphate the muscles have on hand, the more ATP can be replenished during bursts of all-out effort. Of the dozens of studies conducted using creatine supplementation during the 1990s to today, improvements in strength performance were observed mostly in sports that exhibited all-out effort for less than 30 seconds. For example, creatine supplementation improved performance in weightlifting, powerlifting, football, short duration track and field events (sprinting, jumping, throwing, etc.), vertical jump performance, 300-meter sprint, and short rowing events. Increases in VOmax have been observed in a limited number of studies on untrained and moderately active individuals. In addition, the most consistent effect of taking creatine is an increase in lean body mass, which has made creatine popular among bodybuilders and other athletes wanting to increase muscle mass and body weight.

One thing is clear from all of this research: if you are exercising to improve strength, muscle mass, and physical performance, creatine works to enhance these effects more significantly. Most research also reports that athletes taking creatine are in fact reported to reduce the risk of all injuries, including muscle cramps when compared with taking a placebo.

The table on the following page provides an overview of creatine benefits. Like the other nutrients, taking creatine on a consistent basis, in divided dosages two or more times a day, will help provide the body and muscle tissues with a constant supply. Consistency of use is important, using safe and effective dosages, and duration of use as determined by experts under doctor supervision.

If meal intake is timed correctly around workouts, then taking creatine around mealtime will be sufficient. Creatine can be combined with other nutrients and metabolites, like vitamins, minerals, protein, BCAAs, and glutamine. In addition, creatine monohydrate has the most research studies backing its effectiveness.

Health Canada has issued an evidence-based creatine monograph in 2011 for creatine monohydrate. Some of the benefits of taking creatine supplements include:

- Increases body/muscle/lean and mass/size when used in conjunction with a resistance-training program;
- Improves strength/power/performance in repetitive bouts of brief, highly intense physical activity from increasing muscle and intramuscular creatine, phosphocreatine, and energy levels, for example, sprints, jumping, and resistance training.
- Creatine monohydrate dosage examples for healthy adults include a short-term loading phase followed by a lower daily dosage maintenance phase, for example:
- Loading phase option 1:15 to 20 grams per day, not to exceed 5 grams per dosage; five to seven days
- Or Loading phase option 2: 3 to 5 grams per day, for a minimum of four weeks
- Maintenance phase: 2 to 5 grams per day

<table>
<tr><th colspan="3">Summary of Some of the Effects of Creatine Monohydrate Supplementation</th></tr>
<tr><td colspan="3">This table includes a summary of the major conclusions about how creatine monohydrate supplementation improves body composition, physiology, physical performance, and athletic performance.</td></tr>
<tr><th>Body Composition and Physiology Related Improvements</th><th>Athletic Performance Related Improvements</th><th>Athletic Performance Improvements Sports</th></tr>
<tr><td>• Promotes greater gains in increasing FFM (Fat Free Mass, which includes muscle mass).
• Increases muscle fiber size
• (hypertrophy).
• Increases muscle mass.
• Increases myosin muscle fiber content.
• Improves strength training adaptations.
• Improves limb blood flow.
• Reduced ammonia levels.
• Reduced lactate levels.
• Raises lactate threshold.
• Reduces cholesterol levels.
• Reduces homocysteine levels.
• Increases in muscle satellite cells (muscle fiber precursor cells).
Benefits have been measured in men and women; young and old (teenagers to over 70 years of age); and inactive, active, and athletic individuals.
Note: creatine supplementation has not been shown to increase long-term endurance physical / sport / exercise performance. Other supplements, such as carnitine, certain carbohydrates, etc. have been reported to stimulate significant improvements.</td><td>• Improves rate of training induced gains.
• Improves maximal strength and power about 15%.
• Improves work performed during maximal effort muscle contractions about 15%.
• Improves anaerobic power.
• Improves single-effort sprint performance about 5%.
• Improves multiple sprint performance.
• Improves work performed during repetitive sprint performance about 15%.
• Improves performance during exercise of high to maximal intensity.
• Increased number of weightlifting repetitions.
• Increased number of weightlifting sets.
• Greater gains in vertical jump height and power.
• Increased 1 repetition maximum.
• Increased peak force.
• Increased peak power.
• Reduction of athletic injury rates, such as: reduced muscle cramping, reduced dehydration, reduced muscle tightness, reduced muscle pulls, reduced muscle strains, reduced joint injuries, reduced contact injuries, reduced illness, reduced number of missed practices, and reduction in total injuries during the season.</td><td>Reported In Research Studies:
• Bodybuilding
• Football
• Handball / Squash
• Hockey
• Military Performance
• Powerlifting
• Softball / Baseball
• Soccer
• Sprint running Sprint cycling Sprint rowing Weightlifting Wrestling
Sports In Which Improvements Are Expected Due to the Bio- energetic Nature of the Sport:
• Sports involving short-term sustained, or periodic maximum effort strength and power, such as:
• Basketball
• Bobsledding
• Bowling
• Boxing
• Canoeing / Kayaking
• Curling
• Decathlon Fencing Golf
• Ice Skating
• Lacrosse Martial Arts Rodeo
• Skiing, downhill
• Tennis
• Track and Field events that use anaerobic energy systems, such
• as shot put, high jump, long jump,
• etc.</td></tr>
</table>

These dosage examples are consistent with the dosages proven effective in the research studies. Note that creatine is best taken in divided dosages each day, two to four smaller dosages, based on the daily amount. Larger strength athletes may require higher daily dosages during the loading and maintenance phase, which can be determined for individual athletes under doctor supervision, especially for people with kidney disorders or any other abnormal health condition. Gastrointestinal distress may occur. It is important to completely dissolve creatine monohydrate before digesting. Creatine is also compatible with other supplements and food, such as protein or carbohydrates, but if mixed with other nutrients, faster digestion rate is important to maintain to reduce breakdown of creatine to creatinine in the stomach. Also note that elevated creatinine blood and urine levels can occur. Doctors will observe this and may be concerned about disorders that are related to high creatinine levels, such as kidney diseases. Explain to the doctor about creatine supplement use, which may need to be discontinued until normal creatinine levels are demonstrated and kidney disorder is ruled out. Product labels will also have use instructions.

Gamma Oryzanol and Ferulic Acid

Gamma oryzanol is a substance extracted from rice bran oil that has been reported to promote a variety of metabolic effects, including increased endorphin release, antioxidant action, lipotropic action, stress reduction, growth hormone stimulation, growth, and recovery in various types of research studies. Ferulic acid is a part of the gamma oryzanol molecule that is also available as a supplement. Improvements reported in the scientific literature include increased strength, improved recovery, reduced muscle soreness, reduced sensation of fatigue, and decreased catabolic effects of cortisol. Short-term use in research studies reported some potential benefits with dosages of 30 milligrams to 200 milligrams of ferulic acid per day and/or 300–900 milligrams of gamma oryzanol per day.

Eslami and coworkers (2014) found that 600 milligrams per day of gamma oryzanol resulted in improving gains in strength, in the strength-training male subjects at the end of the nine-week study period. The significant increases in strength included 1-RM of bench press and leg curl, which showed that gamma oryzanol improved muscle strength following resistance training. Changes in body composition were not significant. This 2014 study demonstrates how the earlier researchers were indeed on to something and is confirmation of previous findings and widespread use by athletes of a potential gamma oryzanol supplement benefit that may have practical applications for strength-training athletes and for fitness exercisers. Research also reports cardiovascular health benefits of rice bran oil and gamma oryzanol that may be of interest to athletes, such as lowering cholesterol levels.

Ginsengs

Several types of ginseng have been in use for thousands of years as overall promoters of good health and improved energy. The types of ginseng primarily found in supplements are Chinese ginseng *(Panax ginseng)*, American ginseng *(Panax quinquefolius)*, and the related species, Siberian ginseng *(Eleutherococcus senticosus)*, also referred to as Ciwujia and Eleuthero. Herbalists report that American ginseng is less stimulatory. Chinese ginseng and Siberian ginseng are the ones most researched and used for improving athletic performance.

The primary “active” components of ginseng are a group of sponin compounds called ginsenosides/ panaxosides and eleutherosides in Siberian Ginseng. Ginseng also contains the trace mineral germanium, which has been shown to exhibit overall health effects and increase the body’s supply of oxygen. Ginsengs also contain other substances, including botanical antioxidants.

Some of the benefits reported in the research and based on traditional use include the following:

- Improved physical performance Improved oxygen uptake Improved post exercise recovery Improved exercise total workload
- Improved aerobic capacity
- Improved strength performance Increased time to exhaustion
- Reduction of lactate levels during exercise
- Improved $\dot{V}O_2$ max
- Reduced body fat
- Increased fatty acid utilization for energy
- Improved heart rate recovery
- Improved mental performance Improved visual reaction time Improved psychomotor performance Reduced feelings of fatigue Improved visual reaction times Improved recall
- Improved alertness
- Improved motor skill coordination
- Improved auditory reaction time
- Decreased eyestrain

Research reports a range of results from neutral to very significant improvements. When you add up the results from the dozens of research studies, one thing is certain” taking ginseng provides some level of benefit for improved physical and or mental performance.

With ginseng, most preparations use 2 to 4 percent standardized ginseng products as a common guideline. Ginseng products range from single ingredient to multiple ingredients. Chinese ginseng combined with royal jelly is a traditional combination for energy. Siberian ginseng has been the favorite of Russian athletes, who are reported to use it regularly. Chinese ginseng is also widely used and well researched. Another researched combination is ginseng with ginkgo. Dosages of ginseng range between 100 milligrams to 1 gram per day during the season and preseason and as needed during the off-season. Ginseng is also found in some good-quality sports multi-vitamin/mineral supplements, which offer convenience. Safe and effective types of ginseng(s), dosage, and duration of use should be determined by experts, under doctor supervision. There are various potential health concerns and contraindications related to using the ginseng(s). Also, note that ginseng has stimulant effects, so use with other stimulant supplements, foods, or drugs is of concern, as is use with other types of drugs.

Health Canada has also published monographs for ginsengs. Some examples of ginsengs’ uses/benefits of interest to athletes may include the following:

- Improve mental and or physical performance after periods of mental and or physical performance
- Help maintain a healthy immune system
- May affect glucose levels
- Support cognitive function and/or reduce mental fatigue in cases of mental stress
- Help enhance physical capacity/performance in cases of physical stress
- Offer other medical uses that may apply to athletes

Ciwujia (Eleuthero Root) Research Study Focus Examples

Kuo and coworkers reported from their study that after eight weeks of supplementation ciwujia "enhanced endurance capacity and improved cardiovascular function." The study used a double-blind, placebo-controlled crossover design with a washout period of four weeks between cycling trials. Cyclists consumed either a placebo or 800mg of ciwujia. Following a 5-minute warm-up, the pace increased to 75% $\dot{V}O_2$ peak. Ratings of perceived exertion, heart rate and respiratory exchange ratio were measured at rest, 15, 30 min and exhaustion. Subjects receiving ciwujia supplementation had a 23% improvement in endurance time to exhaustion, a 12% improvement in $\dot{V}O_2$ peak, an increase in heart rate with no increase in ratings of perceived exertion and an increase in fatty acid oxidation. (Kuo 2010)

In another research study, Kuo and coworkers found that ciwujia supplementation for eight weeks increases fat oxidation in working muscles during hig-intensity exercise and improves cardiorespiratory function. Eighteen healthy male and female college students participated in an eight-week double-blind study. Subjects consumed daily an oral dose of 600mg of ciwujia and at week 0 and week 8 completed a cycling exhaustion exercise test. The subjects receiving ciwujia supplementation had a statistically significant increase in endurance time of 36%, an increase in maximum heart rate of 4%, a decrease in blood lactic acid of 18%, and a 20% increase in fatty acid metabolism. No side effects were reported (Kuo 2007).

In yet another research study, Kuo and coworkers again showed that after 28 days of treatment with ciwujia, there was a significant increase in running time to exhaustion, heart rate, and fat metabolism. Ten long distance runners consumed ciwujia or placebo for 28 days and then were evaluated for running time to exhaustion, heart rate max and fat metabolism. The group consuming ciwujia had an increase in endurance, an increase in heart rate and an increase in fatty acid metabolism. The authors concluded that supplementation with 800mg of ciwujia for 28 days improved endurance capacity and had no side effects during the study period. (Kuo 2006)

In a study previous to the Kuo et al. series of studies, Wu and coworkers determined that ciwujia increased fat metabolism, increased the anaerobic threshold, and delayed the occurrence of fatigue. Sixteen healthy male adults received ciwujia or a placebo for two weeks. Both before and after two weeks, subjects underwent tests measuring aerobic and anaerobic power. Researchers found that subjects receiving ciwujia had a decrease in blood lactate levels of 31%–33%. The change in lactate levels was paralleled by a similar change in heart rate. Based on change in respiratory quotient, ciwujia increased energy contributed from fat by 43%. The authors concluded that these results indicated that use of ciwujia can have positive implications for athletes because of a glycogen-sparing effect and increase in the anaerobic threshold (Wu 1996).

Glucosamine and Chondroitin Sulfate (CS)

In the body, there are several types of connective tissues. Cartilage, tendons, ligaments, intervertebral discs, pads between joints, and cellular membranes all are composed of connective tissue. All connective tissues have two common components, chief of which is collagen. One-third of the body's total protein volume is composed of collagen, making it the most common protein in the body. The other component is proteoglycans (PGs). PGs form the "framework" for collagenous tissue.

These huge structural "macromolecules" are composed mainly of glycosaminoglycans (GAGs)—long chains of modified sugars. The principal sugar in PGs is called hyaluronic acid, 50 percent of which is composed of glucosamine. The principal amino acids forming collagen are proline, glycine, and lysine. Collagen and PGs must somehow "get together" during the production of new connective tissue. Of the multitude of biochemical reactions that must take place during the synthesis of connective tissue, there is one critical "rate-limiting" step that, once reached, guarantees that new connective tissue is being successfully synthesized. That rate-limiting step is the conversion of glucose to glucosamine.

Glucosamine is the single most important substance in the synthesis of connective tissue. More than 30 years of research has gone into understanding how glucosamine acts as the precursor of GAG synthesis. Glucosamine is so effective, it repairs connective tissue and may very well be a way to reduce the risk of connective tissues problems from occurring

in the first place by maintaining adequate connective tissues in your body. In human clinical trials, glucosamine given orally in doses of 750–1,500 milligrams daily was observed to initiate a reversal of connective tissue degeneration, promote connective tissue maintenance, and also reduce pain in the knee of athletes. Glucosamine as a supplement clearly aids in connective tissue synthesis. All athletes need such a substance, as the repair and growth of connective tissue is never-ending. Research has confirmed that both glucosamine HCl and glucosamine sulfate are effective and may be useful for athletes to help maintain and promote healthy connective tissues and joints.

Benefits for Athletes Are Actually Old News

In 1984, researchers in Frankfurt, Germany, brought to the attention of the world the benefits of glucosamine for healing knee problems in young athletes. A condition called chondropathia patellae is a common disorder of the knee in young athletes. The healing of this affliction must be rapid to avoid the development of future serious degenerative joint disease. After taking a glucosamine supplement (1,500 mg per day for a few months), the teenage athletes quickly recovered and returned to training. Reduction in knee pain was observed in just a few weeks. Furthermore, after a 12-month period of these athletes' returning to training, researchers observed that the athletes did not experience a recurrence of the knee problem. The results of this landmark study clearly demonstrated the potent connective tissue repair, growth-promoting, and maintenance abilities of glucosamine supplements for athletes. The supplements also can help prevent future joint problems, including development of osteoarthritis; this is all too common among athletes and the physically active.

Research Reports More Benefits from Taking G&CS Supplements

The more recent studies even show that taking G&CS supplements helps reduce joint space narrowing due to connective tissue wear-and-tear and can even prevent osteoarthritis from developing in the first place. Remember G&CS builds connective tissues, such as skin, tendons, ligaments, bone, and cartilage, which form the matrix that is involved in holding the entire body together. G&CS are made by the body similar to other metabolites, such as creatine, but active people (especially athletes) create a demand for these substances that can be greater than the body can supply.

Similar to glucosamine, chondroitin sulfate has been tested in humans as a promoter of connective tissue maintenance, growth, and repair. It is important to note that both glucosamine and CS are effective on their own. Research has found that when taken together, they have a synergistic effect. One issue with CS is the high-quality, standardized raw material is several times more expensive than glucosamine and unstandardized powdered forms of CS are. Thus, glucosamine tends to be a cost-effective approach to promote connective health. People who do not respond to glucosamine supplementation after three months of use should consider using CS along with the glucosamine. There are even connective tissue supplements now sold for pets that you may know about from the advertising or may already be using for your pet.

Health Canada has approved-use monographs for glucosamine and CS. Some of the purposes and uses include:

- For Glucosamine Sulfate: Helps to relieve joint pain associated with osteoarthritis; Helps to relieve pain associated with osteoarthritis of the knee; Helps to protect against the deterioration of cartilage; and A factor in maintaining good cartilage and/or joint health. Adult dosage example is 1,500 milligrams per day, minimum four weeks to see beneficial effects.
- For Glucosamine Hydrochloride: A factor in maintaining healthy cartilage; Helps to maintain healthy cartilage; A factor in maintaining joint health; and Helps to maintain joint health. Adult dosage example is 1,500–2,000 milligrams per day, minimum four weeks to see beneficial effects.
- For Chondroitin Sulfate: Helps to relieve joint pain associated with osteoarthritis; and Helps to relieve pain associated with osteoarthritis of the knee. Adult dosage example is 800–1,200 milligrams per day, minimum of three months to see beneficial effects.

Consult the monographs for complete information for safe and effective use.

Melatonin

Melatonin is another metabolite substance produced by the body. Melatonin supplements have not necessarily been shown to directly improve athletic performance, but they have been shown to indirectly improve performance by stimulating certain bodily processes. Melatonin causes deep restful sleep. When quality sleep is had, growth hormone, IGF, and testosterone levels are increased, which promote muscle growth and repair. Additionally, the deep sleep reduces cortisol levels, so the melatonin-promoted deep sleep has beneficial anti-catabolic effects along with anabolic effects.

According to several studies, melatonin helps people fall asleep more quickly, stay asleep, and enjoy a more restful sleep. Furthermore, it does this without causing sleep hangover, which is an after-effect of most sleep medications. Researchers have determined that when the sun sets, the body's melatonin level begins to rise. At dawn, the body's melatonin level begins to drop again. There are times, however, when the body's natural melatonin production may be upset. Traveling across time zones disrupts melatonin production, causing what is commonly known as jet lag.

Nervousness before an important athletic event affects melatonin production, as does the stress of training. Staying up late to study for a test, catch up on work, reading, or watching television can also be disruptive because, according to researchers, lamplight may be enough to suppress proper melatonin production. Millions of people have been using supplemental melatonin with no apparent major side effects.

The amounts typically used successfully in studies for short-term use have ranged from 0.5 milligrams to 6 milligrams per day, although up to 10 milligrams per day is sometimes recommended. However, until researchers determine the effects of long-term supplemental use of melatonin, use only when needed for short periods of time, several days up to 4 weeks. There are also approved melatonin products in Canada that are sublingual, for faster absorption and action. Research has also been conducted using sustained release melatonin, with seems to work better at prolonging sleep by maintaining effective melatonin blood levels longer, compared to the regular dosage forms. Health Canada determined various sleep related purposes for melatonin, including possible side effects and warnings published in their monograph.

For safest use, consult your doctor before using, as there are some potential side effects, including incompatibility with drugs and for people with certain conditions. In addition, disturbed sleep could be a symptom of a disease. Some potential use concerns include people with hormonal disorders, diabetes, liver disease, cerebral palsy, seizure disorders, migraine, depression, and hypertension and may be incompatible with immunosuppressive, sedative, and hypnotic medications. As melatonin causes sleepiness, avoid driving, operating machinery or similar activities for at least five hours after taking melatonin. Avoid use with alcohol and sedative supplement products and drugs. Disturbed sleep may be a symptom of a serious health condition, which requires proper diagnosis and treatment by a doctor.

Nitrates

Research has determined that dietary nitrates are associated with health promoting effects, in particular for the circulatory system, and additional research conducted using dietary nitrates has revealed a sports and exercise performance benefit for some types of athletes and exercisers. Dietary nitrate increases body plasma nitrate, and this in turn can increase the nitric oxide (NO) levels. Increased NO levels can improve blood vessel dilation, improve blood flow, and improve glucose uptake and other body functions beneficial for exercising muscle and cardiovascular system health. Note that arginine- and citrulline-mediated NO production uses a different pathway.

Benefits from nitrate supplements, such as from beetroot, may be variable due to other dietary nitrate sources, use of other NO-boosting supplements, and health conditions of an athlete. In studies where significant benefits in endurance exercise performance based on statistical analysis were not attained, researchers report that a trend toward improvements are often observed that might not meet the level of statistical significance but that may be important to competitive athletes looking to improve their athletic performance by any amount in a positive direction. Regardless, dietary nitrates are certainly an interesting evolving area of sports and health nutrition to be aware of.

Scientific evidence is mounting, and Hoon and coworkers (2013) gathered and reviewed 17 studies. Nine studies used athletic trained subjects. Eight studies used recreationally fit subjects. All studies were controlled trials that employed a randomized crossover design involving a placebo condition and at least one condition using nitrate supplementation.

- 12 studies used beetroot as source of nitrate (11 juice, 1 whole beetroot).
- 5 studies used sodium nitrate, and 1 study used potassium nitrate.
- 8 studies looked at effects from single dosing 75 to 180 minutes before exercise.
- 10 studies used chronic dosing, ranging from several boluses over a 24-hour period before exercise, to 15 days of nitrate loading.
- Research evidence suggests dietary nitrate may aid in endurance exercise performance. Small benefits were observed in some studies.

Benefits for athletes and nonathletes are possible from dietary nitrates in terms of increasing physical endurance during exercise or athletic events and improving cardiovascular health. Although there are various foods and supplements that now contain ingredients like beetroot juice to boost dietary nitrate content, it is challenging to provide general dosage examples due to the other dietary factors that supply dietary nitrate or have similar NO-increasing effects, such as arginine, citrulline, and the following entry, Pycnogenol. Health concerns, such as lowering blood pressure from increasing NO in the body, causing vasodilation, may be a problem for some people. People interested in application of this new growing area of sports and healthy nutrition can consult the scientific references for additional details and contact sports nutrition and other health product companies that sell beetroot juice and other nitrate-containing products for safe and effective use under doctor supervision.

Pycnogenol

Pycnogenol is a trade name for a compound of natural antioxidants extracted from the bark of the French Maritime pine tree—Pinus pinaster, referred to as French Maritime pine bark extract. Loaded with bioflavonoids and other biologically active phytonutrients, or plant nutrients, Pycnogenol is backed by clinical research and a history of use. Studies show that Pycnogenol—a powerful antioxidant—has cardiovascular benefits, boosts the immune system, improves the appearance of the skin, treats varicose veins, relieves the pain of arthritis, and reduces inflammation.

Pycnogenol is indeed a bioflavonoid-containing plant extracts that has undergone numerous experimental and clinical research studies to determine its effects on the human body. Because Pycnogenol is a standardized extract—meaning that each batch of Pycnogenol contains the same amounts of bioflavonoids and procyanidins—other researchers can use it in their experiments to confirm the results of previous studies. This is one of the important criteria of scientific research—that experiments can be successfully reproduced by other researchers and important for consistency of beneficial effects. Once a substance becomes standardized, it often attracts much scientific attention to duplicate previous research and for new research.

The clinically proven benefits of Pycnogenol are numerous. Here are some benefits of interest to athletes:

- Increased nitric oxide in blood vessels, causing increased blood flow
- Antioxidant activity; reduced exercise-related oxidative stress
- Strengthening of capillary walls
- Improve healing time
- Reduce edema
- Alleviates cramping and muscular pain in sports
- Enhances sports endurance
- Increase in 2-mile running time
- Increase number of push-ups and sit-ups
- Swimming, biking, and running performance scores improved
- Triathlon time improved, reduced
- Improved cognitive function
- Skin, eye, joint, circulatory system health improvements
- Reasonable suggested daily dosage

Dosages reported to be effective in the research studies for athletes and fitness exercisers: 100–200 milligrams per day. Good record of safety based on research study dosages and duration of uses. Measurable benefits may take a few to several weeks.

Conclusion

Metabolites and botanicals are a diverse group of ingredients used in supplements. They can affect body function and structure; promote athletic performance, some exhibiting direct measurable ergogenic benefits; while others influence general body function that can support improved health. Duration of use is generally short, such as a few to several months, with some that may be suitable for long-term use, under doctor supervision. Evaluate during the off- and preseasons which of these supplements may provide a benefit for athletes. Keep detailed notes and use a scientific research approach evaluating one at a time to determine safety and effectiveness. Then, if appropriate, add another metabolite or botanical to the program that may provide even more benefits for improved athletic performance.

Summary of Commonly Available Botanicals, Standardization, and Use Examples

The following botanicals are commonly used by athletes and nonathletes. Fitness trainers and other health professionals can be confronted with discussing such botanical products with their clients. Although some of the botanicals may provide benefits that can improve health and or athletic performance, the primary intent of this table is for overview purposes and general knowledge.

The table contains the following columns:

- Botanical names. Common name and scientific name.
- Standardized constituent. Primary bio-active(s). But be aware that additional bio-actives may be present.
- Examples of Some Uses. Uses based on traditional use and or clinical research evidence. Additional uses may also exist.
- Personal Notes Section. A column for making various notes, such as dosages from product labels or other sources; input from other sources, health professionals and clients.

Note: The use of botanicals should be undertaken with caution and doctor supervision. Some herbs can be used on an almost a daily basis for health purposes, such as grape seed extract and garlic; while some herbs are intended for short-term use, which may range from several days, several weeks, or a few months at a time. The following table is for information purposes, and is not intended to replace medical advice. If you have any concerns about using a particular herb, consult your health-care practitioner and the product manufacturing company to confirm proper safe and effective usage.

Botanical **Names**	**Standarization** **Constituent**	**Examples of Some Uses** **Including Examples of Traditional Uses and Clinical Research Evidence- Based Uses.**	**Personal Notes Section**
Bilberry *Vaccinium myrtillus*	Anthocyanosides 15% to 25%	Supports eye health and visual acuity, treats eye disorders. Antioxidant.	
Bromelain *Ananas comosus*	Gelatin-digesting units (GDU) 2,000 GDU per gram	Treatment of sports injuries to promote healing and anti-inflammation.	
Black Cohosh *Cimicifuga racemosa*	Triterpenes (27-deoxyaceteine), 1%	Used to relieve symptoms associated with PMS and menopause.	
Chamomile *Matricaria chamomilla*	Apigenin,1% to 2% Essential Oil, 0.5%	Treats some gastrointestinal disturbances, and promotes calming.	
Echinacea *Echinacea purpurea* *E. angustifolia*	Phenolics, echinacosides, or sesquiterpene esters, 4%	Simulates immune system, treats colds and flu, and reduces associated symptoms and duration.	
Feverfew *Tanacetum parthenium*	Parthenolide, 0.1% to 1.2%	Prevents migraine headaches.	

Botanical Names	Standarization Constituent	Examples of Some Uses Including Examples of Traditional Uses and Clinical Research Evidence- Based Uses.	Personal Notes Section
Garlic *Allium sativum*	Allicin, 1%.	Lower cholesterol and blood pressure.	
Ginkgo *Ginkgo biloba*	Ginkgo flavone glycosides, 24%, and terpenes, 6%	Improves blood flow, brain function, and memory; antioxidant activity.	
Gotu kola *Centella asiatica*	Asiaticosides, 10% to 30%	Stimulates connective tissue development and healing; increases skin building; may improve mental function.	
Grape Seed Extract *Vitis vinifera*	Protanthocyanidins, 40% to 95%	Antioxidant, protects capillaries and connective tissues, decreases platelet aggregation, improves circulation.	
Green Tea *Camellia sinensis*	Catechins/polyphenols (epigallocatechin gallate), 50% to 65%. Also contains caffeine	Antioxidant; protects against digestive and respiratory infections. Preventative health for some cancers and cardiovascular disease. Weight-loss aid; thermogenic.	
Guarana *Paullinia cupana*	Xanthines: guaranine (natural caffeine), theobromine, theophylline), 12.5 to 60%	Stimulant activities due to xanthines; anti-fatigue; mild diuretic.	
Horse Chestnut *Aesculus hippocastanum*	Aescin, 2% to 12%	Increases tonus of veins. Used in treatment of hemorrhoids, varicose veins, and other venous insufficiencies.	
Kava Kava *Piper methysticum*	Kavalactones, 30%	Promotes relaxation, reduces anxiety, promotes restful sleep.	
Licorice root *Glycyrrhiza glabra*	Glycyrrhizin, 2 % to 12%.	Anti-inflammatory activity; used in treating GI ulcers, as an adrenal insufficiency, and as an expectorant.	
Milk Thistle *Silybum marianum*	Silymarin, 80%	Heals liver; liver protectant; counteracts some substances that damage liver.	
Rhodiola *Rhodiola rosea*	0.8–3% salidroside 1–6% rosavins	Adaptogen to temporary relieve symptoms of stress, such as mental fatigue and sensation of weakness. Supports cognitive function such as mental focus and stamina. Provides antioxidants.	
Saw Palmetto *Serenoa repens*	Fatty Acids (sterols), 80%	Used to treat benign prostatic hypertrophy. Reduces prostate inflammation. May reduce the conversion of some testosterone to estrogen.	
St. John's Wort *Hypericum perforatum*	Hypericin, 0.3%	Used to promote a positive mood and to reduce depression, nervousness, and anxiety.	
Turmeric *Curcuma longa*	Curcuminiods	Antioxidant, aid digestion, liver protectant, anti-inflammatory, relieves pain, and assists healing.	
Tribulus (Tribulin tm) *Tribulus terrestris*	Saponins (furanosterols), 20%	Traditionally used for impotence and anti-aging, not for muscle-building anabolic properties.	
Valerian Root *Valeriana officinalis*	Valerianic acids, 0.8%	Used for sleep, a sedative, and to reduce nervous tension.	
White Willow *Salix alba*	Salicin, 8%. Also contains salicortin and other phenolic glycosides	Reduces pain and inflammations.	

Key Words

Capillary

Creatinine

Topics Covered In This Unit

UNIT 10

GUIDE TO FOOD AND SUPPLEMENT PRODUCT LABELING

Unit Outline

I. **Introduction**

II. **All foods are not created equal**

III. **Understanding food and supplement labels**

a. Food and supplement labeling basics

i. Principal display panel (PDP)

ii. Nutritional Panel

b. Revised nutrition facts

i. Features a refreshed design

ii. Revised information and nutrition science

iii. Updated serving sizes and labeling requirements for certain package sizes

iv. Label format: original versus revised

v. Revised label with changes

vi. Serving size changes

vii. How does the FDA define "added sugars"?

viii. Why is trans fat still on the label if the FDA is phasing it out?

ix. Why are vitamin D and potassium being added to the Nutrition Facts label?

x. Why is the FDA no longer requiring vitamins A and C to be included on the label?

xi. Serving Sizes

IV. **Super foods: dietary supplements are born**

a. Revised Supplement Facts Panel

V. **Foods versus supplements**

VI. **Major dietary supplement forms and delivery systems**

VII. **Major categories of sport nutrition and supplements**

VIII. **The economics of sports nutrition**

IX. **Revised Daily Reference Values (DRVs) and Reference Daily Intakes (RDIs)**

X. **Conclusion**

Learning Objectives

After completing this unit, you will be able to:

- Define and describe terms related to food and supplement labeling and packaging;
- Discuss the different forms and types of supplements;
- Be aware of revised nutrition labeling and nutrient reference values for 2018; and
- Discuss application of "chrononutritionals."

Introduction

The nutrients, metabolites, and herbs described in previous units occur in different combinations and amounts as foods and supplements. Foods come in many types, such as **whole foods**, processed foods, frozen foods, canned foods, and aged foods. The selection of supplements is also quite diversified. Vitamins, minerals, herbs, many types of sports supplements, energy pills, and powdered meal replacements can be found on the shelves in the form of tablets, capsules, liquids, and powders.

Whole food: food that is in its natural, complete state; unprocessed food.

The growing available supply of food and supplement choices often leaves the athlete bewildered and forced into a great deal of trial and error shopping and experimentation. This unit will provide an overview of the different types of nutrient sources available to you so that you are familiar with the various options and can target the right stuff. This unit also reviews some of the main features of labels and labeling requirements required by FDA regulations.

Athletic Significance of Food and Sports Supplements

Food supplies the basic caloric and macronutrient intake of an athlete's diet.

Choose wholesome foods.

Avoid or minimize processed foods.

Avoid foods high in saturated fat, cholesterol, and sodium.

Choose foods high in complex carbohydrates and fiber, protein sources low in fat, foods high in nutrients (nutrient dense), and whole grains.

Eat several servings of fruits and vegetables each day.

Make use of Sport Nutrition Supplements.

Sports supplements can provide superior high performance nutrition.

Sports supplements are scientifically developed super foods that target athletes' special performance nutrition needs.

Scientific studies show that many sports supplements do improve performance and recovery, improve heath, and can even reduce risk of certain diseases.

All Foods Are Not Created Equal

From the start, you should know that the nutrient content of food varies considerably. This variation can occur from location to location and even within the same location from year to year. This inconsistency has been one major flaw in the nutrition approaches taken at the institutional level, which assume a potato from Idaho has the exact same nutrient content as a potato grown in Maine does. In the past, dealing with this unknown nutrient content variable was difficult, but with the help of today's modern food technology, meeting your special athletic nutrient demands is now more effectively accomplished. The use of special food preparations and sport supplements makes getting the performance nutrition you need more reliable and economical.

To add to this food saga, some foods tend to be healthier than others. The term "wholesome" has become a popular way to describe foods that are supposed to be fresh, healthy, and packed with nutrients. However, many marketing companies use "wholesome" to describe whatever food they are selling, including high-fat baked goods. The primary good foods to look for are fresh fruit and vegetables, whole grains and cereals, lean meats, fish, and poultry: whole foods.

In response to a growing demand to offer the consumer healthier foods, health food stores and the health food trade continues to grow, and health food sections can be found in grocery stores. Keep in mind that prior to the 1900s, before the invention and widespread use of the many chemicals used both on and in foods, the world was organic. Thus, it is interesting that after about 100 years of experimenting with chemicals in foods, the 21st century was greeted with the growing trend of more organic whole foods of local origin.

But even when eating the heathiest of foods, you need to watch the kind and the amounts you are eating. A common misconception is that you can eat as much as you want of every food found in a health food store. Nevertheless, eating even too much of a good thing can be unhealthy and can eventually slow you down. If you check the labels, you will see that many health foods are high in fat, albeit unsaturated healthy fats.

Aside from fresh whole foods, there are myriad processed foods. In some respects, processed foods are similar to supplements. They are made from various ingredients concocted to make edible (if not delicious) food products. Some processed foods may have reduced nutrition potential from the processing, but primarily they are typically loaded with chemical additives to help with the manufacturing process, increase shelf life, improve appearance, and add to flavor. In addition, it is common that processed foods are higher in fat or sodium content. Looking at processed foods as a group, you will see that some may offer poor nutrition choices; however, some like nutrition bars and drinks and frozen foods may offer adequate or healthier processed food choices. Also, fresh prepared processed foods of all types can be on the healthier side in general, due to being made, for example, at the stores, deli, bakery, juice bar, restaurants, farmer's markets, other local fresh prepared food product stores, or health food stores. The lesson

ORGANIC AGRICULTURE IN THE USA

According to the United States Department of Agriculture, organic agriculture produces products using methods that preserve the environment and avoid most synthetic materials, such as pesticides and antibiotics. USDA organic standards describe how farmers grow crops and raise livestock and which materials they may use.

Organic farmers, ranchers, and food processors follow a defined set of standards to produce organic food and fiber. Congress described general organic principles in the Organic Foods Production Act, and the USDA defines specific organic standards. These standards cover the product from farm to table, including soil and water quality, pest control, livestock practices, and rules for food additives.

- Organic farms and processors:
- Preserve natural resources and biodiversity
- Support animal health and welfare
- Provide access to the outdoors so that animals can exercise their natural behaviors
- Only use approved materials
- Do not use genetically modified ingredients
- Receive annual onsite inspections
- Separate organic food from non-organic food

for purchasing foods for preparation at home and when eating out is to do your homework to make sure they are the freshest, most nutritious foods available and read the nutrition information of food products to help select products that are healthier nutrition choices and nutrient dense.

What are the good things about processed foods? They generally taste great, and this is what keeps us coming back for more. Scientists speculate that the reason we crave snack foods is due to the nutrient content such as fat, simple carbohydrates, and sodium that were not plentiful eons ago when humans depended on hunting and gathering their food. To compensate for this, it seems we have evolved certain built-in cravings that, once triggered, allow us to consume large amounts of food containing these specific nutrients. That's why most of us can eat a pound of potato chips in a few minutes, but when it comes to the good stuff, like broccoli, we can't stand to eat even a few pieces. When striving for maximum performance, athletes must exercise willpower over what they eat. Stay away from the junk foods and the processed foods: eat the good stuff! One exception, supplements. Supplement products are a type of processed super-food, a type of food that is intentionally designed to be healthy, with multiple functions including supporting and promoting athletic performance and good health.

Understanding Food and Supplement Labels

Calorie: a unit of measurement used to express the energy value of food. Carbohydrates, fats, protein, and alcohol in the foods and drinks we eat provide food energy or "calories." Carbohydrates and proteins provide 4 calories per gram, fat has 9 calories per gram, and alcohol has 7 calories per gram.

How do you know what you are getting from the foods you eat? This is a good question with no simple answer. Look at the foods you have around your house. Although most products have a list of ingredients and some also have **calorie** and nutrients-per-serving information, most whole foods do not have any nutrients listed. No whole foods, the healthy foods that should constitute the majority of your diet—like fresh fruits, vegetables, fresh proteins, and so on—have labels on them displaying the nutrients supplied. Figuring out exactly what is supplied by the foods you eat can develop into a full-time job and therefore requires nutritional training on your part. You should make an effort to start learning what foods are good sources of the nutrients you and your clients need. This education can be accomplished by reading the nutrition labels of products that have Nutrition Facts and Supplement Facts part of labels. Start keeping track of what you are eating and teach your clients to do the same. By reading labels, you will be able to decide for yourself whether you should be eating a particular food. Start building a personal healthy food list for your clients. Have them rely on your experience and help them with understanding healthy food choices and building a healthy foods list of whole foods and processed foods.

Under the Food and Drug Administration's (FDA) nutrition labeling regulations, certain ingredients and nutrition information should be listed on most packaged foods. Food labels will have ingredient listings and other nutritional information, such as the amount of fat, protein, carbohydrates, and certain vitamins and minerals. By convention, ingredient charts will list each ingredient in descending order of predominance. If water is the first ingredient, then water is the most prevalent ingredient. This is only a qualitative listing, so you cannot determine exactly what amount of each ingredient you are getting. Therefore, additional nutritional information is provided, and it includes calories per serving, macronutrient content, and selected micronutrient content.

For the athlete, the nutrition information most useful is the total calories and macronutrient information. Because not all the micronutrients are listed, it is impossible to rely on nutrition label information to determine whether you are getting the micronutrients you need from food.

Food and Supplement Labeling Basics

The FDA actually has extensive regulations regarding every aspect of ingredients, packing, manufacturing, labeling, testing, and everything else related to the foods and supplements under its legal authority. Regarding labeling, there is a variety of required information along with rules on placement of the information within different parts of the labels, proper terminology, legal ingredients, size of the fonts used, and use of legal claims. The following provides the basics of food labeling, including the Principal Display Panel and the Information Panel.

Principal Display Panel (PDP).

The PDP, front of packaging contains:

- Product Brand Name
- Statement of Identity (Name of the food)
- Net Quantity of Product (Amount of product)

Information Panel

The Information Panel Contains:

- Nutrition Facts or Supplement Facts
- Ingredients or Other Ingredients List
- Required Major Allergens
- Name and Address of Manufacturer, Packager, or Distributor

REVISED NUTRITION FACTS

In 2016, the FDA published regulations to update the Nutrition Facts panel part of food labels—to be implemented by companies by 2018. Here is an overview of the revised Nutrition Facts Panel. The Nutrition Facts label is designed to provide information that can help consumers make informed choices about the food they purchase and consume. It is up to consumers to decide what is appropriate for them and their families' needs and preferences.

Features a Refreshed Design

The "iconic" look of the label remains, but important updates have been made to ensure consumers have access to the information they need to make informed decisions about the foods they eat. These changes include increasing the type size for "calories," "servings per container," and the "serving size" declaration and bolding the number of calories and the "serving size" declaration to highlight this information.

Manufacturers must declare the actual amount, in addition to percent Daily Value of vitamin D, calcium, iron, and potassium. They can voluntarily declare the gram amount for other vitamins and minerals.

The footnote is changing to better explain what percent Daily Value means. It will read: "*The % Daily Value tells you how much a nutrient in a serving of food contributes to a daily diet; 2,000 calories a day is used for general nutrition advice."

Revised Information and Nutrition Science

"Added sugars," in grams and as percent daily value will be included on the label. Scientific data show that it is difficult to meet nutrient needs while staying within calorie limits if you consume more than 10 percent of your total daily calories from added sugar, and this is consistent with the 2015–2020 Dietary Guidelines for Americans.

The list of nutrients that are required or permitted to be declared is being revised. Vitamin D and potassium will be required on the label. Calcium and iron will continue to be required. Vitamins A and C will no longer be required but can be included on a voluntary basis.

While continuing to require "Total Fat," "Saturated Fat," and "Trans Fat" on the label, "Calories from Fat" is being removed because research shows that the type of fat is more important than the amount is.

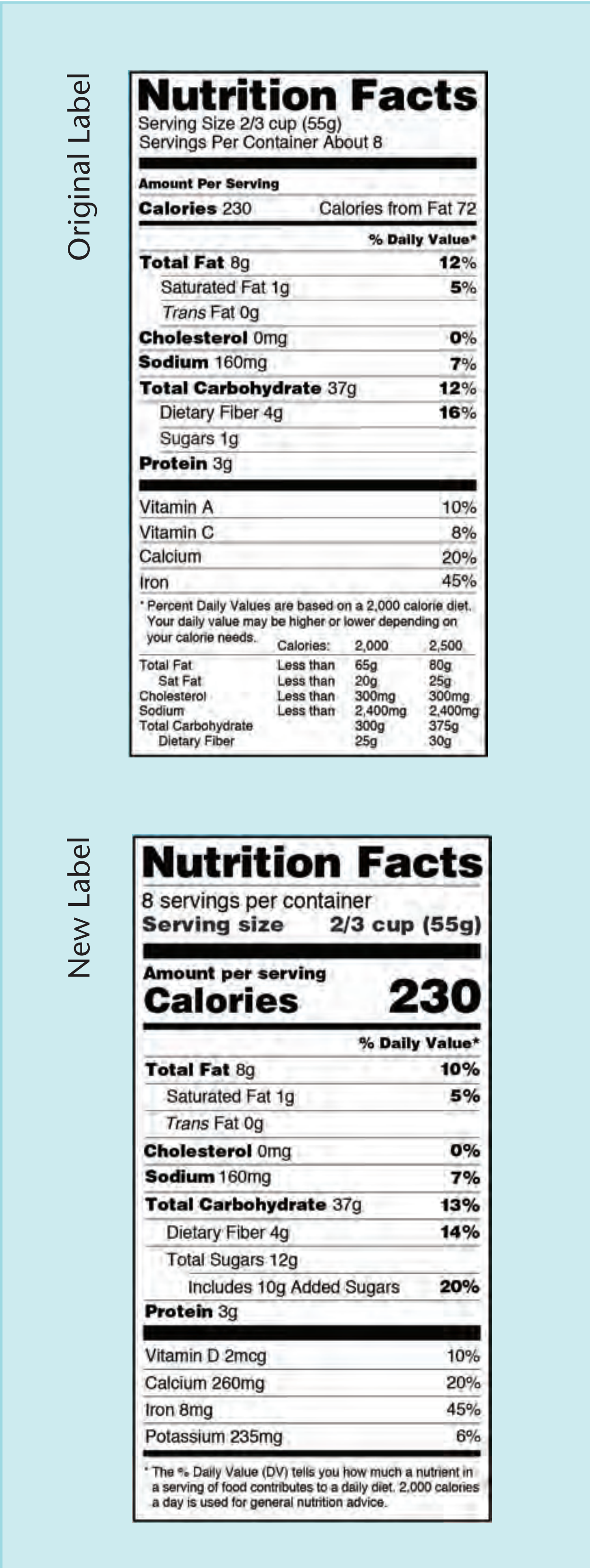
Daily values for nutrients such as sodium, dietary fiber, and vitamin D are being revised based on newer scientific evidence from the Institute of Medicine and other reports such as the 2015 Dietary Guidelines Advisory Committee Report, which was used in developing the 2015–2020 Dietary Guidelines for Americans. Daily values are reference amounts of nutrients to consume or not to exceed and are used to calculate the percent daily value (% DV) that manufacturers include on the label. The % DV helps consumers understand the nutrition information in the context of a total daily diet.

Updates Serving Sizes and Labeling Requirements for Certain Package Sizes

By law, serving sizes must be based on amounts of foods and beverages that people are actually eating, not what they should be eating. How much people eat and drink has changed since the previous serving size requirements were published in 1993. For example, the reference amount used to set a serving of ice cream was previously ½ cup but is being revised to ⅔ cup. The reference amount used to set a serving of soda is changing from 8 ounces to 12 ounces.

Package size affects what people eat. Thus for packages that are between one and two servings, such as a 20-ounce soda or a 15-ounce can of soup, the calories and other nutrients will be required to be labeled as one serving because people typically consume it in one sitting.

For certain products that are larger than a single serving but that could be consumed in one sitting or multiple sittings, manufacturers will have to provide "dual column" labels to indicate the number of calories and nutrients on both a "per-serving" and "per-package"/"per-unit" basis. Examples would be a 24-ounce bottle of soda or a pint of ice cream. With dual-column labels available, people will be able to easily understand how many calories and nutrients they are getting if they eat or drink the entire package/unit at once.



Label Format: Original vs. Revised

Note: The images are meant for illustrative purposes to show how the revised Nutrition Facts label might look compared with the old label. Both labels represent fictional products. When the original hypothetical label was developed in 2014 (the image on the left-hand side), added sugars was not yet proposed, so the "original" label shows 1g of sugar as an example. The image created for the "new" label (shown on the right-hand side) lists 12g total sugar and 10g added sugar to give an example of how added sugars would be broken out with a % Daily Value.

Revised Label with Changes

Serving Size Changes

What's considered a single serving has changed in the decades since the original nutrition label was created. Therefore, now serving sizes will be more realistic to reflect how much people typically eat at one time.

How does the FDA define "added sugars"?

The definition of added sugars includes sugars that are either added during the processing of foods, or are packaged as such, and consists of sugars (free, mono-, and disaccharides), sugars from syrups and honey, and sugars from concentrated fruit or vegetable juices that are in excess of what would be expected from the same volume of 100 percent fruit or vegetable juice of the same type. The definition excludes fruit or vegetable juice concentrated from 100 percent fruit juice that is sold to consumers (e.g., frozen 100 percent fruit juice concentrate) along with some sugars found in fruit and vegetable juices, jellies, jams, preserves, and fruit spreads.

Why is trans fat still on the label if the FDA is phasing out its use?

Trans fat will be reduced but not eliminated from foods, so FDA will continue to require it on the label. In 2015, the FDA published a final determination that partially hydrogenated oils (PHOs), the source of artificial *trans* fat, are not generally recognized as safe, but this determination will not affect naturally occurring *trans* fat, which will still exist in the food supply. *Trans* fat is present naturally in food from some animals, mainly ruminants such as cows and goats. In addition, industry can currently use some oils that are approved as food additives and can still petition the FDA for specific uses of PHOs.

Why are vitamin D and potassium being added to the Nutrition Facts label?

Vitamin D and potassium are nutrients that Americans do not always get enough of, according to nationwide food consumption surveys (http://www.cdc.gov/nchs/nhanes/), and when lacking, are associated with increased risk of chronic disease. Vitamin D is important for its role in bone health, and potassium helps lower blood pressure. Calcium and iron are already required to be included and will continue to be on the label.

Why is the FDA no longer requiring vitamins A and C?

In the early 1990s, American diets lacked vitamins A and C, but now vitamin A and C deficiencies in the general population are rare. Manufacturers can still list these vitamins voluntarily.

Serving Sizes

Some serving sizes will actually be bigger. That doesn't seem to make sense given the current obesity epidemic.

Some serving sizes will increase, and others will decrease because, by law, the serving sizes must be based on the amounts of food and drink that people typically consume, not on how much they *should consume*. Recent food consumption data show that some serving sizes need to be revised. For example, the reference amount used to set a serving of ice cream was previously ½ cup and now is changing to ⅔ cup. The reference amount used to set a serving size of soda was previously 8 ounces and now is changing to

12 ounces. The reference amount for yogurt is decreasing from 8 ounces to 6 ounces. Nutrient information on the revised label will be based on these revised serving sizes so it matches what people actually consume.

Super Foods: Dietary Supplements Are Born

It is unclear where the controversy stems from regarding dietary supplements, also referred to as supplements, food supplements, and nutrition supplements, but in the United States, the official term under FDA laws and regulations is dietary supplements. Supplements represent a major scientific advancement in nutrition, especially sports nutrition. Supplements are more highly regulated compared with conventional foods. Supplements have an overall better safety record, especially regarding rare incidences of food-borne illness, compared with millions of people each year who become ill from ingesting conventional foods. Supplements are intentionally made to be healthy. Supplements are a special category of food, similar to infant formulas and medical foods.

When thinking about supplements, think pasta (food), not penicillin (drug)!

When people think of supplements, they tend to relate them more to drugs than to food. This is partly due to the way they look (tablets, capsules, etc.,) and from their origins in clinical settings. It is also due in part because much of the scientific research is about medical use of the dietary ingredients used in supplements, and in some countries like Canada, the same dietary ingredients used in supplements have nutrition benefits and also disease treatment benefits. Thus, it depends. For example, caffeine is found in some conventional foods, in some drugs, and in dietary supplements. Glucosamine is another example; in the United States, as a supplement, glucosamine is claimed to support connective tissues and joint health. But based on additional clinical research among people with osteoarthritis, Health Canada approved disease treatment claims for glucosamine as a Natural Health Product for relieving pain associated with osteoarthritis in addition to the general maintaining good joint health claims. The unit about claims will elaborate on these issues related to foods and supplements.

The first use of nutrients as supplements likely originated in medical applications. Doctors and clinical nutritionists have long employed special nutrient solutions to feed their patients back to health. These products mainly consisted of intravenous solutions that delivered a liquid nutrient mix right into the bloodstream. Today, doctors prescribe supplements to many patients for a abundance of health reasons, particularly for post-surgery patients, young people, the elderly, and pregnant women. Use of nutrients to accelerate healing is also practiced in hospitals due to new research demonstrating the rapid recovery of patients who had surgery and took supplements to promote healing.

In spite of these clinical uses, it was not until the space program that mass-market potential use of supplements became a reality. It was during the early days of the space program, when scientists performed a wealth of research about feeding the astronauts with specially designed foods, in the form of meal replacements and supplements aimed at maintaining optimum health and performance, versus sick care of nutrition for survival. Among the many other spin-off benefits derived from the space program, supplements are another group of products with “astronaut” appeal. When scientists were preparing to send a man into space for the first time, they had no idea how his digestive system would react to a zero gravity environment. They also wanted to supply a complete diet to the astronauts and reduce the amount of waste products for practical reasons.

This space program nutrition research was a breakthrough for human nutrition because scientists had the funding to experiment on healthy, athletic individuals. Previous research relied mainly on laboratory animals and ailing hospital patients. For the first time, research would be conducted on healthy individuals to optimize their performance. The astronauts were subjected to numerous experiments in which their body weights, blood chemistry, and caloric output were measured along the way. Much vital information on nutrition and human physiology was gathered during this space age research.

Looking back to initial research published in the 1950s, we see that laboratory animals were first used to formulate what was to become known as “chemically defined diets.” Chemically defined diets are nothing more than liquid meals that contain a full profile of amino acids, vitamins, minerals, fatty acids, and so on that are required to support life. Through this research, much was learned about nutrition, growth, and health of laboratory animals. Once the hypotheses were tested, formulations were made and supplied to humans for refinement.

Going from a clinical setting to the mass market was a step that also occurred in the 1950s with weight-loss-related products. Researchers discovered that subjects eating only chemically defined diets would experience an immediate loss of body weight. It was also interesting to note that the initial weight loss of up to 11 pounds would occur only after a short period—several days. Scientists attributed this weight loss to clearance of bulk from the gastrointestinal tract and a drop in water weight. This contention was supported by the observed gain in weight following the first week of normal food after the break with the experimental liquid diets. Typically, subjects gained weight equal to that amount lost during the first week. This may explain why many of the meal replacement products now available on the market will produce an initial rapid loss of body weight, followed by a period of slower loss of body weight.

Ever since the 1960s, nutritional supplements have become increasingly widespread. Many categories of products have evolved as more and more research has discovered how nutrients can benefit health and performance. One of the first categories of sports supplements began with weight-gain powdered drinks. Use of these products has been widespread by bodybuilders, athletes, and teenagers seeking to increase body weight. An emerging subculture of health conscious individuals also uses supplements and eats healthy foods. Supplements are used by almost every person in the United States at some point in his or her life, and use is increasing. Sports nutrition represents one of the largest and fastest growing supplement categories because athletes know that they can derive better results when using these super foods as part of their total sports nutrition program.

Revised Supplement Facts Panel

Current Supplement Facts Panel Example

Supplement Facts

Serving Size 1 Tablet

	Amount Per Serving	% Daily Value
Vitamin A (as retinyl acetate and 50% as beta-carotene)	5000 IU	100%
Vitamin C (as ascorbic acid)	60 mg	100%
Vitamin D (as cholecalciferol)	400 IU	100%
Vitamin E (as dl-alpha tocopheryl acetate)	30 IU	100%
Thiamin (as thiamin mononitrate)	1.5 mg	100%
Riboflavin	1.7 mg	100%
Niacin (as niacinamide)	20 mg	100%
Vitamin B_6 (as pyridoxine hydrochloride)	2.0 mg	100%
Folate (as folic acid)	400 mcg	100%
Vitamin B_{12} (as cyanocobalamin)	6 mcg	100%
Biotin	30 mcg	10%
Pantothenic Acid (as calcium pantothenate)	10 mg	100%

Other ingredients: Gelatin, lactose, magnesium stearate, microcrystalline cellulose, FD&C Yellow No. 6, propylene glycol, propylparaben, and sodium benzoate.

Revised Supplement Facts Panel Example

Supplement Facts

Serving Size 1 Gelcap
Servings Per Container 100

	Amount Per Serving	% Daily Value
Vitamin A (as retinyl acetate and 50% as beta-carotene)	900 mcg	100%
Vitamin C (as ascorbic acid)	90 mg	100%
Vitamin D (as cholecalciferol)	20 mcg (800 IU)	100%
Vitamin E (as dl-alpha tocopheryl acetate)	15 mg	100%
Thiamin (as thiamin mononitrate)	1.2 mg	100%
Riboflavin	1.3 mg	100%
Niacin (as niacinamide)	16 mg	100%
Vitamin B_6 (as pyridoxine hydrochloride)	1.7 mg	100%
Folate	400 mcg DFE (240 mcg folic acid)	100%
Vitamin B_{12} (as cyanocobalamin)	2.4 mcg	100%
Biotin	3 mcg	10%
Pantothenic Acid (as calcium pantothenate)	5 mg	100%

Other ingredients: Gelatin, lactose, magnesium stearate, microcrystalline cellulose, FD&C Yellow No. 6, propylene glycol, preservatives (propylparaben and sodium benzoate).

Note some differences with Vitamin IU vs. mcg; Folate DFE and folic acid; Vitamin D with mcg and IU; different %DVs.

In 2016, the FDA published revised regulations to update the Supplement Facts panel portion of dietary supplement labels, to be implemented by companies by 2018. Here is an overview of the revised Supplement Facts panel. The Supplement Facts label is designed to provide information that can help consumers make informed choices about the food they purchase and consume. It is up to consumers to decide what is appropriate for themselves and for their families' needs and preferences.

More Supplement Facts Panel examples can be observed in the Appendix, where the regulation update is reprinted, along with other related labeling rule and format updates.

It is interesting to note that in the FDA examples, in addition to the expected essential macronutrients and micronutrients, the other types of dietary ingredients are also used, for example: German Chamomile, Hyssop, Oriental Ginseng, Betaine, Glutamic Acid, Inositol, *para*-aminobenzoic acid, Deoxyribonucleic acid, and boron. This helps debunk the controversy about the use of these types of ingredients in dietary supplement products.

Food Nutrients	Dietary Supplement Nutrients
Random amounts in the diet	Controlled, consistent amounts
Nutrients supplied indiscriminately	Target specific requirements
Small, inconsistent nutrient amounts	Concentrated, specific nutrient amounts
Varied bioavailability	Designed to be highly bioavailable
Contains calories, wanted and unwanted	Contains no calories or controlled caloric content
May dislike food supplying nutrients	No taste to "tablet-" type supplements.
Costly, time consuming, perishable	Convenient, long shelf life
Often more expensive, on a nutrient basis	Often less expensive, on a nutrient basis
Usually no instructions	Label/manufacturer use instructions
May have to overeat to get the nutrients needed	Nutrient dense, can avoid overeating unwanted calories
Mandatory, we must eat healthy foods	**Strategic nutritional use**

Foods versus Supplements

The above table lists some of the major points concerning how nutrients from foods and dietary supplements compare.

Major Dietary Supplement Forms and Delivery Systems

Supplements come in several types and forms. Supplement forms can also be referred to as delivery systems, a term borrowed from the pharmaceutical industry.

The major types of dietary supplement forms include:

Tablets	Powders
Caplets	Liquids
Capsules	Herbal Extracts
Softgels	Bars

Some of these forms are also used for conventional foods, such as powders, liquids, herbal extracts, and bars. When you examine a product label, the presence of a Supplement Facts panel or Nutrition Facts panel will further serve to help you identify the products type. Also on supplement products, the term Dietary Supplement, or Supplement as part of the statement of identity is located on the product's principal display panel. For example, Vitamin C Supplement can be used versus Dietary Supplement. Note that the labeling regulations are based on conventional food regulations that require naming the food or food type on the statement of identity. Thus, the FDA likely prefers companies using the name or names of the dietary ingredients as part of the statement of identity, like in the vitamin C supplement for example. But based on the supplement products on the shelves, it seems most product labels contain Dietary Supplement.

Tablets/Caplets. These start out as a powder blend of nutrients that are then pressed by machines into the characteristic tablet form. Tablets come in different shapes and sizes that are safe to swallow. Tablets are also made in chewable form. The term "caplet" is currently being used to describe tablets that are shaped as capsules. Originally, the caplet was a tamper proof, one-piece capsule with a hard outer layer and loosely bound contents.

Tablet delivery systems vary. Current manufacturing technology allows tablets to digest quickly, or provide to sustained release of nutrients, or even to provide time released nutrients. These features give tablets an edge over other pill form supplements. Tablets also have a long shelf life, typically two or more years. Tablets need to be made properly by experienced manufacturers to perform these dynamic delivery functions.

Capsules. These are delivery systems that consist of two halves into which a powder blend is injected. The two halves are brought together to form the capsule. In general, supplement capsules will be quickly digested. They are not designed with a sustained released system, and very few nutrient capsule products are timed released. Some capsules are made from plants, and most are from animal products.

Softgels. Softgels were developed to hold liquid nutrient supplements like lecithin, cod liver oil, and vitamin E. They consist of an outer gelatin shell, soft or hard, and an inner liquid. They are generally quickly digested and absorbed. Softgel manufacturing technology has advanced to allow a greater diversity of dietary ingredients to be contained in the softgel dosage form.

Powder Supplements. There are many types made for multiple reasons containing a wide diversity of nutrients. The most common powder formulations are protein powders, diet powders, energy powders, and weight-gain powders. Supplement powders are a convenient way to get high-quality nutrition in the exact amounts you need, when you need it. Many athletes have hectic schedules and cannot find the time to eat five to six complete meals per day (20 minutes each meal would be two hours just eating). Powdered nutrition supplements therefore provide a convenient high-density source of nutrition to meet individual needs. However, note that technically under FDA regulations, powder supplements can be used to supplement the diet, not replace a meal. But there are similar meal-replacement powder drink mix products with Nutrition Facts panels that do qualify as meal replacements.

Liquid Supplements. Liquid sport supplements include protein drinks, **carbohydrate drinks**, weight-gain drinks, herbal extracts, herbal tinctures, gels, and liquid vitamins and minerals. Many of these

Carbohydrate drink: a sports beverage designed to provide energy substrate and to replenish the glycogen (energy) stores.

Controlled-Release Supplements

Regarding the various controlled-release delivery systems, there are two primary reasons they are being used for dietary supplements. For example, dietary ingredients that would maintain higher potency by shielding them from digestion in the stomach or that would protect the stomach from ingredients that may cause upset or odorous regurgitation (like garlic). Then controlled release is used for ingredients that would benefit the body optimally when their release is slower and prolonged to maintain ideal levels in the bloodstream for longer periods. A combination of both of these controlled-release technologies can be applied to a tablet system and to some other systems developed by the pharmaceutical industry. Thus, control releasing a dietary supplement allows overall effectiveness to be enhanced.

Controlled-Release Technologies

Historically, controlled-release technologies for tablets were designed by the pharmaceutical industry. Since the development of the basic types of delayed-release and sustained-release systems, a variety of more sophisticated systems has been developed; however, the basic types are primarily in use in the dietary supplement industry, as their cost is typically more affordable, with some of the more sophisticated systems being more time consuming and expensive to make in comparison.

Development of controlled-release tablets generally uses the following types of technologies:

- **Enteric coating**, which is resistant to digestion in the stomach but is digestible in the intestines. Also referred to as delayed release.
- Sustained-release matrix, which forms a binder matrix that is more slowly digested. This results in a gradual or extended release of the dietary ingredients.
- Sustained-release pellets, which is a more involved process in producing, making it a higher priced approach compared with the sustained-release matrix. With pellets, a more sophisticated sustained-release delivery can be achieved. Timed-release is often used to describe these types of sophisticated controlled-release delivery system, especially with containing pellets with different coating thicknesses to be released in target areas of the intestines.
- Combination enteric coating and sustained-release matrix, which will protect ingredients susceptible to stomach acid breakdown and will perform sustained release in the intestines
- Some of the other more expensive controlled release systems include time-controlled explosion systems and sigmoidal-release systems.

In addition to tablet product applications, some controlled-release delivery system technologies are also suitable for other dosages systems: capsules, softgels, gelcaps, and liquidcaps. In fact, the classic timed-release product is pellets in a capsule.

continued on next page

ChronoNutritionals – Next Generation Dietary Supplements?

Although there is plenty of opportunity for controlled-release delivery systems to enhance dietary supplement effectiveness by delaying and or sustaining supplement release, an opportunity exists for creating the next generation line of products that are specifically designed to be synchronized to meet the body's metabolic demands created by the natural endogenous cycles, such as circadian rhythms. This approach was again pioneered in the pharmaceutical industry for enhancing the effectiveness of drugs based on the body's natural and disease-caused daily metabolic rhythms. Therefore, chronotherapeutics, chronopharamacokinetics, and chronopharmaceutics are terms that are gaining the attention of dietary supplement developers who are searching for innovations to create the next-generation series of scientifically advanced products. The nutrition industry is no stranger to the idea of nutrient timing of foods and supplements. This has become common practice in specialized areas of nutrition, such as sports nutrition, and for supplements for daytime or nighttime use and among some weight-loss products that are designed to ignite and sustain thermogenic and fat-burning effects during the day and even night, with or without stimulants. Thus, using controlled-release systems can be a vital technology for developing this next generation of dietary supplements: "chrononutritionals."

concoctions are also available in dry form, as either powders or solid dosage forms. Most common to the athlete are the host of carbohydrate drinks, gels, protein, and weight-gain drinks.

Enteric coating: a coating on tablets that delays digestion of the tablets until they pass from the stomach into the intestines.

Bars. Nutrition and supplement bars for athletes have been around for many years but are currently quite popular as more athletes recognize their value. They are designed to offer a way to get a scientifically developed snack that is high in healthy carbohydrates and protein and low in fat. This is the opposite of what most mass-market candy bars offer. Bars are a suitable delivery system for macronutrient, micronutrient, and specialty ergogenic ingredients offering high-density, scientifically engineered sports nutrition.

Major Categories of Sports Nutrition and Supplements

When you walk into any of the major health food stores, you will find up to half the store dedicated to hundreds of different sports nutrition and sports supplements. At first glance, it might seem that many of these products appear to be targeted to the bodybuilding or muscle-building crowd. But as you look more closely, you will see that there are sports nutrition products for every kind of athlete. When shopping online for sports nutrition products, it can be overwhelming to sort through the thousands of products. The following chart is a summary of some sports nutrition product categories/types typically encountered, including Nutrition Facts and Supplement Facts panel-bearing products.

Multivatims	Energy Drinks	Nutrition Bars
Multiminerals	Energy Gels	Nutrition Drinks
Protein	Pre-workout	Nutrition Powders
Amino Acids	During workout	Botanicals
Essential Fatty Acids	Post-workout	Creatine
Conjugated Linoleic Acid	Endurance	L-carnitine
Fish Oils	Weight gain	Beta-alanine
Carbohydrates	Weight loss	BCAAs
Fiber	Meal replacements	Nitric Oxide Boosters
Metabolites	Testosterone Support	Joint Support
Probiotics		

The Economics of Sports Nutrition

Eating the right foods is usually cheaper than eating a hit-or-miss diet that consists of large amounts of expensive restaurant cuisine and fast foods. However, because the typical athlete will eat about twice as much as would a nonathlete, use supplements, consume more beverages, and eat higher amounts of protein, the grocery bills can get expensive. The best approach is to plan and to look for coupons and sales. You may also consider teaming up with some of your friends, forming a co-op, and approaching wholesalers to buy products by the case at 20 percent to 60 percent off the regular retail price. Online retailers usually offer the biggest discounts, and when joining their email lists, you can often receive additional discounts.

When planning your nutrition program, you know that you will need a great many carbohydrate foods and protein foods. You should look for sales and buy these foods. Instead of purchasing a few pieces of chicken or meat here and there, buy a whole chicken and larger cuts of meat. The same is true for potatoes and pasta. In addition, drink a lot of water instead of expensive beverages that consist primarily of water anyway. Buy fresh vegetables and fruits on sale and freeze them for future use to minimize spoilage. Packaged frozen vegetables are also a good choice.

Although the selection of sports nutrition products, like nutrition bars, offers a good choice of athlete nutrition and performance enhancements that are convenient, consuming high quantities of these products can become expensive. To reduce costs of sports nutrition bars and have fresh-made options without the added chemicals, try making batches of homemade nutrition bars. These will also offer the added benefit of being to your exact liking, serving sizes customized to your caloric needs, and macronutrient content to suit nutrient timing goals, such as high-carbohydrate bars and a mix of carbohydrate, protein, and essential fatty acid bars.

Preparing meals to go is a signature characteristic of competitive athletes, who have a reputation for having an array of plastic food containers packed in their cooler bag along with their beverages. For people who do not have the time or talent, talk to family members or neighbors who like to cook and may be interested preparing to-go meals. In addition, the local healthy food restaurants, delis, juice bars, and other local healthy food establishments can be a vital to-go food resource. Some will even have the experience of preparing meals for athletes, a big plus. Some will work with you to make customer to-go meals, while keeping the costs down.

When eating out, select healthy restaurants with good quality food, good reputation, and a salad bar or buffet. These will offer the most food for the price and a nice diversity of foods to choose from. However, conversely, people who have trouble selecting the healthy food choices of a buffet or end up overeating to the point of gaining excess unwanted body fat, should avoid the buffets.

We all love to eat, and a sports nutrition diet can be tasty, diversified, fun, and affordable with a little effort and creativity.

Reference Daily Intakes: VItamins and Minerals Essential in Human Nutrition

According to the FDA's revised labeling regulations, the following RDIs, nomenclature, and units of measure are established for the following vitamins and minerals that are essential in human nutrition:

		RDI			
Nutrient	**Unit of measure**	**Adults and children ≥4 years**	**Infants**	**Children 1 through 3 years**	**Pregnant women and lactating women**
Vitamin A	Micrograms RAE	900	500	300	1,300
Vitamin C	Milligrams (mg)	90	50	15	120
Calcium	Milligrams (mg)	1,300	260	700	1,300
Iron	Milligrams (mg)	18	11	7	27
Vitamin D	Micrograms (mcg)	20	10	15	15
Vitamin E	Milligrams (mg)	15	5	6	19
Vitamin K	Micrograms (mcg)	120	2.5	30	90
Thiamin	Milligrams (mg)	1.2	0.3	0.5	1.4
Riboflavin	Milligrams (mg)	1.3	0.4	0.5	1.6
Niacin	Milligrams NE	16	4	6	18
Vitamin B	Milligrams (mg)	1.7	0.3	0.5	2.0
Folate	Micrograms DFE	400	80	150	600
Vitamin B	Micrograms (mcg)	2.4	0.5	0.9	2.8
Biotin	Micrograms (mcg)	30	6	8	35
Pantothenic acid	Milligrams (mg)	5	1.8	2	7
Phosphorus	Milligrams (mg)	1,250	275	460	1,250
Iodine	Micrograms (mcg)	150	130	90	290
Magnesium	Milligrams (mg)	420	75	80	400
Zinc	Milligrams (mg)	11	3	3	13
Selenium	Micrograms (mcg)	55	20	20	70
Copper	Milligrams (mg)	0.9	0.2	0.3	1.3
Manganese	Milligrams (mg)	2.3	0.6	1.2	2.6
Chromium	Micrograms (mcg)	35	5.5	11	45
Molybdenum	Micrograms (mcg)	45	3	17	50
Chloride	Milligrams (mg)	2,300	570	1,500	2,300
Potassium	Milligrams (mg)	4,700	700	3,000	5,100
Choline	Milligrams (mg)	550	150	200	550
Protein	Grams (g)	N/A	11	N/A	8

[1] RDIs are based on dietary reference intake recommendations for infants through 10 months of age.

[2] RAE = Retinol activity equivalents; 1 microgram RAE = 1 microgram retinol, 2 microgram supplemental β-carotene, 12 micrograms β-carotene, or 24 micrograms α-carotene, or 24 micrograms β-cryptoxanthin

[3] The amount of vitamin D may, but is not required to, be expressed in international units (IU), in addition to the mandatory declaration in mcg. Any declaration of the amount of vitamin D in IU must appear in parentheses after the declaration of the amount of vitamin D in mcg.

[4] 1 mg α-tocopherol (label claim) = 1 mg α-tocopherol = 1 mg RRR- α-tocopherol = 2 mg all rac-α-tocopherol.

[5] NE = Niacin equivalents, 1 mg NE = 1 mg niacin = 60 mg tryptophan.

[6] "Folate" and "Folic Acid" must be used for purposes of declaration in the labeling of conventional foods and dietary supplements. The declaration for folate must be in mfg DFE (when expressed as a quantitative amount by weight in a conventional food or a dietary supplement), and percent DV based on folate in mcg DFE. Folate may be expressed as a percent DV in conventional foods. When folic acid is added or when a claim is made about the nutrient, folic acid must be declared in parentheses, as mcg of folic acid.

[7] DFE = Dietary Folate Equivalents; 1 DFE = 1 mcg naturally-occurring folate = 0.6mcg folic acid.

[8] Based on the reference caloric intake of 2,000 calories for adults and children aged 4 years and older, and for pregnant women and lactating women.

Daily Reference Values: Food Components					
According to the FDA's revised labeling regulations, the following DRVs, nomenclature, and units of measure are established for the following food components:					
		DRV			
Food Component	**Unit of measure**	**Adults and children ≥4 years**	**Infants**	**Children 1 through 3 years**	**Pregnant women and lactating women**
Fat	Grams (g)	[1]78	30	[2]39	[1]78
Saturated fat	Grams (g)	[1]20	N/A	[2]10	[1]20
Cholesterol	Milligrams (mg)	300	N/A	300	300
Total carbohydrate	Grams (g)	[1]275	95	[2]150	[1]275
Sodium	Milligrams (mg)	2,300	N/A	1,500	2,300
Dietary Fiber	Grams (g)	[1]28	N/A	[2]14	[1]28
Protein	Grams (g)	[1]50	N/A	[2]13	N/A
Added Sugars	Grams (g)	[1]50	N/A	[2]25	[1]50

[1]Based on the reference caloric intake of 2,000 calories for adults and children aged 4 years and older, and for pregnant women and lactating women.

[2]Based on the reference caloric intake of 1,000 calories for children 1 through 3 years of age.

Revised Daily Reference Values (Drvs) and Reference Daily Intakes (RDIs)

In 2016, the FDA also published in its revised food and dietary supplement labeling regulations, updates to the RDIs and DRVs for the macronutrients and micronutrients. The predeeding tables present this revised nutrient reference information.

These revised nutrient intake values for product labeling appear to be an example of nutrition for survival, or barely so.

> How can adults and children four years or older have the same nutrient requirements?
>
> Consider the increased essential nutrient and caloric intake demands of athletes.

Conclusion

Consumers have more food and dietary supplement choices than ever, which can be used to perfect a winning sports nutrition program. The revised nutrition labeling may have practical implication to better assist athletes in making appropriate food choices.

Keywords

Whole food

Calorie

Carbohydrate drink

Enteric coating

Topics Covered In This Unit

UNIT 11

LABEL CLAIMS FOR CONVENTIONAL FOODS AND DIETARY SUPPLEMENTS

Unit Outline

I. Introduction

II. Claims for foods and dietary supplements

a. Nutrient content claims

b. Other nutrient content claim examples

c. Health claims

d. Health claims

e. Structure/function claims and related dietary supplement claims

f. Review of FDA's guidance related to structure/function claims for dietary supplements

III. Conclusion

Learning Objectives

After completing this unit, you will be able to:

- Define and describe key terms related to food and dietary supplement claims;
- List the types of scientific evidence required by the FDA to support claims;
- Discuss examples of structure/function claims and the related scientific evidence; and
- Distinguish between structure/function claims and drug/disease claims.

Introduction

In addition to product label and packaging content reviewed in another unit related to the nutrition information, product statement of identity, and contents, another way the FDA, and also the FTC, are involved with regulating foods and supplements is regarding claims made about the ingredients and their function. The FDA primarily is concerned with regulating claims on the product labeling, packaging, inserts, and other promotional materials directly associated with the products, whereas the FTC is primarily concerned with regulating claims in advertisements. There is certainly cooperation between the FDA and FTC when undertaking a regulatory compliance review of claims related to a particular product or products.

Regarding Canada's Natural Health Products, the country's regulatory agency, Health Canada, reviews, approves, and licenses each product. This includes ingredients, claims, and labeling. Health Canada also publishes ingredient monographs that include approved claims and other related information and product requirements. This unit is focused primarily on a special category of claims used in the United

States referred to as structure/function claims. Students interested in learning more about Health Canada's Natural Health Products should visit the website, which contains a library of reference documents.

Main webpage is found at

http://www.hc-sc.gc.ca/dhp-mps/prodnatur/index-eng.php

Ingredient monograph webpage is found at

http://webprod.hc-sc.gc.ca/nhpid-bdipsn/monosReq.do?lang=eng

Claims for Foods and Dietary Supplements

Among the claims that can be used on food and dietary supplement labels are three categories of claims: health, nutrient content, and structure/function.

A common general requirement is that claims must be truthful and not misleading. Certain types of claims require good-quality human studies as evidence to support a claim. Other claims, such as nutrient content claims, are published by the FDA in the regulations, so companies just need to know about these specific requirements and terminology.

Nutrient Content Claims

A nutrient content claims is a claim on a food product that directly or by implication characterizes the level of a nutrient in the food. Some examples of nutrient content claims include "low fat," "high in oat bran," "good source of vitamin C," or "contains 100 calories." The following tables are from the FDA's Food Labeling Guide and provide additional details related to nutrient claim examples. Note that the citation used in the tables "CFR" is the Code of Federal Regulations, Title 21, which are the official FDA regulations the summary information derives from.

Content Claims (“Free,” “Low,” “Reduced/Less”)

Free	Low	Reduced/Less	Comments
Synonyms for “Free”: “Zero,” “No,” “Without,” “Trivial Source of”, “Negligible Source of”, “Dietarily Insignificant Source of” Definitions for “Free” for meals and main dishes are the stated values per labeled serving but are not defined for calories	Synonyms for “Low”: “Little,” (“Few” for Calories), “Contains a Small Amount of”, “Low Source of”	Synonyms for “Reduced/Less”: “Lower” (“Fewer” for Calories) “Modified” may be used in statement of identity Definitions for meals and main dishes are same as for individual foods on a per 100 g basis	For “Free”, “Very Low”, or “Low”, must indicate if food meets a definition without benefit of special processing, alteration, formulation or reformulation; e.g., “broccoli, a fat-free food” or “celery, a low-calorie food”

Nutrient	Free	Low	Reduced/Less
Calories 21 CFR 101.60(b)	Less than 5 cal per RACC and per labeled serving (b)(1)	40 cal or less per RACC (and per 50 g if RACC is small) (b)(2) Meals and main dishes: 120 cal or less per 100 g (b)(3)	At least 25% less calories per RACC than an appropriate reference food (for meals and main dishes, at least 25% fewer calories per 100g) Reference food may not be “Low Calorie” Uses term “Fewer” rather than “Less” (b)(4) & (5)

Comments

“Light” or “Lite”: if 50% or more of the calories are from fat, fat must be reduced by at least 50% per RACC. If less than 50% of calories are from fat, fat must be reduced at least 50% or calories reduced at least 1/3 per RACC 21 CFR 101.56(b)

“Light” or “Lite” meal or main dish product meets definition for “Low Calorie” or “Low Fat” meal and is labeled to indicate which definition is met 21 CFR 101.56(d)

For dietary supplements: Calorie claims can only be made when the reference product is greater than 40 calories per serving 21 CFR 101.60(a)(4)

Nutrient	Free	Low	Reduced/Less
Total Fat 21 CFR 101.62(b)	Less than 0.5 g per RACC and per labeled serving (or for meals and main dishes, less than 0.5 g per labeled serving) (b)(1) Contains no ingredient that is fat or understood to contain fat, except noted below (*).	3 g or less per RACC (and per 50 g if RACC is small) (b)(2) Meals and main dishes: 3 g or less per 100 g and not more than 30% of calories from fat (b)(3)	At least 25% less fat per RACC than an appropriate reference food (or for meals and main dishes, at least 25% less fat per 100g) (b)(4) & (5) Reference food may not be “Low Fat”

Comments

“__% Fat Free”: may be used if food meets the requirements for “Low Fat” 21 CFR 101.62(b)(6)

100% Fat Free: food must be “Fat Free” (b)(6)(iii)

“Light”—see previous Calorie comments

For dietary supplements: total fat claims cannot be made for products that are 40 calories or less per serving 21 CFR 101.62(a)(4)

Content Claims ("Free," "Low," "Reduced/Less"), continued			
Nutrient	**Free**	**Low**	**Reduced/Less**
Saturated Fat 21 CFR 101.62(c)	Less than 0.5 g saturated fat and less than 0.5 g trans fatty acids per RACC and per labeled serving (or for meals and main dishes, less than 0.5 g saturated fat and less than 0.5 g trans fatty acids per labeled serving) (c)(1) Contains no ingredient that is understood to contain saturated fat except as noted below (*)	1 g or less per RACC and 15% or less of calories from saturated fat (c)(2) Meals and main dishes: 1 g or less per 100 g and less than 10% of calories from saturated fat (c)(3)	At least 25% less saturated fat per RACC than an appropriate reference food (or for meals and main dishes, at least 25% less saturated fat per 100g) (c)(4) & (5) Reference food may not be "Low Saturated Fat"
Comments			
Next to all saturated fat claims, must declare the amount of cholesterol if 2 mg or more per RACC, and the amount of total fat if more than 3 g per RACC (or 0.5 g or more of total fat per RACC for "Saturated Fat Free") (or for meals and main dishes, per labeled serving) 21 CFR 101.62(c) For dietary supplements: saturated fat claims cannot be made for products that are 40 calories or less per serving 21 CFR 101.62(a)(4)			
Nutrient	**Free**	**Low**	**Reduced/Less**
Cholesterol 21 CFR 101.62(d)	Less than 2 mg per RACC and per labeled serving (or for meals and main dishes, less than 2 mg per labeled serving) Contains no ingredient that contains cholesterol except as noted below (*) (d)(1)	20 mg or less per RACC (and per 50 g of food if RACC is small) (d)(2) Meals and main dishes: 20 mg or less per 100 g (d)(3)	At least 25% less cholesterol per RACC than an appropriate reference food (or for meals and main dishes, at least 25% less cholesterol per 100g) (d)(4) & (5) Reference food may not be "Low Cholesterol"
Comments			
Cholesterol claims only allowed when food contains 2 g or less saturated fat per RACC; or for meals and main dish products, per labeled serving size for "Free" claims or per 100 g for "Low" and "Reduced/Less" claims Must declare the amount of total fat next to cholesterol claim when fat exceeds 13 g per RACC and labeled serving (or per 50 g of food if RACC is small), or when the fat exceeds 19.5 g per labeled serving for main dishes or 26 g for meal products For dietary supplements: cholesterol claims cannot be made for products that are 40 calories or less per serving			
Nutrient	**Free**	**Low**	**Reduced/Less**
Sodium 21 CFR 101.61	Less than 5 mg per RACC and per labeled serving (or for meals and main dishes, less than 5 mg per labeled serving) (b)(1) Contains no ingredient that is sodium chloride or generally understood to contain sodium except as noted below (*) "Salt Free" must meet criterion for "Sodium Free" (c)(1)	140 mg or less per RACC (and per 50 g if RACC is small) (b)(4) Meals and main dishes: 140 mg or less per 100g (b)(5) "Very Low Sodium": 35 mg or less per RACC (and per 50g if RACC is small). For meals and main dishes: 35mg or less per 100g (b)(2) & (3)	At least 25% less sodium per RACC than an appropriate reference food (or for meals and main dishes, at least 25% less sodium per 100g) Reference food may not be "Low Sodium" (b)(6) & (7)
Comments			
"Light" (for sodium reduced 21 CFR products): if food is "Low Calorie" and "Low Fat" and sodium is reduced by at least 50%. 21 CFR 101.56(c)(1) "Light in Sodium": if sodium is reduced by at least 50% per RACC. 21 CFR 101.56(c)(2) For meals and main dishes, "Light in Sodium" meets definition for "Low in Sodium" 21 CFR 101.56(d)(2) "No Salt Added" and "Unsalted" must declare, "This is Not A Sodium Free Food" either adjacent to the claim or on the information panel. if food is not "Sodium Free" 21 CFR 101.61(c)(2) "Lightly Salted": 50% less sodium than normally added to reference food and if not "Low Sodium", so labeled on information panel 21 CFR 101.56(g)			

Content Claims ("Free," "Low," "Reduced/Less"), continued			
Nutrient	**Free**	**Low**	**Reduced/Less**
Sugars 21 CFR 101.60(c)	"Sugar Free": Less than 0.5 g sugars per RACC and per labeled serving (or for meals and main dishes, less than 0.5 g per labeled serving) (c)(1) Contains no ingredient that is a sugar or generally understood to contain sugars except as noted below (*) Disclose calorie profile (e.g., "Low Calorie")	Not Defined. May not be used	At least 25% less sugars per RACC than an appropriate reference food (or for meals and main dishes, at least 25% less sugar per 100g) May not use this claim on dietary supplements of vitamins and minerals (c)(5) & (6)
Comments			
"No Added Sugars" and "Without Added Sugars" are allowed if no sugar or sugar-containing ingredient is added during processing. State if food is not "Low" or "Reduced Calorie" (c)(2) The terms "Unsweetened" and "No Added Sweeteners" remain as factual statements (c)(3) The claim does not refer to sugar alcohols, which may be present. For dietary supplements: "Sugar Free" and "No Added Sugar" may be used for vitamins and minerals intended to be used by infants and children less than 2 years of age. (c)(4)			
Notes: * Except if the ingredient listed in the ingredient statement has an asterisk that refers to footnote (e.g., "* adds a trivial amount of fat"). RACC = Reference Amounts Customarily Consumed. Small RACC = Reference Amounts Customarily Consumed of 30 g or less or 2 tablespoons or less (for dehydrated foods that are typically consumed when rehydrated with water or a diluent containing an insignificant amount, as defined in 21 CFR 101.9(f)(1), of all nutrients per RACC, the per 50 g criterion refers to the prepared form of the food). When levels exceed: 13 g Total Fat, 4 g Saturated Fat, 60 mg Cholesterol, and 480 mg Sodium per RACC, per labeled serving or, for foods with small RACC, per 50 g, a disclosure statement is required as part of claim (e.g., "See nutrition information for content" with the blank filled in with nutrient(s) that exceed the prescribed levels). The term "light" may be used to describe a physical or organoleptic attribute of the food if it clearly conveys the nature of the product, e.g., "light in color," "light in texture." 21 CFR 101.56(e) If there has been a long history of use of the term "light" associated with a product it may continue to be used, e.g., "light corn syrup," "light brown sugar." 21 CFR 101.56(f) http://www.fda.gov/Food/GuidanceRegulation/GuidanceDocumentsRegulatoryInformation/LabelingNutrition/ucm064911.htm			

Other Nutrient Content Claim Examples

Claim	Requireent
"High," "Rich In," or "Excellent Source Of"	Contains 20% or more of the DV per RACC. May be used on meals or main dishes to indicate that the product contains a food that meets the definition but may not be used to describe the meal. 21 CFR 101.54(b)
"Good Source," "Contains," or "Provides"	10%-19% of the DV per RACC. These terms may be used on meals or main dishes to indicate that the product contains a food that meets the definition but may not be used to describe the meal. 21 CFR 101.54(e)
"More," "Fortified," "Enriched," "Added," "Extra," or "Plus"	10% or more of the DV per RACC than an appropriate reference food. May only be used for vitamins, minerals, protein, dietary fiber, and potassium. 21 CFR 101.54(e)
"Lean"	On **seafood** or game meat products that contain less than 10g total fat, 4.5g or less saturated fat, and less than 95mg cholesterol per RACC and per 100g (for meals & main dishes, meets criteria per 100g and per labeled serving). On mixed dishes not measurable with a cup (as defined in 21 CFR 101.12(b) in table 2) that contain less than 8g total fat, 3.5g or less saturated fat and less than 80 mg cholesterol per RACC. 21 CFR 101.62(e)(1)-(3)
"Extra Lean"	On seafood or game meat products that contains less than 5g total fat, less than 2g saturated fat and less than 95mg cholesterol per RACC and per 100g (for meals and main dishes, meets criteria per 100g and per labeled serving). 21 CFR 101.62(e)(4) & (5)
"High Potency"	May be used on foods to describe individual vitamins or minerals that are present at 100% or more of the RDI per RACC or on a multi-ingredient food product that contains 100% or more of the RDI for at least 2/3 of the vitamins and minerals with RDIs and that are present in the product at 2% or more of the RDI (e.g., "High potency multivitamin, multimineral dietary supplement tablets"). 21 CFR101.54(f)
"Modified"	May be used in statement of identity of a food that bears a relative claim (e.g., "Modified fat cheesecake, contains 35% less fat than our regular cheesecake.") 21 CFR 101.13(k)
"Fiber" Claims	If a fiber claim is made and the food is not low in total fat, then the label must disclose the level of total fat per labeled serving. 21 CFR 101.54(d)(1)
Claims using the term "antioxidant"	For claims characterizing the level of antioxidant nutrients in a food: 1. an RDI must be established for each of the nutrients that are the subject of the claim; 2. each nutrient must have existing scientific evidence of antioxidant activity; 3. the level of each nutrient must be sufficient to meet the definition for "high," "good source," or "more"; Beta-carotene may be the subject of an antioxidant claim when the level of vitamin A present as beta-carotene in the food is sufficient to qualify for the claim. 4. Name(s) of nutrient(s) that is (are) the subject of the claim is (are) included as part of the claim. (e.g., high in antioxidant vitamins C & E) 21 CFR 101.54(g)

Seafood: marine animals that live in the sea and in freshwater lakes and rivers. Seafood includes fish (e.g., salmon, tuna, trout, and tilapia) and shellfish (e.g., shrimp, crab, and oysters).

Health Claims

The FDA reviews and authorizes health claims. Health claims describe a relationship between a food substance (a food, food component, or dietary supplement ingredient) and reduced risk of a disease or health-related condition. There are a few categories of health claims, and some examples are presented herein.

A "health claim" by definition has two essential components: (1) a substance (whether a food, food component, or dietary ingredient) and (2) a disease or health-related condition. A statement lacking either one of these components does not meet the regulatory definition of a health claim. For example, statements that address a role of dietary patterns or of general categories of foods (e.g., fruits and vegetables) in maintaining good health are considered dietary guidance rather than health claims. Dietary guidance statements used on food labels must be truthful and non-misleading. Note that statements related to a role of a specific substance in maintaining normal healthy structures or functions of the body are considered structure/function claims, reviewed in a following section. Structure/function claims are not related to a disease. Improving athletic performance, increasing muscle growth, and improving appetite control would be some examples of structure/function claims.

NLEA-Authorized Health Claims. The Nutrition Labeling and Education Act of 1990 (NLEA) gives the FDA authority to require nutrition labeling of most foods regulated by the agency; and to require that all nutrient claims and health claims meet FDA regulations. FDA authorizes these types of health claims based on an extensive review of the scientific literature, generally as a result of the submission of a health claim petition, using the significant scientific agreement standard to determine whether the substance/disease relationship is well established. They are also referred to as health claims meeting significant scientific agreement (SSA).

The following table presents some examples of NLEA-Authorized Health Claims.

Examples of NLEA-Authorized Health Claims			
Approved Claims	**Requirements for the Food**	**Claim Requirements**	**Model Claim, Statements**
Calcium and Osteoporosis and calcium, vitamin D, and osteoporosis (21 CFR 101.72)	For calcium and osteoporosis claim-high in calcium For calcium, vitamin D and osteoporosis claim-high in calcium and vitamin D -assimilable (Bioavailable) Supplements must disintegrate and dissolve, and Phosphorus content cannot exceed calcium content	The claim makes clear the importance of adequate calcium intake, or when appropriate, adequate calcium and vitamin D intake, throughout life, in healthful diet, are essential to reduce osteoporosis risk. The claim does not imply that adequate calcium intake, or when appropriate, adequate calcium and vitamin D intake, is the only recognized risk factor for the development of osteoporosis. The claim does not attribute any degree of reduction in risk of osteoporosis to maintaining an adequate dietary calcium intake, or when appropriate, an adequate dietary calcium and vitamin D intake, throughout life.	Calcium and Osteoporosis: Adequate calcium throughout life, as part of a well-balanced diet, may reduce the risk of osteoporosis. Calcium, vitamin D, and osteoporosis: Adequate calcium and vitamin D, as part of a well-balanced diet, along with physical activity, may reduce the risk of osteoporosis.
Dietary Fat and Cancer (21 CFR 101.73)	(Fish & game meats: “Extra lean“)	Required terms: “Total fat” or “Fat” “Some types of cancers” or “Some cancers” Does not specify types of fats or fatty acids that may be related to risk of cancer.	Development of cancer depends on many factors. A diet low in total fat may reduce the risk of some cancers.
Sodium and Hypertension (21 CFR 101.74)	Low sodium	Required terms: “Sodium“, “High blood pressure“ Includes physician statement (Individuals with high blood pressure should consult their physicians) if claim defines high or normal blood pressure	Diets low in sodium may reduce the risk of high blood pressure, a disease associated with many factors.
Dietary Saturated Fat and Cholesterol, and risk of Coronary Heart Disease (21 CFR 101.75)	Low saturated fat, Low cholesterol, and Low fat	Required terms: Saturated fat and cholesterol, “Coronary heart disease“ or “heart disease“ Includes physician statement (individuals with elevated blood total--or LDL--cholesterol should consult their physicians) if claim defines high or normal blood total--and LDL--cholesterol.	While many factors affect heart disease, diets low in saturated fat and cholesterol may reduce the risk of this disease.
Fiber-Containing Grain Products, Fruits, and Vegetables and Cancer (21 CFR 101.76)	A grain product, fruit, or vegetable that contains dietary fiber; Low fat, and Good source of dietary fiber (without fortification)	Required terms: “Fiber“, “Dietary fiber“, or “Total dietary fiber“ “Some types of cancer“ or “Some cancers“ Does not specify types of dietary fiber that may be related to risk of cancer.	Low fat diets rich in fiber-containing grain products, fruits, and vegetables may reduce the risk of some types of cancer, a disease associated with many factors.
http://www.fda.gov/Food/GuidanceRegulation/GuidanceDocumentsRegulatoryInformation/LabelingNutrition/ucm064919.htm			

Health Claims Based on Authoritative Statements. The Food and Drug Administration Modernization Act of 1997 (FDAMA) provides a second way for the use of a health claim in food labeling to be authorized. Under FDAMA, a new health claim can be authorized by submitting a notification to FDA of a claim based on an "authoritative statement" from certain scientific bodies of the US government or the National Academy of Sciences, for example, whole grains reducing the risk of heart disease. The following table presents additional examples of FDAMA health claims from the FDA.

FDAMA (FDA Modernization Act) Health Claims (Health Claims Authorized Based on an Authoritative Statement by Federal Scientific Bodies)

Approved Claims	Food Requirements	Claim Requirement	Model Claim Statements
Whole Grain Foods and Risk of Heart Disease and Certain Cancers (Docket No. 1999P-2209)	Contains 51% or more whole grain ingredients by weight per RACC, and Dietary fiber content at least: • 3.0 g per RACC of 55 g • 2.8 g per RACC of 50 g • 2.5 g per RACC of 45 g • 1.7 g per RACC of 35 g	Required wording of the claim: "Diets rich in whole grain foods and other plant foods and low in total fat, saturated fat, and cholesterol may reduce th	NA
Potassium and the Risk of High Blood Pressure and Stroke (Docket No. 2000Q-1582)	Good source of potassium Low sodium Low total fat Low saturated fat Low cholesterol	Required wording of the claim: "Diets containing foods that are a good source of potassium and that are low in sodium may reduce the risk of high blood pressure and stroke."	NA
Fluoridated Water and Reduced Risk of Dental Carries (Docket No. 2006Q-0418)	Bottled water meeting the standards of identity and quality set forth in 21 CFR 165.110 Meet all general requirements for health claims in 21 CFR 101.14) with the exception of the minimum nutrient contribution (21 CFR 101.14(e)(6)), Total Fluoride: >0.6 to 1.0 mg/L Excluding bottled water products	Required wording of the claim: "Drinking fluoridated water may reduce the risk of [dental caries or tooth decay]."	NA
Saturated Fat, Cholesterol, and Trans Fat, and Reduced Risk of Heart Disease (Docket No. 2006Q-0458)	Low saturated fat Low cholesterol Bear quantitative trans fat labeling Contain less than 0.5 g trans fat per RACC Contain less than 6.5 g total fat	Required wording of the claim: "Diets low in saturated fat and cholesterol, and as low as possible in *trans* fat, may reduce the risk of heart disease."	NA
Substitution of Saturated Fat in the Diet with Unsaturated Fatty Acids and Reduced Risk of Heart Disease (Docket No. 2007Q-0192)	Low fat Low cholesterol Meets all general requirements for health claims in 21 CFR 101.14	Required wording of the claim: "Replacing saturated fat with similar amounts of unsaturated fats may reduce the risk of heart disease. To achieve this benefit, total daily calories should not increase."	NA
http://www.fda.gov/Food/GuidanceRegulation/GuidanceDocumentsRegulatoryInformation/LabelingNutrition/ucm064919.htm			

Qualified Health Claims. This is a special category for health claims resulting from a lawsuit filed by industry members against the FDA. This allows for the submission of health claims that are based on emerging research that might not have yet met the level of significant scientific agreement standard used for NLEA-authorized health claims. The compromise that was reached for health-claim submissions based on emerging scientific evidence resulted in a system in which the FDA authorizes a claim with a disclaimer to alert a consumer as to its opinion about the level of research. The following provides examples of claims and disclaimer statements for phosphatidylserine.

Dementia claim and disclaimer:

"Consumption of phosphatidylserine may reduce the risk of dementia in the elderly.

Very limited and preliminary scientific research suggests that phosphatidylserine may reduce the risk of dementia in the elderly. FDA concludes that there is little scientific evidence supporting this claim."

Cognitive dysfunction claim and disclaimer:

"Consumption of phosphatidylserine may reduce the risk of cognitive dysfunction in the elderly.

Very limited and preliminary scientific research suggests that phosphatidylserine may reduce the risk of cognitive dysfunction in the elderly. FDA concludes that there is little scientific evidence supporting this claim."

http://www.fda.gov/Food/IngredientsPackagingLabeling/LabelingNutrition/ucm072999.htm

Structure/Function Claims and Related Dietary Supplement Claims

Structure/function claims have historically appeared on the labels of conventional foods and dietary supplements and drugs. The Dietary Supplement Health and Education Act of 1994 (DSHEA) established some special regulatory requirements and procedures for using structure/function claims and two related types of dietary supplement labeling claims, claims of general well-being, and claims related to a nutrient deficiency disease.

Structure/function claims may describe the role of a nutrient or dietary ingredient intended to affect the normal structure or function of the human body, for example, "calcium builds strong bones." In addition, they may characterize the means by which a nutrient or dietary ingredient acts to maintain such structure or function, for example, "fiber maintains bowel regularity," or "antioxidants maintain cell integrity."

General well-being claims describe general well-being from consumption of a nutrient or dietary ingredient. Nutrient deficiency disease claims describe a benefit related to a nutrient deficiency disease (like vitamin C and scurvy), but such claims are allowed only if they also say how widespread the disease is in the United States.

What is the definition of a disease?

Section 101.93(g) defines disease as:

...damage to an organ, part, structure, or system of the body such that it does not function properly (e.g., cardiovascular disease), or a state of health leading to such dysfunctioning (e.g., hypertension); except that diseases resulting from essential nutrient deficiencies (e.g., scurvy, pellagra) are not included in this definition.

http://www.fda.gov/Food/GuidanceRegulation/GuidanceDocumentsRegulatoryInformation/ucm103340.htm

Note that in the United States, these three types of claims are not pre-approved by the FDA, but the manufacturer must have substantiation that the claim is truthful and not misleading and must submit a notification with the text of the claim to the FDA no later than 30 days after marketing the dietary supplement with the claim. If a dietary supplement label includes such a claim, it must state in a "disclaimer" that the FDA has not evaluated the claim. The disclaimer must also state that the dietary supplement product is not intended to "diagnose, treat, cure, or prevent any disease," because only a drug can legally make such a claim (with the exception of an approved Health Claim, and reduction of diseases.) It is through this notification process that the FDA has the chance to review the structure/function claims a company is using on its product labels, and the FDA can and does contact a company if it has issues with claims—for example, if the claim is a drug claim, or if the FDA is aware of claims being used that are not supported by the scientific evidence.

Structure/function claims for conventional foods focus on effects derived from nutritive value, whereas structure/function claims for dietary supplements may focus on non-nutritive and nutritive effects. The FDA does not require conventional food manufacturers to notify the FDA about their structure/function claims, and disclaimers are not required for claims on conventional foods.

Review of FDA's Guidance Related to Structure/Function Claims for Dietary Supplements

The following will be a comprehensive review, including excerpting FDA's publication "Guidance for Industry: Substantiation for Dietary Supplement Claims Made Under Section 403(r) (6) of the Federal Food, Drug, and Cosmetic Act." US Department of Health and Human Services, Food and Drug Administration, Center for Food Safety and Applied Nutrition, December 2008.

http://www.fda.gov/Food/GuidanceRegulation/GuidanceDocumentsRegulatoryInformation/DietarySupplements/ucm073200.htm

Due to the tens of thousands of dietary supplement products, including sports nutrition supplements, bearing a variety of structure/function claims, students have requested more information in this area of the FDA regulation requirements. The next several pages will therefore contain information reprinted from the FDA's guidance document, with some minor editing, which is within public domain. The unedited guidance document can be viewed online at the aforementioned website address.

[Start of FDA's Guide Excerpt]

Section 403(r)(6) of the Federal Food, Drug, and Cosmetic Act (the Act) (21 U.S.C. 343(r)(6)) requires that a manufacturer of a dietary supplement making a nutritional deficiency, structure/function, or general well-being claim (2) have substantiation that the claim is truthful and not misleading.

Under the Act, FDA has exclusive jurisdiction over the safety, and primary jurisdiction over the labeling, of dietary supplements. The FTC has primary jurisdiction over advertisements for dietary supplements. Given these jurisdictional assignments, we and the FTC share an interest in providing guidance on what "substantiation" means. In April 2001, FTC issued a guidance document entitled, "Dietary Supplements: An Advertising Guide for Industry." (6) Our guidance document is modeled on, and complements, the FTC guidance document.

Dietary supplement manufacturers should be familiar with the requirements under both DSHEA and the Federal Trade Commission Act that they have substantiation that labeling and advertising claims are truthful and not misleading. Our approach provides manufacturers flexibility in the precise amount and type of evidence that constitutes adequate substantiation. Providing a standard for substantiation may also help to preserve consumer confidence in these products. To ensure compliance with the Act, we recommend that dietary supplement manufacturers carefully draft their labeling claims and carefully review the support for each claim to make sure that the support relates to the specific product and claim, is scientifically sound, and is adequate in the context of the surrounding body of evidence.

The FTC has typically applied a substantiation standard of "competent and reliable scientific evidence" to claims about the benefits and safety of dietary supplements and other health-related products. FDA intends to apply a standard for the substantiation of dietary supplement claims that is consistent with the FTC approach. This guidance document, using examples of claims that might be made for a dietary supplement, describes criteria to be considered in evaluating the nature of the claim and the amount, type, and quality of evidence in support of the claim.

A. What is the Substantiation Standard?

The FTC standard of competent and reliable scientific evidence has been defined in FTC case law as “tests, analyses, research, studies, or other evidence based on the expertise of professionals in the relevant area, that has been conducted and evaluated in an objective manner by persons qualified to do so, using procedures generally accepted in the profession to yield accurate and reliable results.”(7)

Although there is no preestablished formula regarding how many or what type of studies are needed to substantiate a claim, we, like the FTC, will consider what the accepted norms are in the relevant research fields and consult experts from various disciplines. If there is an existing standard for substantiation developed by a government agency or other authoritative body, we may accord some deference to that standard.

In determining whether the substantiation standard has been met with competent and reliable scientific evidence, we recommend that firms consider the following issues in their assessments:

1. The meaning of the claim(s) being made
2. The relationship of the evidence to the claim
3. The quality of the evidence
4. The totality of the evidence

Each of these issues is discussed further in this guidance.

B. Identifying the Meaning of the Claim

The first step in determining what information is needed to substantiate a claim for a dietary supplement is to understand the meaning of the claim and to clearly identify each implied and expressed claim. When a claim may have more than one reasonable interpretation, we recommend that a firm have substantiation for each interpretation. Consumer testing may be useful to determine consumer understanding of each claim, in context. We recommend that firms focus on not only individual statements or phrases but also on what expected effect or benefit is being promoted when all the statements being made for the product are considered together. Although it is important that individual statements be substantiated, it is equally important to substantiate the overall “message” contained when the claims are considered together.

Example 1: The label of a dietary supplement containing "X" uses the following claims: "The amino acid 'X' is the chemical precursor to nitric oxide. Blood vessel cells contain enzymes that produce nitric oxide. Nitric oxide is important in maintaining blood vessel tone." Assuming this statement were supported by sound science so that each individual statement has been substantiated, the "message" conveyed by the claims, when considered together, is that taking oral "X" will affect nitric oxide production and blood vessel tone. Therefore, we recommend in this case that the dietary supplement manufacturer have substantiation that taking the amount of "X" provided by the product affects nitric oxide production and blood vessel tone under the product's recommended conditions of use.

The firm's clear understanding of the meaning of the claim is useful in ensuring that the evidentiary basis for substantiation is appropriate for the claim. Understanding the claim's meaning will help identify the appropriate study hypotheses and measurable endpoints, which can be used to ensure that the firm has appropriate studies to substantiate the claim. For example, a firm making a claim that a dietary supplement "helps maintain blood vessel tone" or "supports healthy immune system" should have a clear understanding of the claim's meaning to develop endpoints that could be measured and replicated in studies used as a basis for substantiation.

Example 2: The labeling of a dietary supplement includes the statement "promotes weight loss." The dietary supplement contains various vitamins and minerals and a botanical extract. The manufacturer relies on a randomized controlled double-blind clinical study showing that subjects who took the botanical extract had a small but significant increase in metabolism over subjects taking a placebo over a 24-hour period. The study did not examine the effect of the extract on subjects' weight, and there is no research showing that a short-term increase in metabolism will translate into any measurable weight loss. The weight-loss claim would likely not be adequately substantiated.

Example 3: The labeling for a dietary supplement contains a statement saying, "Recommended by Scientists," in connection with the product's claim. The statement gives consumers the impression that there is a body of scientists, qualified experts, who believe that the claim being made is supported by evidence. Consumers might also reasonably interpret the statement as meaning that there is general scientific agreement or consensus regarding the claim. If the manufacturer does not possess evidence to demonstrate such a consensus, the claim may not be substantiated. The opinion of a single scientist or small group of scientists not adequate substantiation for such a claim.

Example 4: The labeling states, in connection with the product's claim, that the dietary supplement has been "studied for years" in a particular country or region and is the subject of clinical or "university" research. Here, the labeling conveys the impression that the product has been studied and also conveys the impression that there is a substantial body of competently conducted scientific research supporting the claim. We recommend that manufacturers possess evidence to substantiate both the express statements and their implied meaning.

C. The Relationship of the Evidence to the Claim

Whether studies or evidence has a relationship to the specific claim being made or to the dietary supplement product itself is an important consideration in determining whether a claim is substantiated. The following are some threshold questions in determining this relationship:

- Have the studies specified and measured the dietary supplement that is the subject of the claim? We recommend that the studies being used as substantiation for dietary supplement claims identify a specific dietary supplement or ingredient and serving size and that the conditions of use in the studies are similar to the labeling conditions of the dietary supplement product. Factors that would tend to indicate a stronger relationship between a substance that is the subject of a study and the substance that is the subject of the dietary supplement claim include similarities in formulation, serving size, route of administration, total length of exposure, and frequency of exposure. Manufacturers should be aware that other substances involved in the study or included in the dietary supplement product itself might also affect the dietary supplement's performance or the study results.

Example 5: To illustrate this issue, assume that a firm has high-quality studies that are also consistent with the totality of the scientific evidence. The firm would like to use these studies to substantiate a claim that its dietary supplement has a particular effect on the human body, but the studies involved the effect of a specific ingredient in foods on the human body and did not involve the dietary supplement product itself. In this instance, although the studies might be of high quality, the results of these studies of conventional foods are not applicable to the specific dietary supplement product. (8)

- Have the studies appropriately specified and measured the nutritional deficiency, structure/function, or general well-being that is the subject of the claim? We recommend that the studies clearly identify the endpoints that are to be used to substantiate the claimed effect.
- Were the studies based on a population that is similar to that which will be consuming the dietary supplement product? For example, if the study involved young adults, but the product's claims involve conditions seen only in the elderly, the study might not be applicable to the claims.
- Does the claim accurately convey to consumers the extent, nature, or permanence of the effect achieved in the relevant studies and the level of scientific certainty for that effect?

A note on foreign research: Foreign research could be sufficient to substantiate a claim as long as the design and implementation of the foreign research are scientifically sound and the foreign research pertains to the dietary supplement at issue. In evaluating data from studies conducted in a foreign population, care should be taken in extending the results to what might be expected in consumers in the United States who will use the product. Differences between the two populations, such as differences in diets, general health, or patterns of use, could confound the results. In addition, it is important to make sure that the study examined the same dietary ingredient about which the claim is being made since there may be instances where, due to provincial or regional differences in custom, language, or dialect, the same name is given to different substances or different names to the same substance.

<u>Example 6</u>: A firm claims that its dietary supplement contains an ingredient shown to promote claim Y. The firm conducts a literature search and finds several references for carefully conducted, well-controlled studies demonstrating that the substance appears to be helpful in persons with claim Y associated with aging when the substance is applied topically to the affected area. However, there is no information provided concerning the effect of the substance when taken orally. Although the evidence may demonstrate that the product is effective when used topically, this information would generally not be useful to substantiate a claim for a dietary supplement (by definition, a product that is intended for ingestion (section 201(ff)(2)(A) of the Act (21 U.S.C. 321(ff)(1)(A)).

<u>Example 7</u>: A dietary supplement firm wants to promote an amino acid product to improve blood circulation and improve sexual performance. The firm conducts a literature search and finds many abstracts and articles about the amino acid's effect on biological mediators of circulation and a few animal and human studies designed to study the effect of the amino acid on blood flow. The firm intends to use this list of studies as substantiation for its claim.

Although the firm appears to have a significant amount of information for its claim, the list is likely not adequate because the firm has not demonstrated that the information is directly related to the claim being made. For example, in this situation we would recommend that the firm provide information to clarify the meaning of "improves blood circulation" and "improves sexual performance." We would also recommend that the firm determine whether the studies examined a dosage of product similar to the firm's product and whether any study measured outcomes (i.e., improved sexual performance) other than blood flow/blood circulation. Until the firm has reviewed the underlying studies, it should not assume that merely finding studies testing the same substance constitutes adequate substantiation.

<u>Example 8</u>: A firm wishes to market its mineral supplement by using a claim that "studies show that the mineral supplement promotes "Z." The firm has the results of a randomized, double-blind, placebo-controlled study conducted in a foreign country showing that a similar product did, in fact, promote "Z," although the study indicates that the foreign study subjects had low blood levels of the mineral at the start of the study. The general US population does not have such a mineral deficiency. Although this study is a high-quality one, it may not be adequate to substantiate a claim about the product's use intended for consumers in the United States because it is confounded by the initial abnormal blood levels of the mineral. Because the study is not designed to answer the question of whether the effect would be expected to occur in subjects with normal blood levels of the mineral, the study might not be adequate evidence to substantiate the claim.

<u>Example 9</u>: A firm is marketing a product specifically to reduce nervousness during stressful everyday situations, such as public speaking. The firm has results from several small studies demonstrating that the product will raise blood levels of a chemical well known to relax people in stressful situations. The firm also has two small, randomized,

placebo-controlled studies showing that its product positively affected measurable indices of anxiety in people placed in stressful situations, including public speaking. These studies may be adequate evidence to support the product claims. Although the studies may be small in terms of the numbers of subjects tested, they are well-designed studies that resulted in statistically significant positive results, consistent with the larger body of scientific evidence related to stress anxiety in public situations.

Example 10: A firm has developed a product to improve memory and cognitive ability and now intends to market the product to parents for their school-age children. The firm has several high-quality clinical studies that examined the ingredient's effect in elderly people with diagnosed, age-related memory problems. These studies alone would likely not be adequate substantiation for a claim about memory improvement in young children because the patient population (elderly people with memory problems) is completely different from the intended population (children) in the claim.

Example 11: A dietary supplement firm is marketing an iron dietary supplement with the claim that the dietary supplement is to correct iron-deficiency anemia in the 10 percent of menstruating women with menorrhagia. The firm has not studied the product in this population of women directly, but has assembled and carefully reviewed the scientific literature of studies that have investigated the oral dosage and intestinal absorption of the type of iron used in its product, both in the population in general and in women who match the product's target consumer. Using this information, the firm has formulated its product to provide the amount of bioavailable iron needed by this population of women. Even though the firm did not test its product directly, it has examined the existing scientific literature and has formulated the product in a manner to meet the standards of products shown effective in well-controlled studies. There is, therefore, a basis to conclude that the existing literature is applicable to the product in the target population for whom it is intended. Thus, the firm's claim that the product will be useful in correcting iron-deficiency anemia would likely be adequately substantiated.

Example 12: A firm claims that its multivitamin, multi-mineral product "provides the vitamins and minerals needed to promote good health and wellness." In this case, the firm's claim is likely substantiated by the substantial scientific evidence showing that certain vitamins and minerals are essential nutrients needed to maintain good health, despite that the firm does not have data from specific scientific studies to show that its product results in any measurable outcome. Scientific evidence studying the firm's particular product formulation probably would not be needed for this claim unless the firm were to make claims that its formulation is different from or superior to other formulations or confers benefits above and beyond the benefits demonstrated to be associated with adequate intake of vitamins and minerals.

D. The Quality of the Evidence

In deciding whether studies substantiate a claim, an important consideration is the scientific quality of studies. Scientific quality is based on several criteria including study population, study design and conduct (e.g., presence of a placebo control), data collection (e.g., dietary assessment method), statistical analysis, and outcome measures. For example, if the scientific study adequately addressed all or most of the above criteria, it could be considered of high quality. Generally accepted scientific and statistical principles should be used to determine the quality of the studies used as evidence to substantiate a claim. The "gold" standard is randomized, double-blind, placebo-controlled trial design. However, trials of this type may not always be possible, practical, or ethical. Several systems are available to rate scientific information. (9) Firms making claims are encouraged to refer to these systems when developing substantiation for claims or relying on existing information. The following provides some commonly accepted scientific principles in evaluating the quality of scientific evidence.

What Are the Types of Evidence That May Substantiate a Claim?

As a general principle, one should think about the type of evidence that would be sufficient to substantiate a claim in terms of what experts in the relevant area of study would consider competent and reliable. Competent and reliable scientific evidence adequate to substantiate a claim would consist of information derived primarily from human studies.

Human studies can be divided into two types: intervention studies and observational studies. (10) Of these types of studies, intervention studies can provide causal evidence to substantiate the effect of a dietary supplement in humans because they can evaluate the product's direct effect in the human body. Observational studies have a more limited ability than intervention studies have to distinguish relationships between a substance and the outcomes being evaluated and cannot provide causal evidence.

Intervention studies

In intervention studies, an investigator controls whether the subjects receive the treatment or intervention of interest to test whether the intervention or treatment supports a predetermined hypothesis. Firms should determine the hypothesis that should be supported or tested prior to identifying supportive documentation or developing a study protocol. Randomized, double-blind, parallel group, placebo-controlled trials offer the greatest assessment of a relationship between a dietary supplement and an outcome. Although intervention studies are the most reliable studies for determining a cause-and-effect relationship, generalizing from such evidence on selected populations to different populations may not be scientifically valid. For example, as described in Example 10 above, if there is evidence to demonstrate a relationship in a specific population (elderly patients with diagnosed age-related memory problems), then such evidence should not be extrapolated to a different population (children).

Observational studies

In observational studies, the investigator does not have control over the exposure to the treatment or intervention of interest. In prospective observational studies, investigators recruit subjects and observe them before a particular outcome occurs. In retrospective observational studies, investigators review the records of subjects and interview subjects after the outcome has occurred. Retrospective studies are usually considered more vulnerable to recall bias (error that occurs when subjects are asked to remember past behaviors) and measurement error, but are less likely to require large sample size or high costs or to encounter the ethical problems that may occur in prospective studies. Types of observational studies include:

- Case reports, which describe observations of a single subject or a small number of subjects.
- Case-series studies, which are a descriptive account of a series of "outcomes" observed over time and reported for a group of subjects. No control group is described.

- Case-control studies, which compare subjects with a condition (cases) to subjects who do not have the same condition (controls). Subjects are enrolled based on their outcome rather than based on their exposure.
- Cohort studies, which compare the outcome of subjects who have been exposed to the substance to the outcome of subjects who have not been exposed.
- Cross-sectional (prevalence) studies, which compare, at a single point in time, the number of individuals with a condition who have been exposed to a substance to the number of individuals without the condition who were not exposed to the substance.
- Time-series studies, which compare outcomes during different time periods, e.g., whether the rate of occurrence of a particular outcome during one five-year period changed during a subsequent five-year period.
- Epidemiological studies, which compare the rate of a condition across different populations.

What types of information are useful as background to support a claim?

The following additional types of information would generally be considered background information but alone may not be adequate to substantiate a claim.

- Animal studies – Animal studies may provide useful background on the biological effects of a substance. However, they often have limited or unknown value in predicting the effect of the substance in humans. Care should be exercised in extrapolating results obtained in animal research directly to the human condition. The strongest animal evidence is based on data from studies in appropriate animal models, on data that have been reproduced in a variety of laboratories, and on data that give a statistically significant dose-response relationship. Without any data from human studies, the results of animal studies alone are not sufficient to substantiate a claim.
- In vitro studies are studies conducted outside a living body. For example, such studies might examine a product's effect on isolated cells or tissues. These studies are of limited value in predicting the effect of a substance when consumed by humans. The strongest in vitro evidence would be based on data that have been reproduced in different laboratories, but this evidence alone would not substantiate a claim.
- Testimonials and other anecdotal evidence – This type of evidence includes descriptions of experiences of individuals using a dietary

supplement product or ingredient. It might also include descriptions of the use of the product or ingredient by others, for example, by other cultures in the past or present. It might consist of an opinion or statement of an expert or someone who endorses the product. Anecdotal evidence generally would not be sufficient to substantiate claims regarding a dietary supplement's effect because each individual's experience might be attributable to factors other than the dietary supplement itself. For example, a person might have experienced a placebo or coincidental effect rather than an effect attributable to the dietary supplement itself. Additionally, the "honest opinion" of a consumer testimonial or an expert endorsement would not be enough to substantiate a claim; rather, the endorsement should also be supported by competent and reliable scientific evidence.

- Meta-analysis is the process of systematically combining and evaluating the results of clinical trials that have been completed or terminated. Meta-analysis may identify relevant reports, which may provide substantiation for the claim.
- Review articles summarize the findings of primary reports. Review articles may identify relevant primary reports, which may provide substantiation for the claim. Review articles may also provide background information that is useful to understand the scientific issues about the relationship between the substance and the claimed effect.
- Comments and letters to the editor usually focus on a particular issue or issues from a study, presentation at a meeting, and so on. Comments generally do not present a study's results. Comments and letters to the editor may identify relevant primary reports, which may provide substantiation for the claim. Comments and letters to the editor may also provide background information that is useful to understanding the scientific issues about the relationship between the substance and the claimed effect.
- Product monographs are prepared by the manufacturer to convey specific information about a product such as its specifications. Product monographs may provide background information that is useful to understanding the scientific issues about the relationship between the substance and the claimed effect.

Example 13: A dietary supplement claim states, "Data suggest that including Substance X in the diet may promote brain neuron health in healthy individuals." The firm cites a study in which rats were fed diets containing Substance X, and the brains of all rats were examined for ischemia-induced brain damage. The study does not provide a basis that Substance X would have the same effect on brain health in otherwise healthy humans. This study alone likely would not provide adequate substantiation of the claim being made because it relies solely on animal data.

Example 14: A dietary supplement claim states, "Grain Y has been used effectively for centuries to promote gastrointestinal health." The firm has no clinical studies in humans but has an industry monograph that relies only on historical descriptions of grain Y use by pre-modern civilizations. Although the monograph may be an accurate review of the historical use of grain Y, it would likely not constitute competent and reliable evidence to support the claim because it is not based on objective scientific evidence. Rather, it is largely anecdotal evidence that cannot be objectively evaluated to determine whether it applies to the consumers who would use the product.

Example 15: A dietary supplement label claims that, in laboratory tests (i.e., in vitro tests), the enzymes in the supplement can digest up to 20 grams of protein and 15 grams of dietary fat, and the firm is promoting the supplement to assist in breaking down protein and fat that its users eat. The firm has not tested its product or the ingredients in the supplement in humans. Although this evidence may be accurate, it would generally not be adequate substantiation for the claimed effects on dietary components because it is insufficient for reaching a conclusion on whether the enzymes, when consumed, would behave equivalently in the human body. Corroborating evidence from some human studies would likely be needed to determine whether the in vitro findings reflect the outcomes of the product when consumed by humans.

Example 16: A botanical product label uses the claim "improves vitality." The substantiation that the firm is relying on consists of testimonial experience it has collected from consumers and descriptions of the botanical product's traditional use. Although the firm may have testimonial experience to back up the basic claim being made, the claimed benefit would likely not be adequately substantiated because neither source is based on scientific evidence. If the firm wants to make a claim of this type, we recommend that it have scientific evidence that some measurable outcome(s) associated with the general conditions cited in the claim is (are) significantly improved.

What Design Factors Affect the Quality of a Study?

Multiple factors should be considered in study design. These include, but are not limited to, bias, confounders, and other limitations. Potential sources of bias include lack of appropriate randomization and blinding, the number of subjects called for in the protocol vs. the number of subjects who actually participated in the trial, demographics, adequacy of primary variables, compliance, control agent, dropouts, statistical procedures, subgroup analysis, safety issues, and reproducibility of results. Confounders are factors associated with the intervention and the outcome in question and thus prevent the measured outcome from being attributed unequivocally to the intervention. Potential confounders include variability in the quantity of the dietary supplement being administered or the presence of other dietary ingredients that may have their own independent effects. These factors can limit the study's reliability.

Quality assessment criteria – Factors that contribute to higher quality studies include:

- Adequacy and clarity of the design
- The questions to be answered by the study are clearly described at the outset.
- The methodology used in the study is clearly described and appropriate for answering the questions posed by the study.
- The duration of the study intervention or follow-up period is sufficient to detect an effect on the outcome of interest.
- Potential confounding factors are identified, assessed, and/or controlled.
- Subject attrition (subjects leaving the study before it is completed) is assessed, explained, and reasonable.

Population studied

- The sample size is large enough to provide sufficient statistical power to detect a significant effect. (If the study is underpowered, it may be impossible to conclude that the absence of an effect is not due to chance.)
- The study population is representative (with respect to factors such as age, gender distribution, race, socioeconomic status, geographic

location, family history, health status, and motivation) of the population the claim will be targeted to.

- The criteria for inclusion and exclusion of study subjects were clearly stated and appropriate.
- The study used recruitment procedures that minimized selection bias.
- For controlled interventions, the subjects were randomized. If matching was employed to assign the subjects to control and treatment groups, appropriate demographic characteristics and other variables were used for the matching. The randomization was successful in producing similar control and intervention groups.

Assessment of intervention or exposure and outcomes

- The analytical methodology and quality control procedures to assess dietary intake are adequate.
- The dietary supplement serving size is well defined and appropriately measured.
- The background diets to which the dietary supplement was added, or the control and interventional diets, are adequately described, measured, and suitable.
- In studies with crossover designs, the "washout" period (the period during which subjects do not receive an intervention) between dietary supplement exposures is appropriate. Lack of a sufficient washout period between interventions may lead to confusion as to which intervention produced the health outcome.
- The form and setting of the intervention represent the way the product will be normally used.
- Other possible concurrent changes in diet or health-related behavior (weight loss, exercise, alcohol intake, and smoking cessation) present during the study that could account for the outcome identified are assessed and/or controlled.
- The study's outcomes are well defined and appropriately measured.
- Efforts were made to detect harmful and beneficial effects.

Data Analysis and Assessment

- Appropriate statistical analyses were applied to the data.
- "Statistical significance" was interpreted appropriately.
- Relative and absolute effects were distinguished.

Peer Review – The nature and quality of the written report of the research are also important. Although studies or evidence used to substantiate a claim do not have to be published in a peer-reviewed journal or publication, such publications do give some level of assurance that qualified experts have reviewed the research and found it to be of sufficient quality and validity to merit publication. In contrast, an abstract or informal summary of an article is less reliable because such documents usually do not provide the reader enough insight into how the research was conducted or how the data were analyzed to objectively evaluate the quality of the research data and the conclusions drawn by the authors. Moreover, the mere fact that the study was published does not necessarily mean that the research is competent and reliable evidence adequate to substantiate a particular claim.

Example 17: A dietary supplement label claims, "Randomized, double blind, placebo-controlled studies demonstrate that herbal extract 'Z' is beneficial in relieving menopausal symptoms." The firm is relying on the results of more than one randomized, double-blind, placebo-controlled intervention study using menopausal women as subjects, and the results of those studies are in general agreement. The claim would likely be substantiated because it relies on high-quality studies in humans that directly addressed conditions described in the claim.

E. Consider the Totality of the Evidence

How Well Does the Totality of Evidence Support the Claims?

In determining whether there is adequate evidence to substantiate a claim, one should consider the strength of the entire body of evidence, including criteria such as quality, quantity (number of various types of studies and sample sizes), relevance of exposure, and consistency and replication of the findings.

To determine whether the available scientific evidence is adequate to substantiate a claim, it is important to consider all relevant research, both favorable and unfavorable. Ideally, the evidence used to substantiate a claim agrees with the surrounding body of evidence. Conflicting or inconsistent results raise serious questions as to whether a particular claim is substantiated. If conflicts or inconsistencies exist in the scientific evidence, one should determine whether there are plausible explanations for such conflicts or inconsistencies. For example, an inconsistency between two studies might be attributable to different concentrations of the dietary supplement, different test methodologies, different study populations, (11) or other factors.

There is no general rule for how many studies, or what combination of types of evidence, is sufficient to support a claim. However, the replication of research results in independently conducted studies makes it more likely that the totality of the evidence will support a claim.

Although the quality of individual pieces of evidence is important, each piece should be considered in the context of all available information; that is, the strength of the total body of scientific evidence is the critical factor in assessing whether a claim is substantiated.

Example 18: A firm intends to promote an herbal product “X” to “help maintain cognitive performance” of people who are fatigued. The firm has researched the scientific literature and found many studies that demonstrate that the botanical ingredient is effective. However, some studies demonstrate no effect. Still other studies examined the botanical ingredient combined with other ingredients, typically caffeine, which demonstrated mixed positive and negative results. Many reports do not adequately describe the study participants and products examined. Consequently, it is not possible to explain the disparate results. However, the firm’s review suggests that either the botanical and/or caffeine are the most likely dietary ingredients that act to maintain better cognition test results in fatigued study participants. As a result, the firm conducts a large, randomized, placebo-controlled study to compare the botanical ingredient against caffeine in the treatment of cognitive performance deficits associated with fatigue. The results demonstrate that caffeine improved cognition test results in all the fatigued subjects who received caffeine, whereas test performance was unaffected in all subjects receiving the botanical ingredient. The study cannot explain the results reported in the earlier studies; however, it demonstrates that the botanical ingredient studied is most likely ineffective in improving or maintaining cognitive performance in fatigued people.

Example 19: A firm plans to promote its herbal product “to effectively relieve occasional nocturnal leg cramps.” The firm has one study demonstrating the product to be effective in ameliorating nocturnal leg cramps. The firm is also aware of several other randomized controlled trials that do not show a benefit. All these studies are of equal quality and used similar patient populations and test materials. When considered as a whole, even though some evidence to support the claim exists, the totality of the evidence does not support the proposed claim. If no plausible explanation can be found to explain the disparate results, the available evidence would likely not be considered adequate to substantiate the claim.

Example 20: An herbal product is promoted "to help you get to sleep when you have difficulty falling asleep." The firm has one randomized, placebo-controlled study in volunteers who had trouble falling asleep. The study showed that those who used the product decreased the amount of time needed time to fall asleep. There are several other high-quality studies, however, that found that the herbal ingredient used in the product did not consistently help people get to sleep. It is not clear whether the different results of the various studies are a consequence of differences in product formulation or dosage or some other factor. Even though the firm's single study is positive, it may not provide adequate substantiation, because the totality of existing evidence suggests that the herbal ingredient does not decrease time to fall asleep in persons who have trouble falling asleep. Given the contrary evidence against the claim, it is unlikely that this sleep-related claim would be substantiated for this product.

Example 21: A company plans to promote its product containing ingredient X to athletes "to improve endurance performance." There are some well-designed published studies demonstrating that other products containing ingredient X are effective, but other well-designed studies show no effect for certain products containing ingredient X. The firm sponsored a randomized, blinded, six-month study comparing its product to four other products containing ingredient X in a dose (serving size)-response fashion. The findings demonstrate that the firm's product and two other products that provided the highest amount of ingredient X per day produced substantial, statistically significant improvements in athletic endurance. When the firm compared the results of this study to those of prior studies, the firm concluded that the explanation for previous conflicting study results is that when the serving size of ingredient X is below a certain amount, there is no measurable benefit. Taken together, the positive results from its study, and the identification of a plausible explanation to explain why some studies showed no positive effects, would likely provide evidence to substantiate adequately the endurance performance claim for the dietary supplement.

F. Conclusion

Section 403(r)(6) of the act requires dietary supplement manufacturers to have substantiation that structure/function, nutrient deficiency, and general well-being claims on a dietary supplement product's labeling are truthful and not misleading. We recommend that to meet this statutory requirement, manufacturers should possess adequate substantiation for each reasonable interpretation of the claims. We intend to apply a standard that is consistent with the FTC standard of "competent and reliable scientific evidence" to substantiate a claim. We consider the following factors important to establish whether information would constitute "competent and reliable scientific evidence:"

- Does each study or piece of evidence bear a relationship to the specific claim(s)?
- What are the individual study's or evidence's strengths and weaknesses? Consider the type of study, the design of the study, analysis of the results, and peer review.
- If multiple studies exist, do the studies that have the most reliable methodologies suggest a particular outcome?
- If multiple studies exist, what do most studies suggest or find? Does the totality of the evidence agree with the claim(s)?

Guidance Document References:

(1) The Office of Nutrition, Labeling, and Dietary Supplements in FDA's Center for Food Safety and Applied Nutrition prepared this guidance document.

(2) Under section 403(r)(6)(A) of the Act (21 U.S.C. 343(r)(6)(A)), such a statement is one that "claims a benefit related to a classical nutritional deficiency disease and discloses the prevalence of such disease in the United States, describes the role of a nutrient or dietary ingredient intended to affect the structure or function in humans, characterizes the documented mechanism by which a nutrient or dietary ingredient acts to maintain such structure or function, or describes general well-being from consumption for a nutrient or dietary ingredient...."

(3) Comments to the Draft Guidance published November 9, 2004 (69 FR 64942), questioned the constitutionality, under the First Amendment, of the substantiation requirement in section 403(r)(6), as interpreted by the Draft Guidance. This Guidance offers FDA's non-binding interpretation of what constitutes substantiation and does not change the statutory or Constitutional requirement in any way. We believe the statutory substantiation requirement in section 403(r)(6) is constitutional under the Supreme Court's analysis governing commercial speech in Central Hudson Gas & Electric Corp. v. Public Service Commission of New York (447 U.S. 557 (1980)). Claims made under section 403(r)(6) are misleading when made

without substantiation. The misleading nature of a claim made under section 403(r)(6) that is not substantiated cannot be cured by a disclaimer stating that the claim lacks support. For example, a product cannot claim "to promote the structure and function of the skeletal system" and then attempt to cure the misleading nature of the claim with a statement "no evidence exists that this product promotes the structure and function of the skeletal system." However, nothing in this Guidance addresses the circumstances under which a claim made under section 403(r)(6) that includes qualifying language may be substantiated.

(4) This guidance does not discuss the criteria to determine whether a statement about a dietary supplement is a structure/function claim under section 403(r)(6) of the Act or a disease claim. Please see the *Federal Register* of January 6, 2000 (65 FR 1000, codified at 21 CFR 101.93) (www.cfsan.fda.gov/~lrd/fr000106.html) for the final rule defining structure/function claims for dietary supplements and the January 9, 2002 Small Entity Compliance Guide for structure/function claims (www.cfsan.fda.gov/~dms/sclmguid.html)(Updated web reference: Structure/Function Claims; Small Entity Compliance Guide).

(5) See Report of the Commission on Dietary Supplement Labels, November 1997, at page 42. The Commission's recommendations on substantiation are at pages 42 through 45 of the report.

(6) See Bureau of Consumer Protection, Federal Trade Commission, "Dietary Supplements: An Advertising Guide for Industry," April 2001 (hereinafter referred to as "FTC Advertising Guide"), available at www.ftc.gov.

(7) *See, e.g. Vital Basics, Inc.*, C-4107 (Consent April 26, 2004); *see also In Re Schering Corp.*, 118 F.T.C. 1030, 1123 (1994).

(8) For example, a study using a conventional food or a multi-nutrient supplement would not substantiate a single ingredient dietary supplement claim. When the substance studied contains many nutrients and substances, it is difficult to study the nutrient or food components in isolation (Sempos, et al., 1999). It is not possible to accurately determine whether any observed effects of the substance were due to: 1) the substance alone; 2) interactions between the substance and other nutrients; 3) other nutrients acting alone or together; or 4) decreased consumption of other nutrients or substances contained in foods displaced from the diet by the increased intake of foods rich in the substance at issue. Furthermore, although epidemiological studies based on the recorded dietary intake of conventional foods have indicated a benefit for a particular nutrient, it has been subsequently demonstrated in an intervention study that the single ingredient nutrient-containing dietary supplement did not confer a benefit or actually was harmful. See Lichtenstein and Russell, 2005. We note that the D.C. Circuit Court in *Pearson v. Shalala*, 164 F.3d 650, 658 (D.C. Cir. 1999) indicated that FDA had "logically determined" that the consumption of a dietary supplement containing antioxidants could not be scientifically proven to reduce the risk of cancer where the existing research had examined only foods containing antioxidants as the effect of those foods on reducing the risk of cancer may have resulted from other substances. The court, however, concluded that FDA's concern with granting antioxidant vitamins a qualified health claim could be accommodated by simply adding a prominent disclaimer noting that the evidence for such a claim was inconclusive given that the studies supporting the claim were based on foods containing other substances that might actually be responsible for reducing the risk of cancer. Id. The court noted that FDA did not assert that the dietary supplements at issue would "threaten consumer's health and safety." Id. at 656. As the agency has stated in the context of qualified health claims, that is, claims regarding the relationship between a substance and the reduced risk of a disease, there is a more fundamental problem with allowing qualified health claims for nutrients in dietary supplements based solely on studies of foods containing those nutrients than the problem the D.C. Circuit held could be cured with a disclaimer. As noted in endnote 3, even if the effect of the specific component of the food constituting the dietary supplement could be determined with certainty, recent scientific studies have shown that nutrients in food do not necessarily have the same beneficial effect when taken in the form of a dietary supplement. Such studies established either that there was no benefit when the nutrients are taken as a supplement and some studies even showed an increased risk for the very disease the nutrients were predicted to prevent. We would expect similar issues with structure/functions claims made under § 403(r)(6). Thus, an observational study based on food does not provide competent and reliable scientific evidence for a dietary supplement and, and therefore, cannot substantiate a claim made under § 403(r)(6).

(9) See "Systems to Rate the Strength of Scientific Evidence. Evidence Report/Technology Assessment Number 47, "Agency for Healthcare Research and Quality and Research (AHRQ), Publication No. 02-E016, April 2002.

(10) See Spilker, B. *Guide to Clinical Trials*. Raven Press, New York, 1991.

(11) For example, with respect to human drug products, it is fairly well known that children and the elderly may experience different drug effects compared to those seen in the adult population. These differences may be due to physiological differences (such as hormonal differences, differences in kidney function, etc.) between children, adults, and the elderly.

[End of FDA's Guide Excerpts]

Conclusion

Making claims for foods and dietary supplements is a highly regulated area of labeling and advertising. Both the FDA and FTC are involved in the United States. In Canada, the Natural Health Product approach utilizes preapproved claims, product review, and licensing. This Canadian approach may offer advantages, as it nearly eliminates controversy about the regulated health products.

In the United States, the FDA authorizes health claims and nutrient content claims. The category of claims referred to as structure/function claims are not preapproved by the FDA, and the responsibility for basing claims in adequate scientific evidence is required by each company selling such products. In the health product market, sports nutrition food and supplements represent a major segment of the market and typically are packed with a variety of claims, including structure/function claims.

The information in this unit can therefore can applied for fitness trainers and other health professionals to review product claims, determine whether the evidence is adequate to support claims, and improve communication about the variety of product claims with clients and when dealing with sports nutrition product companies.

Key Word

seafood

PART TWO
Anatomy and Metabolism Determine Nutrient Needs

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Topics Covered In This Unit

UNIT 12

ANATOMY OF AN ATHLETE: CELLS, TISSUES, AND SYSTEMS

Learning Objectives

After completing this unit, you will be able to:

- Define and describe key human anatomy terms;
- Discuss cell structure;
- Understand the main systems of the body; and
- Describe the different skeletal muscle fiber types and muscle contraction.

Introduction

The pages of this book—locker room talk, magazine articles, and visits with your doctor, trainer, or coach—all share a common element: terminology that relates to the human body and its parts. This unit is included as a reference unit so that you can build a fundamental knowledge in this area of science. This unit also includes some interesting discussion on the makeup of muscle tissue and its functions. The following will serve to acquaint you with the fundamental units of the body, anatomic terms, and concepts commonly encountered in sports science.

Anatomy & Physiology Simple Definitions.

Anatomy = body structures.

Physiology = body functions.

Cells, Cells, Cells

The human body is an incredible biological phenomenon composed of several interdependent systems responsible for maintaining life. For example, the muscle system needs the nervous system to fire-off muscle contractions. The circulatory system is needed to provide the muscle system with nourishment and at the same time carry away metabolic waste products. These complex systems are made up of fundamentally simpler units, or building blocks. The digestive system consists of several organs, which in turn consists of tissues, which in turn consist of cells of different form and function. Furthermore, each individual cell possesses subcellular organelles, such as the mitochondria, which are involved with making energy. Finally, organelles are composed of various molecules (e.g., proteins, DNA) that serve as the building blocks of the human body and are involved in biosynthesizing molecules for use by cells.

The Cell— Fundamental Unit of Life

Just as every molecule has building blocks, so do tissues and structures. Cells form the fundamental units of life. Together they somehow organize themselves into a human body. The human body is composed of an estimated 100 trillion cells of various form and function. Striated muscle cells can be several inches long and have the unique ability to shorten in length, thereby causing muscle contractions. Fat cells are small and round in shape and function to store fatty acids for energy needs during lean times.

Another magnificent characteristic of cells is that they can reproduce themselves. In fact, cells can only arise from preexisting cells. Our complex body originates from the union of two existing cells, the female egg and the male sperm. These sex cells merge to form one larger cell called the zygote, which is the starting point of a multitrillion-celled human body. The zygote divides and forms two cells. (Sometimes, these two zygote cells become separated and develop independently of each other. That's how identical twins come about.) The two zygote cells continue to divide and form four cells. This process continues forever. Even when the total number of cells reaches a relatively fixed amount, cells continue to divide to replace old or dead cells.

As we live, cells are continually dying and being produced. This remarkable process goes on automatically. All we have to do is eat food to keep it going. But proper nutrition practices can make the body work much better and be much healthier. For example, scientists have suspected for years that a byproduct of metabolism, the so-called free radical, can damage cell structures and molecules. Free radicals also become more prevalent during strenuous activity and periods of fat loss. Cellular damage due to free radicals must be repaired, which takes time and can impair your rate of recovery. Free radical damage has also been linked to the development of cancer, cardiovascular disease, cataract formation, and aging. The body can manufacture antioxidant compounds, such as superoxide dismutase and glutathione, which can be optimized with nutrition, and additionally benefit from intake of antioxidants from foods and supplements, to be reviewed in another unit.

Cellular Components

Each cell has its own anatomy and physiology. This is accomplished by subcellular structures called organelles. Each cell typically contains the following organelles.

Plasma membrane. Picture the cell as an inflated balloon. The outer boundary is called the plasma membrane, or cell membrane. It is a complex structure made up of mostly proteins and a phospholipid bilayer. The phospholipid bilayer (which is made up of glycerol, two fatty acids, and a phosphate group) forms a double-walled balloon like structure, with proteins embedded in these bilayer sheets. Proteins in the cell membrane provide structural support, form channels for passage of materials, act as receptor sites, function as carrier molecules, and provide identification markers.

The nutritional significance of this structure is that the cell membrane is made up of fatty acids, which are part of the phospholipid bilayer. This means that fats are an important part of the diet for energy production but also for bodybuilding materials, and while we need to make sure we do not eat too much, we do need an appropriate amount to serve as the essential building blocks for all cells. Fats are especially important for athletes training to gain muscle mass and for long-distance athletes whose metabolism burns up a tremendous amount of fatty acids. (Fats in the body can consist of three fatty acids attached to the three carbon glycerol molecules, thus the name, triglycerides.)

The plasma membrane can allow the transport of molecules through it and also actively transport certain compounds across it via special mechanisms. It is therefore referred to as a semi-permeable plasma membrane. This gives the cell control over which substance and how much of a substance it wants inside it. Additionally, the cell can rid itself of undesirable compounds while retaining desirable ones. Insulin is an important hormone that is responsible for stimulating the uptake of glucose and amino acids across the plasma membrane. Insulin levels increase in the body after a meal to ensure these vital nutrients get into the cells. There are ways to maximize insulin's functioning through supplementation and timing of meals around training, which will be discussed later.

Nucleus. The nucleus was first discovered more than a century and a half ago in 1830 and credited to the scientist Robert Brown. Usually it is situated in approximately the center of each cell and is slightly darker than the surrounding cytoplasm is. The nucleus is essentially a cell within a cell, which has a membrane of its own and houses the cells' genetic material, DNA (Deoxyribonucleic Acid). Strands of DNA form chromosomes. The human cell contains two sets of 23 chromosomes making a matching set of 23 pairs and a total of 46 chromosomes. Each parent contributes one set of chromosomes from his and her sex cells, the sperm and egg. The chromosomes contain the genetic information responsible for the way we look. The nucleus is commonly called the cell's control center. The chromosomes are suspended in a liquid called the nucleoplasm. The liquid between the plasma membrane and nuclear membrane is called cytoplasm, or cytosol.

The nucleus typically functions to initiate production of substances needed by the cell. The process is initiated by an intracellular (within the cell) signal, which causes specific genes on certain chromosomes to produce exact copies of the gene sequence being activated. These pieces of material-carrying genetic information are called messenger RNA (Ribonucleic Acid). The information contained on the messenger RNA strands may be the sequence of amino acids needed for a protein molecule, such as insulin. The messenger RNA is then transported from the nucleus, through pores in the nuclear membrane, and on to the cytoplasm. Once in the cell's cytoplasm, the strand of messenger RNA is used as a template to make molecules in the cytoplasm. For this to occur, ribosomes must be connected to the messenger RNA strand.

Ribosomes, discussed below, are also organelles. They run along the messenger RNA strands while in the cytoplasm. As the ribosomes go along the messenger RNA strand, they function to connect each code point along the RNA to the corresponding transfer RNA, which has an amino acid attached to it. In the same way that the ribosomes roll along the messenger RNA, amino acids are strung together to form proteins, enzymes, and so on. If certain amino acids are missing, the protein chains cannot be completed. This is why adequate and effective protein intake is mandatory for the athlete. If an essential amino acid is lacking, protein synthesis can be reduced or temporarily stopped. This concept of the limiting nutrient is important to consider. The diet can be abundant in calories, but a short supply of an essential nutrient can limit certain reactions needed for the cell to thrive.

The nucleus has another important function. It initiates cell division. During cell division, each chromosome must duplicate itself so the new cell will contain a full set of 23 pairs of chromosomes.

Ribosomes. The next organelle, which was just mentioned above, plays a role in the synthesis of proteins and cellular components.

Phenotype and Genotype

Talk of genetics has grown in popularity in recent decades, and along with discussion of this topic came a host of scientific terms. Two of these terms, genotype and phenotype, are commonly used and misused. The word genotype refers directly to the genetic information stored on your chromosomes. The word phenotype refers to actual morphological characteristics you possess: eye color, hair color, foot size, and so on.

Your phenotype is said to be a result of your genotype and the surrounding environmental factors. Some of your phenotypic makeup cannot be greatly influenced by the environment, such as the color of your eyes. But other aspects, such as body weight, athletic performance, and some diseases can be controlled. Environmental factors include your surroundings, climate, food, activity, stress, and so on. Expression of genes (phenotype) is therefore dynamic.

Ribosomes are extremely small in size and were not discovered until the electron microscope was in use. The electron microscope can achieve magnification many times more than the traditional light microscope that most people are familiar can. Light consists of energy waves with a certain range of wave lengths. Think of the waves that are formed when a stone is dropped into water. The distance between the top of two waves is the wavelength. Our eyes can only detect certain wave lengths, and you must have entire wave lengths to see. Thus, one limitation of the light microscope is the wave length of visible light. The lenses of the light microscope actually function to bring your eye closer and closer to the subject. The maximum magnification, or the closest your eye can be to something and see it, is one wavelength of visible light.

Scientists wanted to increase magnification to see smaller particles. To do this, they developed the electron microscope. This microscope sees with electrons, which are many times smaller than light waves are. The only limitation is that we cannot directly look through an electron microscope because our eyes cannot see electrons. As such, we either take photos with special film or use special cameras to view the subject on a TV monitor, as with the scanning electron microscope.

Ribosomes are extremely small, spherical organelles made up of protein and RNA. They are by far the most numerous of cell organelles. They are found scattered throughout the cell's cytoplasm and also along the surface of another organelle, the endoplasmic reticulum. Ribosomes function in pairs as two subunits, with one subunit smaller than the other. Ribosomes are located in the cytoplasm and make various compounds from messenger RNA for local cellular needs. Ribosomes situated on the endoplasmic reticulum synthesize compounds for use outside the cell and can be channeled out of the cell for export, such as with hormones, **digestive enzymes**, and the like.

Digestive enzyme: an enzyme that acts as catalysts for the breakdown of food components.

Endoplasmic Reticulum (ER). This organelle forms a network of intracellular canals within the cytoplasm involved in transport of materials in the cell. ER exists in two forms, rough ER and smooth ER. Rough ER is ER with ribosomes attached. Here then is where proteins and other biomolecules can be made and transported through the ER's canal network to other parts of the cell and outside the cell. Smooth ER is without ribosomes, and its function is less clear, although it appears that smooth ER may be the site of steroid synthesis in the testes and adrenal glands. Evidence also indicates that some lipid and cholesterol metabolism occur in smooth ER of the liver cells.

Golgi Apparatus. The Golgi apparatus consists of stacks of tiny oblong sacs embedded in the cell's cytoplasm near the nucleus. It is active in the modification and transport of proteins. Research has presented evidence that the Golgi sacs are responsible for synthesis of certain carbohydrate biomolecules. These carbohydrates are then combined with the proteins made in the endoplasmic reticulum to form glycoproteins. Glycoproteins function as enzymes, hormones, antibodies, structural proteins, and so on. As the amount of glycoprotein produced within the Golgi sac increases, the sac becomes inflated. At this point, small spheres form along the surface of the Golgi sac and break away. These globules contain the glycoproteins, which are transported to the cell membrane and then out of the cell and into the bloodstream to be used by other cells. Other functions are possible and being explored.

Lysosome. Lysosomes are other sac-like structures whose size and shape change with the degree of their activity. They start out small and, as they become active, increase in size. Lysosomes contain a variety of enzymes (which act as catalysts, directing all major biochemical reactions). These enzymes are capable of breaking down all of the cell's main components, such as protein, fat, and nucleic acid. The breakdown products formed inside the lysosome can be used as raw materials for synthesis of new biomolecules or for energy. In this way, lysosomes serve to contain and isolate these important cellular digestive enzymes and thereby prevent complete digestion of the cell. They also play a limited role in the engulfing and destroying of bacteria that may enter the cell.

Mitochondrion (plural, mitochondria). Next to the nucleus, this is probably the most known and talked about organelle, in the athletic arena, due to its role in the generation of energy. Called the cell's powerhouse, mitochondria are small complex organelles that resemble a sausage in shape. They consist of a smooth outer membrane that surrounds an inner membrane, forming a sac within a sac. The inner membrane is folded like an accordion and forms a number of inward extensions called cristae.

It is here in the mitochondria that the enzymes exist that are essential for making one of the most important biomolecules: ATP (adenosine triphosphate). ATP stores a great deal of energy, which is used to power biological functions. More will be said about ATP in the units to follow. Within the inner mitochondria membrane, catabolic enzymes (which are involved in breaking down of biomolecules) catalyze reactions that provide the cells with life-sustaining energy.

Nutrients like glucose and fatty acids are made of carbon atoms linked together with chemical bonds. When these chemical bonds are broken, energy is released. Within the intricate confines of the mitochondria, this energy can be trapped and stored in the ATP molecule, which can then make use of it. In other words, the energy from glucose is transferred to the ATP molecule, and the energy is now in a form that the body's bio-machinery can make use of. Quite remarkable. The popular nutrient L-carnitine is involved in transport of fatty acids from the cytoplasm into the mitochondria and is a supplement commonly taken with the intent of increasing the amount of fatty acids used for energy, which may help spare glycogen and speed up fat loss and the energy-producing process of endurance athletes. There are other ways the body can make ATP; however, it is in the mitochondria where the greatest ATP generally occurs.

Another interesting fact about mitochondrion is the discovery of its own DNA. Mitochondrial DNA is circular.

These are the cell's main components. Some of the other structures include glycogen granules, which store glycogen and enzymes for glycogen breakdown and synthesis, and peroxisomes, which contain enzymes and function to get rid of toxic cellular substances. Although not a structure, the cytoplasm is worth mentioning. This liquid portion of the cell is the site of many reactions, including **gluconeogenesis** (glucose and glycogen formation), fatty acid synthesis, activation of amino acids, and **glycolysis** (the first phase of breaking down glucose to make ATP molecules for energy).

Gluconeogenesis: the metabolic process in which glucose is synthesized from noncarbohydrate sources.

Glycolysis: the metabolic process in which glucose is converted to lactic acid.

Tissues

Although the cell is the fundamental unit of life, tissues are the fundamental units of function and structure for the human body. Tissues are defined as the aggregation of cells bound together that work together to perform a common function. For example, cells of the adrenal cortex form a glandular tissue that produces several hormones, including androgens, glucocorticoids, and mineralocorticoids. Then there is muscle tissue, which is made up of special muscle fiber cells that have the ability to shorten in length and that form the basis of contractile tissue.

In this section, you will learn about the basic tissues that make up your body. Despite that the human body seems considerably complex, the tissues that form it can be separated into five basic groups: epithelial, connective, muscle, nervous, and reproductive.

Epithelial Tissues

These tissues are found throughout the body: as a continuous external layer over the whole body (skin), on most of the body's inner cavities, or making up the body's several glands. On the surface, epithelial tissues function to protect underlying cells from bacterial invasion, adverse chemicals, and drying. On the inside, they function as absorbing and secreting tissues, such as digestive system glands. Epithelial tissues are divided into four groups and are distinguished according to the shape of the cells they are composed of. They are as follows:

1. Squamous epithelium – tissue composed of one layer of flat cells. Located in the linings of the mouth, esophagus, and blood and lymphatic vessels. Substances can easily diffuse through this layer of cells.
2. Cuboidal epithelium – cube-shaped cells as found in the lining of kidney tubules.
3. Columnar epithelium - tissue cells resembling columns or pillars in shape. They are widespread throughout the body, forming linings in the digestive tract and respiratory tract. They function as secretory cells or absorptive cells. Some also have small hairs, called cilia, which beat rhythmically and move materials out of a passage, as in the respiratory tract where cilia serve to sweep out foreign matter that may pass into the lungs.
4. Glandular epithelium – epithelial cells that specialize to secrete mucus and hormones, like those of the salivary and thymus glands

Connective Tissues

Connective tissues are widespread tissues in the body and serve to connect and support. For example, connective tissue joins other tissues to each other, muscles to bone, and bone to bone. Connective tissues are composed of cells embedded in a nonliving matrix. The nature of the matrix, rather than that of the cells themselves, determines the function of a particular type of connective tissue. Connective tissues consist predominantly of intercellular material interspersed among relatively few cells. Blood, for example, is considered a connective tissue because it consists of a fluid matrix with cells suspended within.

Some connective tissues have the consistency of soft gels that are firm but flexible, whereas others are hard, tough, and rigid. Most of us have chewed into a very hard, tough structure while eating meat. This was most likely a piece of connective tissue that the butcher left behind. The important distinguishing characteristic of connective tissues is that the matrix gives a particular connective tissue its identity.

Connective tissues are made up of many constituents. Many types of connective tissues are formed from the same substance made up of a mixture of salts, water, protein, and carbohydrates. Embedded in this substance are cells and fibers. Among the cells and fibers are elastic fibers for elasticity, collagen fibers for strength, reticular fibers for support, microphages and white blood cells to fight infection, fat cells for storage, and plasma cells to produce antibodies.

One or more of the three fibers (collagen, reticular, and elastic) are contained in connective tissue. The three fibers are listed below with their characteristics and main functions.

1. Collagen Fibers – tough, strong fibers that form the major fibrous component of the skin, tendons, cartilage, ligaments, and teeth. Made of the amino acids glycine, proline, lysine, hydroxyproline, and hydroxylysine. Collagen gives connective tissue its versatility because of its ability to interconnect with other molecules and minerals and thereby form an alloy of a sort, with a higher tensile strength than its separate parts have. Collagen fibers occur in bundles, which gives them great tensile strength.

2. Reticular Fibers – delicate, supporting fibers of connective tissue that occur in networks and support delicate structures such as capillaries and nerve fibers.
3. Elastic Fibers – elastic and extendible.

The connective tissues covered here will be those most familiar to the athlete. The other types of connective tissues will be listed at the end of this section. The connective tissues to be discussed are cartilage, bone, tendons, and ligaments.

Cartilage forms the foundation of bone tissue. It is found at bone ends, in spinal disks and makes up the soft "bone" in the nose. Mature cartilage does not contain blood vessels or nerves. It obtains nutrition through small holes that allow nutrients to seep in. There are three types of cartilage, the hardness of which depends on the number of collagen fibers. They include elastic cartilage in ear and Eustachian tubes; tough fibrous cartilage, found between bones of the spine (disks); and hard hyaline cartilage, found in bone ends, nose, larynx, and trachea.

Bones form the skeleton, which act to support and protect the body. Bone both resembles and differs from cartilage. Like cartilage, bone consists more of intercellular substances (matrix) than of cells. But in bone, the intercellular substance is calcified and hardened as opposed to cartilage, which is a firm gel. Calcium salts impregnate and cement the matrix, a fact that explains the rigidity of bones. Collagen fibers are embedded in the calcified matrix.

Bones are not as lifeless as they seem. Within this hard, non-living, calcified, intercellular matrix exist many living cells that continually receive food and oxygen and that excrete their wastes through the numerous blood vessels found in bone tissue and bone marrow.

Tendons and ligaments are flexible but strong. In fact, they are the strongest connective tissues. The intercellular matrix consists of a collagen and reticular fiber network, which originates from the cells that tendons surround. Tendons can be thick, as with the Achilles tendon. They can be thin, as with the epicranial aponeurosis, a thin layer of connective tissue that covers the skull. Tendons function to connect muscle to bone or other structures. Ligaments join bone to bone, usually as joints.

Because of the nature of connective tissue, you can appreciate that damage to this tissue is a serious occurrence. As connective tissues consist only of a few cells and mostly nonliving matrix, they have a very limited capacity to regenerate themselves. This is one reason that tendon and ligament injuries often need surgery for repair. Proper nutrition and strength training can help build strong connective tissues that will become more resistant to injury.

The connective tissues discussed above are the types most often referred to in the realm of athletics. Some other types of connective tissues are reticular tissue of the spleen, lymph nodes, and bone marrow, which functions as a filtering media for blood and lymph; areolar tissue, which occurs between organs and other tissues and functions to connect; and adipose tissue, which contains fat and is found under the skin in various spots throughout the body. Adipose tissue functions to protect, insulate, support, and serve as a food reserve. Also included as connective tissues are blood, myeloid (red bone marrow), and lymph.

Examples of dietary supplements that have been shown to exhibit beneficial effects for connective tissue health include glucosamine and chondroitin sulfate.

Muscle Tissues

Muscle tissue makes up approximately 43 percent of a man's body weight and 34 percent of a woman's. Some 620 muscles work together with the support of the skeletal system to create motion. An additional 30 or so muscles are required to ensure the passage of food through the digestive system, to circulate blood, and to operate specific internal organs. In exercise physiology, muscles are the main operative tissue, expending energy, generating wastes, and requiring substantial nutrition.

The main function of muscle tissue is contraction. This contraction of muscle can be brought about by either involuntary or voluntary stimuli. Voluntary muscle tissues receive nerve fibers from the somatic nervous system. Therefore, their contraction can be voluntarily controlled. Skeletal muscles are the major voluntary muscle tissue. Involuntary muscle tissues receive nerve fibers from the autonomic nervous system and cannot be voluntarily controlled, except in a few rare cases. The eternal pump, the heart, is an example of an involuntary muscle tissue.

Muscles also differ in appearance when observed under the microscope because of their underlying cellular structure. Two appearances are recognized: striated muscle tissue and smooth muscle tissue. Based on functional and structural differences, muscle tissue is divided into three types (skeletal, cardiac, and smooth).

Skeletal muscle tissue (striated-voluntary muscle tissue) – is found attached to bones, in extrinsic eyeball muscles, and in the upper third portion of the esophagus. Skeletal muscle tissue functions to move the bones and eyes. It also moves food during the first part of swallowing. Skeletal muscle tissue is made up of long muscle cells (muscle fibers) that bear the unique characteristic of containing many nuclei, called multi-nucleate. Characteristically, skeletal muscle tissue cannot sustain prolonged all-effort contractions, as they easily fatigue.

With few exceptions, single muscles never contract by themselves. Rather, specific sets of muscles contract together or in sequence. The production of complex movements responsible for even the simplest of tasks depends on a correspondingly subtle control mechanism. This is the responsibility of the nervous system, which neutralizes the actions of muscles that are not required and causes the contraction of muscles that are required. The spinal cord and brain exercise this control through the motor nerve fibers.

Each muscle cell does not have an individual line from the CNS (central nervous system). Impulses travel down the nerve axon from the CNS, branching off to supply a group of muscle cells that contract together. To coordinate muscular movement, the CNS must be supplied with information about the length of the muscle and the tension of the tendons that attach it to the skeleton. This information is provided by special sense organs called "muscle spindles," which measure the strain in the muscle and can be used to preset the tension of muscles.

Skeletal muscles must contract rapidly in response to signals from the CNS, and they must develop adequate tension at the same time to produce an effective mechanical force. Examination of skeletal muscle reveals a junction between the nerve fiber and the muscle surface.

The surface acts as an amplifier, increasing the effect of the tiny current coming down the nerve fiber to stimulate the larger muscle fiber. The arrival of the nerve impulse triggers the release of a chemical called **acetylcholine** from the motor nerve ending. This passes across the gap to stimulate the membrane of muscle fiber. This stimulation, in the form of an electric current, passes along the surface of the muscle and causes it to contract. It takes only 1/1000th of a second for the current to pass along the surface of the muscle fiber. The fiber releases unless yet another impulse arrives. If this chemical mechanism were blocked, the result would be paralysis.

Acetylcholine: a neurotransmitter that is critical for optimum nervous system functioning.

The Mechanics of Muscular Contraction

To the naked eye, the external skeletal muscles appear grainy because they are made up of small fibers. These fibers are cylinder-like and may be several centimeters long. In length, they are divided into bands (striations), much like coins stacked in a pile. Each individual fiber is surrounded by a thin plasma membrane, the sarcolemma. Some 80 percent of the fiber's volume is filled with tiny fibrils, known as myofibrils, which may number from several hundred to several thousand per fiber. These fibrils are the structures directly involved in contraction of the muscle fiber. The remainder of the muscle fiber is filled with a jelly-like intracellular fluid called sarcoplasm. The sarcoplasm contains many nuclei and other cell constituents, such as mitochondria, within which energy-producing biochemical reactions take place.

Further examination of the fibrils shows that they are made of two types of protein—actin and myosin—which are in the form of long filaments. The thick ones consist of myosin, and the thin ones are made of actin. These filaments are able to interlock and slide over each other to accommodate the stretching of the muscle. During shortening (contraction), they slide into one another, and it appears that cross-links are made between the actin and myosin filaments. These cross-links are almost instantaneously broken, and new links are set up farther along the filaments. The process of breaking these cross-links causes the two filaments to move toward one another, causing the muscle to shorten (contraction).

The term "contraction" does not always refer to the shortening of a muscle. Technically, it refers to the development of tension within a muscle. There are two major contractions. A contraction in which the muscle develops tension but does not shorten is termed “isometric.” A contraction in which the muscle shortens but retains constant tension is said to be “isotonic.” For example, a person trying to curl a heavy barbell strains against the weight. The arm muscles develop tension but do not shorten because the amount of resistance generated by the heavy barbell is greater than the muscle’s tension. But when the barbell is lightened by removing some plates, the load is lightened, and the working muscles shorten as they contract. This is an isotonic contraction. When muscles shorten by overcoming resistance to a load (weight), the isotonic contraction is said to be concentric. When the biceps lengthen while the barbell is let down, but they maintain a constant tension during the lengthening movement, this type of isotonic contraction is termed “eccentric.” The muscles lengthen as they act to maintain tension.

The energy for contraction is derived from the chemical reaction between the food components we eat and the oxygen we breathe. Blood, therefore, is needed to bring the essential nutrients and oxygen to the muscles and to remove waste products. The biochemical process of energy production involves the breakdown of glucose (fatty acids or fructose) to eventually just carbon dioxide and water. This breakdown releases the energy used by muscle proteins to cause contraction. This specific chemical reaction requires an extremely abundant supply of oxygen, which is often unavailable. Even during intense exercise, the blood supply is often insufficient to carry enough oxygen to the muscles. The muscles solve this problem by converting glucose into lactic acid, without oxygen, which still gives an ample release of energy.

The excess lactic acid eventually enters the bloodstream and is circulated to the liver where it can be reassembled into glucose and returned into the bloodstream or stored as glycogen. Some of the lactic acid can also be converted back into the molecule pyruvic acid and enter into the mitochondria to be completely broken down for energy. The heart, and perhaps other organs and tissues, can utilize lactate for energy. More about lactate will be reviewed in the unit related to metabolism.

Muscles (and other tissues) store glucose in a form of complex carbohydrates called glycogen. It is this storehouse of energy that the body calls upon during a high-intensity, low-duration activity, such as weightlifting (as opposed to caloric draw during a low-intensity, high-duration activity, such as long-distance running, which uses a mixture of glucose from glycogen and fatty acids from fat stores).

Fast-Twitch and Slow-Twitch Muscle Fibers

Skeletal muscle tissue is composed of two general types of muscle fibers: fast twitch and slow twitch. Fast-twitch fibers are selectively recruited when heavy workloads are demanded of the muscles and strength and power are needed. They are recruited for high-intensity, short-duration work. They contract quickly, yielding short bursts of energy, and are recruited in high numbers during brief, intense exercises such as sprinting, weightlifting, shot putting, or even swinging a golf club. But these fast-twitch muscle fibers exhaust quickly. Pain and cramps settle in rapidly from byproducts of their own metabolism.

Slow-twitch muscle fibers produce a steadier low-intensity, repetitive contraction, characteristic of endurance activities. They are capable of sustaining workloads of low intensity and long duration, such as long-distance running. Athletes of high-intensity sports such as weightlifting, wrestling, and sprinting, tend to have a greater percentage of fast-twitch muscle fibers. Athletes of low-intensity sports, such as long-distance running, tend to have a higher percentage of slow-twitch muscle fibers.

There are several points of interest to the athlete. The first is that when you train, the intensity and duration will influence the physiology of muscle tissue and development of muscle fibers. The long-distance runner tends to develop slow-twitch muscle fibers, whereas the power lifter develops fast-twitch muscle fibers. One reason the fast-twitch muscle fibers increase in size is to increase the capacity to store more adenosine triphosphate and creatine phosphate (ATP and CP). ATP and CP are needed for explosive energy that lasts only a few seconds. The second reason is that the physiological conditioning of muscle tissue determines which fuel source is used. Power athletes need more muscle glycogen to fuel their muscles, whereas endurance athletes need both muscle glycogen and fatty acids. One reason it is typical for some power athletes to tend to carry excess fat is that their diets are too high in fats, and their mode of training does not burn much fat. The excess fat develops into large fat stores.

Muscular Hypertrophy

Muscular hypertrophy is simply the increase in the size of muscle fibers. The principal mechanism for muscular hypertrophy is by individual muscle cells increasing the number of their myofibrils. This probably occurs as a result of increased amino acid transport into the cells (caused by tension), which enhances their incorporation into contractile protein. However, muscle hypertrophy also occurs as a result of proliferation (in size and number) of mitochondria, myoglobin (storage protein), extracellular and intracellular fluid, capillarization (tiny blood vessels surrounding cells), and fusion between muscle fibers (principally Type IIb) and surrounding satellite cells. Buildup of creatine phosphate (phosphocreatine), from creatine supplementation, can also contribute to muscular hypertrophy.

In addition to increasing the size of the muscle fibers, increasing the number of muscle fibers also seems to be a logical mechanism of muscle growth. Increasing the number of muscle cells is called "hyperplasia." Researchers have reported the possibility of fiber splitting in their research reports (longitudinal division of muscle fibers resulting in new muscle cells). However, new muscle fiber development from special cells referred to as muscle precursor cells also occurs with the correct training stimulus, nutrition program, period of rest, and good sleep to maximize the nocturnal anabolic cascade, which is important for muscle recovery, regeneration, and growth.

Cardiac Muscle Tissue. Cardiac muscle tissue (striated-involuntary muscle tissue) composes the wall of the heart. It functions to contract the heart and pump blood through body. Cardiac muscle cells are often branched, and their nuclei are more centered than with skeletal muscle cells. They have a tendency to branch and fuse into each other. Fortunately, cardiac muscle tissue does not fatigue easily; the period of rest in between contractions is all it needs. Even during periods of intense exercise, skeletal muscles fatigue first.

Smooth Muscle Tissue. Smooth muscle tissue (smooth-involuntary muscle tissue) is found in walls of the tubular viscera of digestive, respiratory, and genitourinary tracts; in walls of blood vessels and large lymphatics; in ducts of glands; in intrinsic eye muscles (iris and ciliary body); and in arrector pili muscle of hairs. It functions to move substances along their respective tracts, change diameter of blood vessels, move substances along glandular ducts, change the diameter of pupils and the shape of the lens, and erect hairs. Like cardiac muscle tissue, smooth muscle tissue cells are elongated but differ in having pointed ends and only one nucleus per cell. They contract more slowly than striated muscle does and therefore do not fatigue easily.

Nervous Tissues. The nervous tissues are composed of several types of cells that are responsible for the control of the bodily functions. Nervous tissues are found in the brain, spinal cord, and nerves that branch out to all parts of the body. The types of nervous tissues are neurons, neuroglia, and neurosecretory cells. 1) Neurons conduct nerve impulses, register sensory impulses, and conduct motor impulses. The central neuron body contains a nucleus surrounded by cytoplasm and two projections at either end. The two types of projections are axons and dendrites. 2) Neuroglia may provide nutrients for neurons or play a role in their embryological growth and orientation. 3) Neurosecretory cells, as their name implies, secrete substances that may have an effect elsewhere in the body.

Reproductive Tissues. The final and most vital tissue responsible for propagating the human species is reproductive tissue. As its name implies, reproductive tissue is composed of

Skeletal Muscle Fiber Types

Type I (Slow-Twitch Oxidative, SO)

Slow twitch (slow speed of muscle fiber contraction), low-force capacity, high oxidative metabolism capacity, highly fatigue resistant, with little capacity for exercise-induced hypertrophy, high resistance to exercise-induced structural damage. High density of mitochondria per fiber, which increases with aerobic endurance training. Small diameter, high capillary density.

Type II a (Fast-Twitch Oxidative-Glycolytic, FOG)

Fast twitch (fast speed of muscle fiber contraction), medium-force capacity, oxidative-glycolytic metabolism, highly fatigue resistant, high capacity for exercise-induced hypertrophy, moderate resistance to exercise-induced structural damage. Medium density of mitochondria per fiber. Important for sustained power endurance. Medium diameter, intermediate capillary density, intermediate glycogen content.

Type II b (Fast-Twitch Glycolytic, FG)

Fast twitch (fast speed of muscle fiber contraction), high-force capacity, high capacity for glycolytic metabolism, low-oxidative capacity, highly susceptible to fatigue, great capacity for exercise-induced hypertrophy, great susceptibility to exercise-induced damage. Low mitochondria density per fiber. Generates explosive strength and power. Larger diameter, high glycogen content, low capillary density.

cells specialized to produce the next generation. These cells are the egg cell (ovum) in females and the spermatozoa (sperm) in males. Egg cells are spherical in shape and contain yolk to feed the developing offspring from the instant of fertilization until it can obtain food in some alternative way.

Systems

All of the tissues interact in one way or another to form functional body units referred to as systems. Actually, the body is one living system made up of subsystems. However, for academic purposes, anatomists and physiologists refer to these subsystems as systems. These basic tissue types are organized together to form the systems of the human body. As previously mentioned, the body is composed of several interdependent systems, meaning that although each system can be separated out from the rest, and without the other systems, its function cannot be carried out to completion. For example, if the muscular system were disconnected from the nervous system, nerve impulses sent down neurons would have no effect on stimulating muscle contractions. The following nine major systems are generally recognized as the systems composing the human body. General information is included here, and a few of the systems whose understanding is more pertinent to the athlete and nutrition will be reviewed again in subsequent units.

Skeletal System

The skeletal system comprises all the bones plus the joints formed by their attachments to each other. Predominant tissues include bone, cartilage, ligaments, and hematopoietic tissue (blood cell-forming tissue in red bone marrow – myeloid tissue, also in lymphatic tissue). The skeletal system provides these basic functions: support, protection, movement, and hematopoiesis.

Skeletal Muscle System

The skeletal muscle system is composed of skeletal muscle tissue (striated-voluntary) and tendons, is nourished by the circulatory system, and is controlled by the somatic nervous system. Skeletal muscles function mainly in movement of the body. Skeletal muscle also functions to a limited extent as a storage tissue of protein (amino acids). However, degradation of muscle tissue is undesirable to the athlete and only beneficial for survival during periods of starvation.

Nervous System

The nervous system is composed of neurons, neuroglia, and neurosecretory cells. The nervous system's function is to provide memory and to integrate bodily functions, communication, and control. Its responses are generally rapid, whereas those of the endocrine system are generally slow.

Respiratory System

The respiratory system is composed of the following organs: nose, pharynx, larynx, trachea, bronchi, and lungs. It functions to connect the gaseous external environment with the trillions of internal cells that make up the human body. The respiratory system provides a conduit for the intake of required oxygen and the expulsion of the gaseous metabolic waste—carbon dioxide. The respiratory system requires the circulatory system to complete its functions of transferring gases from the lungs, through the lung membrane, into the bloodstream, and to the cells. The reverse is true for the waste gas (carbon dioxide) and water.

Cardiovascular (Circulatory) System

This system consists of the heart, veins, arteries, and the lymph system. The lymph system is considered part of the circulatory system since it consists of a moving fluid, lymph, derived from the blood and a group of vessels called lymphatics. The circulatory system performs vital pickup and delivery service for the body. Blood picks up food and oxygen from the digestive and respiratory systems and delivers them to the cells. From cells, blood picks up wastes and delivers them to excretory organs, the kidneys for example. Blood also picks up endocrine hormones and delivers them to target tissues. Directly or indirectly, the circulatory system contributes to every function of every cell.

Digestive System

Five organs form the alimentary canal (also called gastrointestinal tract). They are the mouth, pharynx, esophagus, stomach, and intestines. Six accessory organs are connected to or exist in the digestive system. They include the salivary glands, teeth, liver, gall bladder, pancreas, and vermiform appendix. The digestive system functions to break down food so it can be absorbed by cells and metabolized through the body. Because this book is about nutrition, an entire unit is dedicated to reviewing the digestive system. (Refer to Digestion Unit for more details.)

Urinary System

The urinary system consists of the following organs: kidney, ureters, bladder, and urethra. They all function in the following manner. The kidneys (two of them) filter wastes from the blood (e.g., urea), maintain electrolyte balance and acid-base balance, and play a role in **homeostasis**. They are also known to influence blood pressure. Any waste products that are selectively removed from the blood by the kidneys are collected and transported via the two ureters to the bladder. It should be pointed out that the kidneys also reabsorb 97 percent to 99 percent of the substances needed by the body that are initially filtered out with wastes. The bladder collects and stores the waste fluid (urine). When the bladder fills, the urine is then expelled from the body through

Homeostasis: the tendency of the body to maintain an internal equilibrium.

the single urethra. Urine normally contains nitrogenous wastes from protein metabolism (urea, uric acid, ammonia and creatine); electrolytes, which mainly contain sodium, potassium, ammonia, chloride, bicarbonate, phosphate, and sulfate; toxins; pigments; hormones; and various abnormal constituents, such as glucose, albumin, blood, and so on.

Reproductive System

The reproductive system contains those organs that function to produce viable sperm in the male and fertile eggs and an internal environment for the fertilized egg to develop in the female. The male reproductive organs include a pair of testes, which produce sperm and testosterone, the hormone responsible for masculinity; a pair of seminal vesicles, which store the sperm until it is time for ejaculation; one prostate gland, which produces the nutritive media that enable the sperm to survive in the vaginal environment; and a pair of bulbourethral glands, which secretes an alkaline fluid to be included in the semen. Various ducts connect these organs together.

The female reproductive system consists of: two ovaries, which contain the unfertilized eggs; two fallopian tubes, which carry the eggs down to the uterus; a uterus, which is the site of implantation of the fertilized egg; the cervix, which is a small cylindrical muscle that allows the flow of menstrual blood from the uterus to the vagina, and directs the sperms into the uterus during intercourse; and the vagina, which functions as the vestibule for the erect penis and as the birth canal.

The above systems that compose the body must be functioning at maximum efficiency for optimal athletic performance. Proper nutrition is essential for this to occur.

Endocrine System

The endocrine system consists of several glands which release their secretions into the blood stream. They function in control, communication, and integration. The endocrine system is similar to the nervous system, but accomplished through different mechanisms, namely endocrine gland secretions (hormones). Chemically, hormones may be classified as either proteins or steroids. All of the hormones in the human body, except the sex hormones and those from the adrenal cortex, are proteins or protein derivatives.

Hormones' activities are carried by the blood throughout the entire body, yet they affect only certain target cells. The specific cells that respond to a given hormone have receptor sites for that hormone, referred to as the lock-and-key mechanism. If a hormone fits the receptor site, then there will be an effect. If a hormone and a receptor site do not match, then there is no reaction. All the cells that have receptor sites for a given hormone make up the target tissue for that hormone. In some cases, the target tissue is localized in a single gland or organ. In other cases, the target tissue is diffuse and scattered throughout the body so that many areas are affected. Hormones bring about their characteristic effects on target cells by modifying cellular activity.

Protein hormones react with receptors on the surface of the cell, and the sequence of events that results in hormone action is relatively rapid. Steroid hormones typically react with receptor sites inside a cell. Because this method of action actually involves synthesis of proteins, it is relatively slow.

Control of Hormone Action

Hormones are incredibly potent substances, which means that very small amounts of a hormone might have profound effects on metabolic processes. Due to their potency, hormone secretion must be regulated within very narrow limits to maintain homeostasis in the body. Many hormones are controlled by a negative feedback mechanism. In this type of system, a gland is sensitive to the concentration of a substance that it regulates. A negative feedback system causes a reversal of increases and decreases in body conditions to maintain a state of stability or homeostasis. Some endocrine glands secrete hormones in response to other hormones. The hormones that cause secretion of other hormones are called tropic hormones. A hormone from gland G1 causes gland G2 to secrete its hormone. A third method of regulating hormone secretion is by direct nervous stimulation.

Note that some glands also have non-endocrine regions that have functions other than hormone secretion. For example, the pancreas has a major exocrine portion that secretes digestive enzymes and an endocrine portion that secretes hormones. The ovaries and testes secrete hormones and produce the ova (egg) and sperm. Some organs, such as the stomach, intestines, and heart, produce hormones, but their primary functions are not hormone secretion.

Conclusion

The structure and function of the human body is very complex with cells, tissues, and systems interconnected and interdependent upon each other. Regarding sports nutrition, a focus of food and supplement intake needs to be purposeful to consider the needs of the entire body at every level. This thinking goes beyond simply eating to satisfy hunger but to satisfy the structure and function of the athlete's body for maximum performance and optimum health.

Some of the Body's Glands and Hormones		
Gland	**Hormone Secreted**	**Examples of Effects**
Adrenal Cortex	Mineralocorticoids; Aldosterone	Regulation of some blood mineral levels.
	Glucocorticoids; cortisol	Catabolism, increases blood sugar levels.
Ovaries	Estrogens	Develops feminine characteristics; egg production.
Pancreas	Insulin	Decreases blood sugar level; promotes glycogen, protein and lipid synthesis.
	Glucagon	Increases blood sugar level; **glycogenolysis**, breakdown of glycogen to glucose.
Parathyroid	Parathyroid Hormone (PTH)	Regulation of calcium levels.
Pineal	Melatonin	Control of circadian rhythms.
Pituitary (Anterior)	Follicle Stimulating Hormone (FSH)	Stimulates testosterone secretion and sperm development in testes; egg production and estrogen secretion by the ovaries.
	Growth Hormone (GH)	Helps regulate metabolism, stimulates both hard and soft tissue growth.
	Thyroid Stimulating Hormone (TSH)	Stimulates secretion of the thyroid gland.
	Andrenocorticotropic Hormone (ACTH)	Stimulates secretion of the adrenal cortex gland, cortisol.
	Luteinizing Hormone	In males, testosterone production in testis. In females, stimulates progesterone and estrogen secretion (ovaries), ovulation, prepares uterus for fertilized egg, aids in mammary gland development.
	Prolactin	Stimulates milk secretion from mammary glands.
Pituitary (Posterior)	Vasopressin, or Antidiuretic Hormone (ADH)	Regulates water absorption by kidneys, causes arteriole constriction.
	Oxytocin (OT)	Stimulates uterine contraction and mammary milk ejection.
Testes	Testosterone	Develops masculine characteristics; develops male sex organs; sperm production.
Thymus	Thymosin	T lymphocyte production and function.
Thyroid	Thyroxine	Increases metabolic rate.

Glycogenolysis: the metabolic process in which glycogen is broken down.

Key Words

Digestive enzyme	Acetylcholine
Gluconeogenesis	Homeostasis
Glycolysis	Glycogenolysis

Topics Covered In This Unit

UNIT 13

DIGESTION AND ABSORPTION

Unit Outline

Learning Objectives

After completing this unit, you will be able to:

- Define and describe terms related to digestion;
- Discuss how digestion takes place in the human body;
- Understand the anatomy of the digestive system; and
- Identify the digestive enzymes.

Introduction

Most people enjoy eating. In fact, the average person eats several hundred pounds of food every year. When you think about it, it's amazing that all we need to do to survive is shovel some food in our mouths, drink some liquid, and let our bodies do the rest. If you are just eating for survival, this approach is fine. But if your goal is to extend your life and improve athletic performance, attaining an understanding of digestion is necessary. This unit will cover the basics of digestion.

The digestive system starts at the mouth, runs some 25 feet through the trunk of the body, and ends at the anus. It is essentially a strong muscular tube lined with thick epithelium with specialized cells, which differ depending on which part of the digestive system you examine. The digestive system is also referred to as the alimentary canal, gastrointestinal system, and the gut. The digestive system is the body's life support connection with the external environment. Food is eaten, and somehow the body breaks it down into useful biomolecules to obtain the energy necessary for life and the building blocks necessary for growth.

Digestion is therefore the process that breaks food down through chemical and physical means. Via this process, the nutrients contained in food can be absorbed through the intestinal walls, transported by the blood to the liver, and then transported further onto the trillions of cells via the bloodstream. As you will soon discover, the digestive system is quite complex and remarkable. Note that because of the complex issues involved in determining the functioning of digestive system in humans, this area of anatomy and physiology is constantly being refined as new discoveries are made related to digestive enzymes and other issues concerning digestive system structure and functioning.

The functions of the digestive system include:

- Receipt, mastication (chewing), and transport of ingested substances and waste products;
- Secretion of acid, mucus, digestive enzymes, bile and other materials needed to break down food;
- Digestion of ingested foodstuffs;
- Absorption of nutrients;
- Storage of waste products;
- Excretion; and
- Certain auxiliary functions.

The Digestive System—Physical Components

The digestive system is composed of several anatomically different structures that make up the gut and several organs attached to the gut that provide essential functions to the entire process of digestion. The pancreas, for example, supplies important enzymes to help break apart complex food substances. The following will review these major structures and discuss their functions.

Mouth

Food enters the digestive system through the mouth. The mouth then has four functions that it exerts on the ingested food. First, it physically breaks apart food by chewing and reducing it in size. Second, it mixes the food with saliva into a moist mass, called a bolus, which is then made ready for swallowing. In this way, saliva serves to lubricate the food for its journey down the esophagus into the stomach. Mucus also makes the food particles stick together with a protein it contains. Second, the saliva also contains the digestive enzyme ptyalin, also known as salivary amylase, which begins the chemical breakdown of starch (carbohydrates).

The masticated food mass is swallowed and passed through the pharynx and then into the esophagus. Chewing your food thoroughly is vital to the digestive process. By thoroughly chewing your food, you will get the full benefit of the digestive enzyme ptyalin and physically reduce in size the other foodstuffs, like protein, so the stomach can perform its digestion functions more easily.

Third, the mouth regulates temperature by either cooling or warming the food. Temperature regulation is important as enzymes function at their best in a narrow temperature range. For the human, this range is tightly held around body temperature. In addition, delivery of cold food can hasten the emptying of the stomach and reduce the efficiency of digestion. One exception is when drinking fluid before and during exercise or competition, emptying faster will rehydrate the body faster. The fourth major function of the mouth is that it consciously initiates swallowing when the bolus is ready.

Esophagus

The esophagus extends between the pharynx and stomach and is the transport conduit for food and water traveling to the stomach. When the bolus enters the esophagus, an involuntary wave of muscle contractions is triggered, which propels the food mass down into the stomach. This muscle contraction action is known as peristalsis. This peristaltic wave travels down the esophagus about three inches per second. Once at the base of the esophagus, a ring-like muscle is reached, the esophageal sphincter, which relaxes to let the food into the stomach. Keep in mind that at the same time food is let into the stomach, the esophageal sphincter is keeping food from spurting out of the stomach and back up the esophagus. If the sphincter weakens or malfunctions, the acidic contents of the stomach might shoot up into the esophagus and produce an unpleasant, bitter sensation in the throat known as heartburn, which has nothing to do with the heart except that pain may develop in the area of the heart. To reduce stress on the esophageal sphincter, it is a good practice to eat sitting up and to try not to over fill the stomach with huge meals.

Stomach

The stomach is a muscular sac about two quarts in size but varies in size from person to person. It functions in the storage and gradual release of food into the small intestine, digestion through chemical secretions and the physical activity of churning the digesting food, and transport of ingested food down the gut.

The stomach secretes substances to aid in the breakdown of food. Mucus acts as a protective layer to lubricate the stomach wall and to buffer the acid secretions. **Hydrochloric acid** helps keep the stomach relatively free of microorganism (bacteria) and maintains a low pH in the stomach. Hydrochloric acid also acts to catalyze the action of pepsin, a protease, which begins the digestion of proteins. Then there is an intrinsic factor secretion, which binds with vitamin B12 and allows it to be absorbed in the small intestine. The hormone gastrin is also secreted in the stomach and helps regulate stomach secretions during digestion. Gastrin is a hormone involved in gastric activity regulation and in stimulating gastric acid release (hydrochloric acid, potassium chloride, and sodium chloride).

When macronutrients are taken alone, they leave the stomach at different rates of time. Carbohydrates will empty from the stomach the most quickly. For this reason, pure carbohydrate drinks taken during exercise can get into the bloodstream fast and replenish the body's primary energy source, glucose. Proteins empty from the stomach next in time sequence, and fats take the longest to empty. When carbohydrates, proteins, and fats are consumed together, because they will all be mixed together, the stomach will take longer to empty. Carbohydrate and some lipid breakdown also occur in the stomach. The stomach normally takes one to four hours to empty, depending on the amount and kinds of foods eaten.

Although the intestines are known as the primary location for absorption, some nutrients can be absorbed by the stomach. In general, the following can be absorbed by the stomach: some water, alcohol, glucose, and some vitamins, such as niacin. These are the main examples, and undoubtedly, others of lesser importance or new ones are yet to be determined.

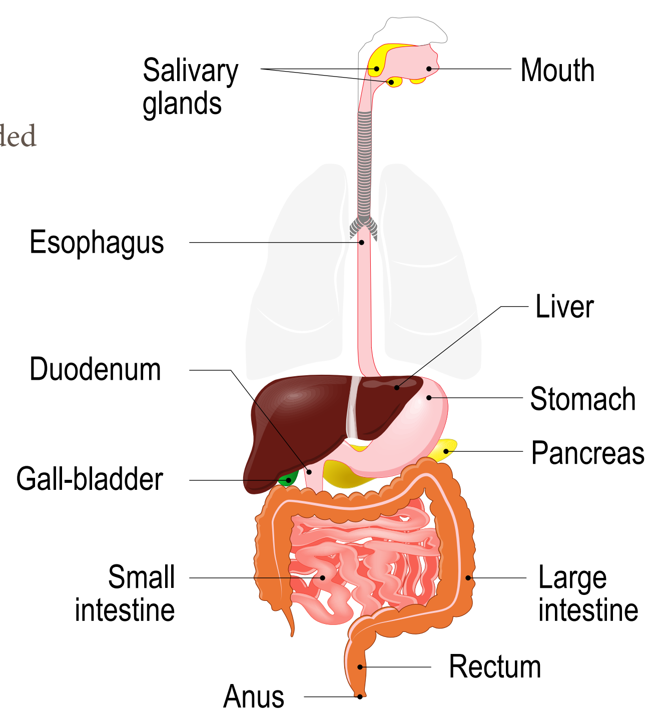
Hydrochloric acid: a stomach secretion that functions in protein metabolism, helps keep the stomach relatively bacteria-free, and assists in the maintenance of a low pH balance in the stomach.

The fact that water and glucose can partially be absorbed through the stomach is a benefit for quick replenishment of these nutrients during exercise. Some popular sports drinks take advantage of this and contain glucose as an ingredient, along with fructose, which is more slowly absorbed, and complex carbohydrates, which release glucose at a slow rate as they are digested. Glucose ingestion can help spare your body's glycogen supply, but glucose must be ingested just prior to exercise, within one half hour, or it can cause an influx of insulin that will upset energy generation during exercise.

The stomach only begins the process of breaking down complex molecules, like proteins, into their smaller components, such as amino acids in the case of proteins. This breakdown process, also called hydrolysis, continues in the intestines. The partially digested material of the stomach that enters the small intestine through the pyloric sphincter muscle in squirts is called chyme. Generally, chyme consists of gastric juices and partially digested food.

The Small Intestine

The small intestine stretches about 12 feet long and is divided into three main regions: duodenum, jejunum, and ileum. The duodenum is connected to the stomach and composes the first part of the small intestine. Some absorption takes place here, but it is a location of continued breakdown of food and storage. The next regions of the small intestine are responsible for the majority of nutrient absorption: these are the jejunum and ileum.



Some of the digestive enzymes in the small intestines are provided by the pancreas (see pancreas section below) and some from the intestinal cells, for example, maltase, lactase, peptidases, and nucleosidases. Bile from the gall bladder is introduced to help digest fats.

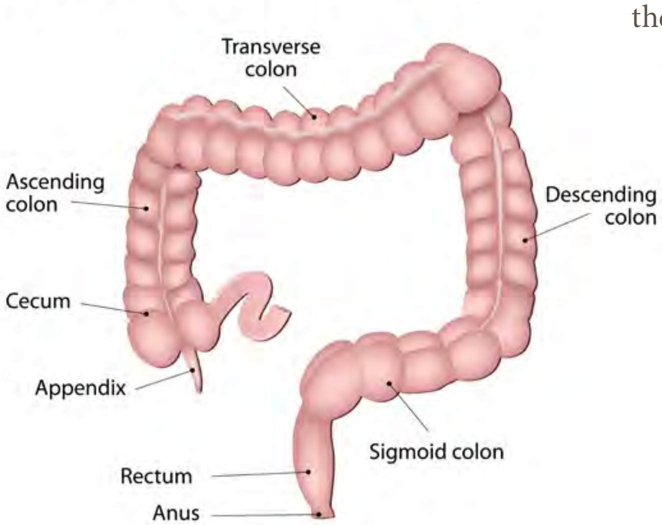
Anabolism: the biochemical process in which different molecules combine to form larger, more complex molecules.

To accomplish complete absorption, the inside surface of the small intestine has a unique anatomy. Instead of being a flat surface, like that of the skin, the small intestine is lined with special cells called villi. These villi are very small finger-like projections that line the entire inner surface of the intestine. In this way, the surface area of the intestine is greatly increased. Each villus has blood vessels that run into it. When nutrients pass through the cells of the villus, they are transported into the blood vessels and then transported to the liver. In addition to the breakdown of fats, the small intestines absorb proteins and carbohydrates and vitamins and minerals.

Another transport system is also present in the villus: the lymphatic system. A small projection called a lacteal also extends into the villus. The lymphatic system primarily transports fats. About 60 to 70 percent of the ingested fats are transported to the liver in this way. Shorter fats can be taken up through the blood vessels and transported directly to the liver from the intestines. These short-chain and medium-chain triglycerides have become popular in athletes' diets for this reason and because they do not convert easily to body fat. The medium-chain triglycerides are the most known and used for this purpose.

Large Intestine and Rectum

The large intestine (colon) is about three feet long. The area where the ileum and large intestine join is called the cecum. The vermiform appendix is also located in this area. In the large intestines, some final absorption of water, some minerals, and some vitamins occurs. Here is where live microbes are present, and through their metabolism, they produce some vitamins that are absorbed, such as Vitamin K. The large intestine (also called colon) stores the waste products of digestion. The further decomposition of fecal matter by microbial action produces gas, and depending on the nutrient substrata that makes it down to the colon, the amount of gas produced varies.



When the proper stimulus occurs, the colon will empty its contents into the rectum, triggering defecation. The more fiber in the diet, the softer the feces, and the easier it is to eventually defecate.

Pancreas

The pancreas is situated along the small intestine near the stomach and is an accessory organ of the gut. The pancreas produces several secretions important for digestion and absorption of the nutrients that are secreted into the small intestine. Examples of pancreatic digestive enzymes include lipase, amylase, trypsin, and nuclease.

Another vital type of secretion the pancreas produces helps control carbohydrate metabolism. These hormonal secretions are insulin and glucagon. Insulin is secreted into the bloodstream during a meal. It functions to mediate the transport of glucose and amino acids across cell membranes. It also fosters lipogenesis, the formation of fat. Insulin, therefore, has an anabolic function. **Anabolism** includes all the chemical reactions and changes that build new substances for growth and maintenance.

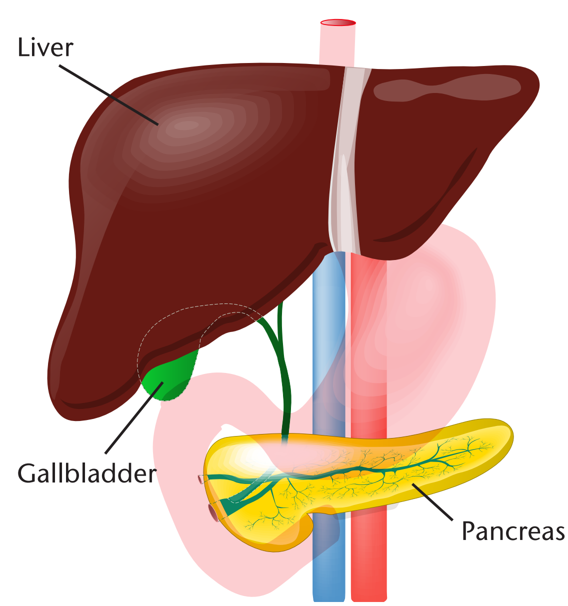
Glucagon is a hormone that is functionally the opposite of insulin. It initiates a series of reactions that causes the breakdown of glycogen to mobilize glucose into the blood for energy. During exercise, glucagon levels in the blood are increased, liberating energy for exercise. Insulin and glucagon work together in a seesaw fashion to maintain appropriate blood glucose levels. Pancreatic enzymes include amylase, trypsin, peptidase, and lipase. Pancreatic secretions are controlled by the hormones secretin and cholecystokinin.

Liver and Gall Bladder

Digestion is not complete until the nutrients have been delivered to the liver and then released into the bloodstream. The intestines are connected directly to the liver by the portal vein. In this way, the nutrients taken up from the intestines are delivered directly to the liver. Fats that travel through the lymphatic system enter the bloodstream directly and then are circulated to the liver for processing. In general, nutrients are control-released from the liver into general circulation.

The liver cells process the digested nutrients and store many substances for later use or release nutrients for immediate use. These cells can change nutrients into substances the body will need and store them until they are required. The liver acts as a processing organ that is responsible for maintaining nutrient balance and storing some essential nutrients and glycogen (glucose) for energy. Glucose stored in the liver is used mainly to supply the brain with energy. The gall bladder is a storage sac for a digestive mixture called bile.

Bile is a solution of cholesterol, bile salts, and pigments. Bile is secreted into the small intestine in the duodenum. It is essential for the action of lipase, for the digestion and absorption of fats, and for the absorption of fat-soluble vitamins.



Factors Affecting Digestion

Eating should not be taken for granted. The proper digestion of food requires developing good eating habits. To get the most out of meals, consider the following points.

- Eat slowly and chew food thoroughly.
- Maintain posture in an upright position. Avoid eating while lying down.
- Eat several meals of moderate size as opposed to eating a few large meals.
- Eat while calm. Nervousness can affect the movements of the digestive system and cause gastrointestinal disturbances.
- Allow some time for digestion to occur. Strenuous physical activities should be avoided directly after eating.
- Avoid foods that may irritate the stomach, such as hot spices and alcohol.
- Consulting a physician when digestive system disorders are present or suspected.
- When consuming multi-nutrient liquid meal-type products and protein powders, drink slowly, sip by sip, so the digestive system recognizes that nutrients are being ingested from a meal.

Hunger Pangs

The body has developed an intricate communication system that sends “I’m full” and “I’m hungry” signals to the brain. Hunger pangs are the body’s signal that says “feed me.” But what are hunger pangs, and what causes them?

Experiments on human subjects provide some answers. A device used to measure the contractions of the stomach was used to determine what causes hunger pangs. The subjects would signal the experimenter when feeling hunger pangs. The experimenter would then make a mark on the readout device that was charting the contractions of the stomach. The results showed that hunger pangs are caused by increased contractions of the empty stomach.

The scientific evidence on what triggers the hunger pangs is less clear. The stomach contractions causing the hunger pangs were not controlled by the nervous system, because they still occurred when the gastric nerves were cut. Sugar content in the blood may initiate hunger pangs. When blood sugar levels are reduced, hunger pangs are initiated. Thus, to a limited extent, hunger pangs are controlled by blood sugar levels. This is not always the case however.

In conditions of out-right starvation, hunger pangs gradually reduce in frequency. It is thought that the ketones from incomplete fat metabolism play a role in this phenomenon. Though some of the puzzle remains unsolved, maintaining adequate blood glucose levels is one proven way to control hunger pangs. That is why eating a plentiful amount of complex carbohydrates is a good nutrition practice and an easy way to control hunger, including whole grains. Complex carbohydrates, such as those found in rice, potatoes, and pasta, provide a prolonged supply of glucose to the bloodstream. Another part of the puzzle that has not been conclusively solved yet is finding out why contractions of the empty stomach cause pangs and why contractions of the full stomach do not.

About Digestive Supplement Aids

Digestive enzyme supplements have been available for many decades and are appearing more and more in sports nutrition products, such as in some protein products. Digestive enzymes are special molecules that act as catalysts for the breakdown of food components. (Note: enzymes also catalyze building-up processes and speed up many biochemical reactions.) It must first be noted that under normal circumstances, a healthy digestive system is generally efficient, and a healthy digestive system will usually adjust to increased food consumption by increasing enzyme production accordingly.

Digestive enzymes in the form of supplements are of plant or animal origin and can be derived from microbial commercial production. Example of plant enzymes include bromelain (from pineapple) and papain (from papaya). Bromelain has also gained popular use as a nutritional aid for the healing and reduction of inflammation. Some microbial-produced digestive enzymes include bacterial protease, beta-glucanase, catalase, hemicellulase, maltase, and phytase. The variety of digestive enzyme supplements also includes distase, glucoamylase, pectinase, xylanase, pepsin, and lipase.

Caution: As with any health problem, gastrointestinal disorders should be promptly treated by physicians. When experiencing pain, excessive gas, blood in the stool, or any gastrointestinal irregularity, you should immediately seek a physician's advice. Individuals with existing gastrointestinal problems should not use digestive enzymes unless they are under the supervision of their physicians.

Lactose Intolerance

Lactose intolerance is an example of a condition experienced by millions of people that requires medical supervision and a special diet and may require medication and/or use of digestive enzyme supplements. Lactose intolerance is a condition in which people have digestive symptoms after eating lactose-containing dairy products, including bloating, diarrhea, and gas. Lactase deficiency and lactose malabsorption may lead to lactose intolerance.

- Lactase deficiency. In people who have a lactase deficiency, the small intestine produces low levels of lactase and cannot digest much lactose.
- Lactose malabsorption. Lactase deficiency may cause lactose malabsorption. In lactose malabsorption, undigested lactose passes to the colon where bacteria may break down undigested lactose and create fluid and gas and upset.

It is interesting to note that people who experience lactose intolerance may be able to tolerate a minor amount of lactose per eating occasion. What's more, the types of lactose-containing foods may have different levels of tolerance, milk versus yoghurt for example, in which a person may be extremely sensitive to milk but less sensitive to yoghurt. Lactase supplements are sometimes used by people who experience lactose intolerance, but they should check with their doctors about this. People taking protein supplements of dairy origin should be aware that lactose can be present in sometimes significant amounts. Even people who are not normally lactose intolerant may experience some symptoms when ingesting high amounts of lactose.

The following article published by the FDA provides an overview of lactose intolerance and various issues of interest.

Problems Digesting Dairy Products?

Does your stomach churn after you drink milk? Do you have diarrhea soon afterward? If so, you may be lactose intolerant. The National Institute of Diabetes and Digestive and Kidney Diseases (NIDDK) estimates that 30 to 50 million Americans are lactose intolerant.

Being lactose intolerant means you can't digest lactose—the natural sugar found in milk and other dairy products. People who cannot digest lactose have a shortage, or deficiency, of an enzyme called lactase, which is produced in the small intestine. Lactase breaks down milk sugar into two simpler forms of sugar, which are then absorbed into the bloodstream.

Intolerance Is Not Allergy

Lactose intolerance is not the same as a milk allergy, says Kavita Dada, Pharm.D., a senior health promotion officer in the Food and Drug Administration's (FDA's) Division of Drug Information. "For most people with lactase deficiency, it's a discomfort." People who have trouble digesting lactose can learn which dairy products and other foods they can eat without discomfort and which ones they should avoid.

But a food allergy—an abnormal response to a food triggered by the immune system—can be life-threatening. People with food allergies must avoid certain foods altogether. People with food intolerances can often eat small amounts of the offending foods without having symptoms.

Symptoms

When there is not enough lactase to digest the lactose in the foods a person eats or drinks, the person may have

- gas
- stomach cramps
- bloating
- nausea
- diarrhea

These symptoms typically occur within 30 minutes to two hours after consuming food containing lactose. Some illnesses can cause these same problems, but a health care professional can do tests to see if the problems are caused by lactose intolerance or by another condition.

Who Becomes Lactose Intolerant?

Lactose intolerance is more common in some ethnic groups than others. NIDDK estimates that up to 75% of all adult African Americans and Native Americans and 90% of Asian Americans are lactose intolerant. As people age, their bodies produce fewer lactase enzymes, so most people don't have symptoms until they are adults.

Most people inherit the condition from their parents. Lactose intolerance is not very common in children under two years of age, unless the child has a lactase deficiency because of an injury to the small intestine. If you think your infant or child may be lactose intolerant, talk to your child's pediatrician.

Managing Lactose Intolerance

There is no treatment to make the body produce more lactase enzyme, but the symptoms of lactose intolerance can be controlled through diet.

Most older children and adults do not have to avoid lactose completely. People have different levels of tolerance to lactose. Some people might be able to have a tablespoon of milk in a cup of coffee with little or no discomfort. Others have reactions that are so bad they stop drinking milk entirely. Some people who cannot drink milk may be able to eat cheese and yogurt—which have less lactose than milk—without symptoms. They may also be able to consume a lactose-containing product in smaller amounts at any one time.

Common foods with lactose are

- milks, including evaporated and condensed
- creams, including light, whipping, and sour
- ice creams
- sherbets
- yogurts
- some cheeses (including cottage cheese)
- butters
- Lactose may also be added to some canned, frozen, boxed, and other prepared foods such as
- breads and other baked goods
- cereals
- mixes for cakes, cookies, pancakes, and biscuits
- instant potatoes, soups, and breakfast drinks
- lunch meats (other than Kosher)
- frozen dinners
- salad dressings
- margarines
- candies and other snacks

Dietary supplements with lactase enzyme are available to help people digest foods that contain lactose. However, the FDA has not formally evaluated the effectiveness of these products, and you may want to ask your doctor if these supplements are right for you.

Look at Labels

"Lactose-free" or "lactose-reduced" milk and other products are widely available in grocery stores. These products may be fortified to provide the same nutrients as their lactose-containing counterparts.

There is no FDA definition for the terms "lactose free" or "lactose reduced," but manufacturers must provide on their food labels information that is truthful and not misleading. This means a lactose-free product should not contain any lactose, and a lactose-reduced product should be one with a meaningful reduction. Therefore, the terms lactose free and lactose reduced have different meanings, and a lactose-reduced product may still contain lactose that could cause symptoms.

Lactose-free or lactose-reduced products do not protect a person who is allergic to dairy products from experiencing an allergic reaction. People with milk allergies are allergic to the milk protein, which is still present when the lactose is removed.

Look at the ingredient label. If any of these words are listed, the product probably contains lactose:

- Milk
- Cream
- Butter
- Evaporated milk
- Condensed milk
- Dried milk
- Powdered milk
- Milk solids
- Margarine
- Cheese
- Whey
- Curds

Highly sensitive individuals should also beware of foods labeled "non-dairy," such as powdered coffee creamers and whipped toppings. These foods usually contain an ingredient called sodium caseinate, expressed as "caseinate" or "milk derivative" on the label, which may contain low levels of lactose.

Testing for Lactose Intolerance

A doctor can usually determine if you are lactose intolerant by taking a medical history. In some cases, the doctor may perform tests to help confirm the diagnosis. A simple way to test at home is to exclude all lactose-containing products from your diet for two weeks to see if the symptoms go away and then reintroduce them slowly. If the symptoms return, then you most likely are lactose intolerant. But you may still want to see your doctor to make sure that you are lactose intolerant and do not have a milk allergy or another digestive problem.

Tips for Consumers

If you are lactose intolerant, try lactose-free milk or dairy products lower in lactose, such as yogurt and cheese. You may be able to consume dairy products in small amounts without symptoms.

Consume milk or other dairy products with other foods. This helps slow down digestion, making it easier for your body to absorb lactose.

If you're eating few or no dairy products, ask your doctor or dietitian if you are getting enough calcium in your diet. You may need to take dietary supplements with calcium to keep your bones healthy.

Raw Milk and Lactose Intolerance

FDA warns consumers not to drink raw, or unpasteurized, milk. "Raw milk advocates claim that pasteurized milk causes lactose intolerance," says John Sheehan, director of FDA's Division of Plant and Dairy Food Safety. "This is simply not true. All milk, whether raw or pasteurized, contains lactose, and pasteurization does not change the concentration of lactose, nor does it convert lactose from one form into another."

Raw milk advocates also claim that raw milk prevents or cures the symptoms of lactose intolerance. Arguing that raw milk contains Bifidobacteria, they claim these microorganisms are beneficial (probiotic) and create their own lactase, which helps people digest the milk.

"This is not true, either," says Sheehan. "Raw milk can contain Bifidobacteria, but when it does, the bacteria come from fecal matter (animal manure) and are not considered probiotic, but instead are regarded as contaminants."

Drinking raw milk will still cause uncomfortable symptoms in people who are correctly diagnosed as being lactose intolerant. But worse than this discomfort are the dangers of raw milk, which can harbor a host of disease-causing germs, says Sheehan. "These microorganisms can cause very serious, and sometimes even fatal, disease conditions in humans."

Source: https://www.fda.gov/forconsumers/consumerupdates/ucm094550.htm

Intestinal Microbials (Microorganisms)

Within everyone's intestinal tract live billions of microscopic bacteria, fungi, and other microorganisms. Human babies are born with a group of bacteria called the *Lactobacillius* present in their bodies. A week or two later, another group of bacteria also begins to inhabit the intestines, the *Bifidobacteria*. These bacteria are the indigenous flora of the intestines and are important in maintaining proper intestinal functioning and overall health. Probiotics is a term used to connote live microorganisms in the body that can have a health benefit versus the pathogenic microorganisms in the body that can cause adverse health effects.

Two crucial microbial species are *Lactobacillius acidophilus* and *Bifidobacterium bifidum*. These bacteria benefit the health of the entire body by suppressing growth of harmful microorganisms in the bacteria, producing some vitamins, and maintaining of the intestinal environment for proper intestinal absorption to occur. Both *Lactobacillius* and *Bifidobacterium* species are available in supplement form. Probiotics are also provided from foods, in particular cultured foods like yoghurt, and in fermented foods.

When using probiotics, be sure to follow the directions as indicated on the labels for proper use under supervision of a physician or other health professional. When used correctly, probiotics can provide health benefits. However, they are not a replacement for poor nutrition. To get the best benefits from dietary probiotics, follow a healthy diet. Note that a diet that is high in processed foods, added sugar, and preservatives can work against the healthy probiotics becoming established in the gut.

Here are some of the approved uses/purposes presented by Health Canada, in general:

- Help support gastrointestinal health
- Promote regularity
- Could promote a favorable gut flora
- Aid in digestion, improves nutrient absorption
- For certain species, help reduce the symptoms of diarrhea

Improving immune system health is another benefit associated with regular use of probiotic supplements. In the United States, there are

Examples of some Probiotic Species used in dietary supplements:		
Bifidobacterium adolescentis	*Bifidobacterium animalis*	*Bifidobacterium bifidum*
Bifidobacterium breve	*Bifidobacterium longum*	*Lactobacillus acidophilus*
Lactobacillus brevis	*Lactobacillus buchneri*	*Lactobacillus casei*
Lactobacillus crispatus	*Lactobacillus curvatus*	*Lactobacillus fermentum*
Lactobacillus johnsonii	*Lactobacillus kefiranofaciens*	*Lactobacillus kefiri*
Lactobacillus mucosae	*Lactobacillus panis*	*Lactobacillus paracasei*
Lactobacillus paraplantarum	*Lactobacillus plantarum*	*Lactobacillus pontis*
Lactobacillus reuteri	*Lactobacillus rhamnosus*	*Lactobacillus salivarius*
Lactobacillus sanfranciscensis	*Saccharomyces boulardii*	*Saccharomyces cerevisiae*

a variety of probiotic supplements and foods containing probiotics with similar health benefit claims, usually determined by the product companies, based on their independent reviews of the scientific evidence. Although most probiotics are bacterial microorganisms, there are some like Saccharomyces (yeasts) that are fungi.

Fiber and Digestion

The importance of fiber intake has gained notice recently. Nutrition surveys indicate that during the past 60 years, daily fiber consumption has dropped in the United States. Researchers have determined an array of health benefits to be associated with a high fiber diet, including proper bowel function, increased satiety, and cholesterol lowering (bran and pectin).

In the United States, the dietary reference intakes for total fiber ranges from 25.2 to 33.6 grams of dietary fiber per day for adults. This is accomplished primarily by eating more whole grain products, fruits and vegetables, and fiber supplements. Refer to Unit 3 for a reference chart containing foods high in dietary fiber and for information about prebiotics, which are certain types of complex carbohydrates that are the preferred food for the probiotics.

Conclusion

Digestion and digestive system health is of vital importance for athletes to optimize the digestion and absorption of nutrients and to avoid gastrointestinal update that becomes counterproductive to athletic performance. Care must be exercised for the selection, storage, and preparation of foods that are most compatible for the athletic client. Even healthy foods can cause annoying side effects, such as gastrointestinal gas, increased rate of defecation, or reduction in appetite, followed by inadequate caloric consumption. Food and supplement strategies should be developed to optimize digestion and digestive function, provide the required nutrients and calories, and promote health and athletic performance.

Key Words

Hydrochloric acid

Anabolism

Topics Covered In This Unit

UNIT 14

BODY COMPOSITION

Unit Outline

I. **Introduction**

II. **Body composition assessment**

III. **Methods of body composition determination**

IV. **How to use the Fat-O-Meter skinfold caliper**

   a. Generalized adult equations to determine percent body fat most accurately

      i. The sites listed in the formulas and charts are as follows:

   b. Use of skinfold data

   c. Percentage of body fat?

V. **Body mass index (BMI)**

VI. **Body types (somatotype)**

VII. **Conclusion**

Learning Objectives

After completing this unit, you will be able to:

- Define and describe terms related to body composition;
- Discuss the variety of body composition measurement approaches; and
- Determine body composition.

Introduction

To achieve maximum athletic performance, you must mold and sculpt the athlete's body to best meet specific goals. Trainers and athletes need to know more information about their bodies than what the bathroom scale or the height-weight charts can provide. You need to know what the body is made of and how it responds to nutrition and training. The amount of body fat and lean body weight the body is composed of is vital information. Additionally, you need to know about metabolism. How is an athlete's metabolism working? How many calories are needed? Is nutrition intake adequate based on body composition and metabolic needs and other factors? This unit provides this essential information, which you can then apply to an athletic performance program.

Body Composition Assessment

Body composition assessment is an important part of your initial assessment procedure with new athlete clients and an important ongoing evaluative test with existing clients and with other types of clients as well. Excessive levels of body fat are associated with cardiovascular disease, cancer, and other maladies. Body composition assessment is also a crucial source of motivation for clients, as it demonstrates (we hope) positive changes in overall fitness levels. Although many methods of determining body fat levels exist, use of **skinfold calipers** offers a choice between accuracy, profitability, and cost-effectiveness. The Fat-O-Meter is available through online retailers. Examples of other brands of skinfold calipers include Lange and Harpenden.

Skinfold calipers: the specialized calipers used to measure the thickness of skinfolds.

Skinfold measurement: a method for determining body composition that involves measuring the thickness of selected folds of skin using special calipers.

Skinfold measurements are one type of body measurement. In scientific research and surveys, skinfold and other physical body measurements are referred to collectively as anthropometric measurements. Examples of other anthropometric measurements include the ones considered routine and part of any fitness trainers approach, such as weight, height, BMI, and body circumferences.

Methods of Body Composition Determination

Before we review use of skinfold calipers, let's examine some of the various techniques available to determine body composition to become acquainted with other options.

Underwater Weighing. A widely used technique is underwater or **hydrostatic weighing**. A comparison is made of weight in air to weight of the completely submerged subject who has exhaled completely. A statement of body's density is then determined (fat is less dense than water is). A person with a high amount of fat will weigh less underwater than will a person of similar weight who has less fat. Correlations are, of course, made for amount of air in the lungs during the measurements (i.e., corrected for residual volume—the amount of air left in the lungs after a complete exhalation) and for gastrointestinal air. This technique, in the hands of skilled technicians and subjects who are comfortable underwater, provides a good estimate of the density of the body, which can then be converted to an estimate of fat percentage.

Hydrostatic weighing: a method for determining body composition that involves weighing the body underwater.

Air Displacement Plethysmograph. The BOD POD Gold Standard Body Composition Tracking System is an air displacement plethysmograph that uses whole-body densitometry to determine body composition (fat and fat-free mass) in adults and children and can accommodate a wide range of populations. A full test requires only about five minutes and provides highly accurate, safe, comfortable, and fast test results. Each BOD POD Gold Standard is a complete turnkey system with a dedicated computer system, the ability to measure thoracic gas volume (TGV), and data management capabilities. Note that McCrory and coworkers (1995) conduced a comparison of air displacement to underwater weight and found that the two approaches yielded similar results. Note too that when comparing air displacement to other approaches like skinfold, the skinfold technique used by the researchers was similar to the air displacement, which helps provide additional scientific evidence on the usefulness of both techniques (Bentzur 2008).

Bioelectrical impedance. This approach was developed on the basis that water conducts electricity better than fat does. Because muscle has high water content and fat has a very low water content, the rate at which your body conducts electricity can be used to estimate body fat. Many bioelectrical impedance devices have been developed. They are easy to use hand-held versions that give an instant reading. These devices were developed primarily for the population at large and use calculations and norms for the average person but can be used with athletes. However, they should be compared with another method for verification when possible. In general, crosschecking of any of the body composition methods is typically a good practice. Be aware that dehydration may alter the results of BI, as can body temperature. When using BI, and other methods, make sure to choose a time of day when the athlete is rested and adequately hydrated to serve as a good baseline measurement. Experimenting with taking measurements during and post-exercise can also provide additional insights. When accumulating a database of anthropometric measurements, using these data for fine-tuning an athlete's training and nutrition program can often provide a competitive advantage, as do exercise physiology and medical data.

Dual Energy X-Ray Absorptiometry (DEXA, or DXA). Highly sophisticated, DEXA machine body composition determination uses what is referred to as a three-compartmental model that differentiates the body into the components of bone, fat soft tissue, and lean soft tissue. The DEXA method is usually expensive and requires a qualified radiologist. This method is commonly used in research studies.

B-mode (brightness mode) ultrasound. The use of ultrasound is growing in many fields of medicine and recently has gained attention by researchers for determining subcutaneous body fat measurements as an alternative to using skinfold calipers. The use of a Brightness Mode (B-mode) ultrasound as a measure of body composition has been found to be a valid and reliable way to estimate an individual's body fat. B-mode ultrasound imaging functions by sending an acoustic wave from a transducer and interpreting the reflection of the wave by a receiver, which is located within the transducer. These reflections are interpreted by the machine and displayed as an image, and on-screen measurements can be determined from this.

Parker Hyde (2015) conducted a study for a Master of Science thesis requirement comparing skinfold calipers to B-mode ultrasound, taking measurements from football players. Hyde's study results provided more evidence of similar results using skinfold caliper measurements compared with the B-mode ultrasound device. Some advantages noted for the ultrasound included speed of use, having images records of the sites, and not needing to fold the skin.

Skinfold Caliper (Fat-O-Meter). This method of body fat determination is the skinfold caliper, taking the measurement of a skinfold. Because some body fat is subcutaneous (under the skin), it follows that the thicker the skinfolds (a fold of skin and fat but not the underlying muscles), the greater the amount of fat a person is carrying. Specially designed calipers are used to measure the thickness of representative sites throughout the body. These measurements are put in as a mathematical equation to estimate the body's density. The measurements are then converted into a body fat percentage. This technique of measuring skinfolds is inexpensive, portable, and appropriate in both laboratory and field settings when used by experienced and skilled individuals. For example, it is widely used in school systems, by athletic teams, and in YM/YWCAs, for example. The following section focuses on this technique.

NOTE: Cadaver Analysis—The direct analysis of a human cadaver.

The body's fat is measured by direct examination of the fat stores throughout the body. Human studies are rare and have only accounted for a handful of cadavers. Animal studies are more plentiful. In humans, the limitations of the cadaver procedure are obvious. It is interesting to note, however, that many of the body composition calculations are based on assumptions made on cadaver analysis performed on one reference man and one reference wom

How to Use the Fat-O-Meter Skinfold Caliper

Before you actually get started with clients predicting leanness/fatness, we recommend the following to provide you with the most accurate results:

1. Allow a considerable amount of practice using the skinfold calipers, taking measures one at a time at many sites in rotational order. Check your test-retest reliability after all the measurements have been taken.
2. Be careful in locating the site for measurement by using the appropriate anatomical landmarks.
3. Check the caliper jaw pressure to ensure that no damage has occurred to the spring. Springs are warranted for one year against normal usage. Researchers agree that the pressure exerted by the caliper jaw should be approximately 10g/mm2 and remain constant with repeated openings and closings.
4. Measure the sites in the rotational order, taking one measurement at each site throughout the full complement of tests. Check each site two to three times and use the average.
5. Select the most valid prediction equation to make your prediction.

Skinfold measurement is a two-handed operation and requires practice. Take hold of the skin and subcutaneous fat (no muscle) in the left thumb and forefinger, or middle finger; grasp the caliper in the right hand with the scale facing you.

With your thumb on the serrated portion of the caliper, slide the caliper open, enabling you to easily place the caliper around the selected skinfold site. Slowly, allow the caliper to close around the fold. Note the caliper location on the crest of the fold about one centimeter (cm) away from the fingers. Next, take the reading in millimeters to the nearest one-half mm. Finally, reopen the caliper to remove. Manually close the caliper, but do not allow the spring to close the caliper.

Notes:

1. When taking measurements, do so directly on the skin, not through the clothes. Readings should be taken in a standing position and on one side of the body—normally the right side.
2. Take readings in triplicate and use the average of the two closest readings for use in the appropriate formula.
3. **Practice, Practice, Practice, and More Practice.**

Generalized Adult Equations to Determine Percent Body Fat Most Accurately

Numerous investigations have produced large numbers of equations for use on the general populations and on specific subgroups, such as athletes. What has been discovered is that these equations have high correlations only with the populations upon which they were developed, and subsequent use has produced substantially lower correlations. Studies have developed this set of prediction equations, which were generalized for males and females, see below.

This body density formula is then used in other formulas to calculate percent body fat. Two of the following tables provide the calculations for men and women for a wide range of skinfold thicknesses and ages. Note that the Siri formula was used to calculate the percent body fat numbers on the chart. You simply need to measure the sites as specified for men and women and then refer to these charts for an easy way to look up percent body fat. You will also notice that nomograph carts using just two sites are also provided. You should use both the three-site and two-site methods to see how the percent body fat will differ. As you become more sophisticated using skinfold methods, you can employ calculations that use 12 or more sites. But always remember that there is roughly up to a 5 percent margin of error using the skinfold and other body composition measurements. As such, it is important to keep track of how the skinfold measurements are changing and how the total percent body fat is changing, along with the primary body circumferences. You need to look at the whole body to keep track of how it is changing from diet and training.

[Prediction equations are from McArdle, W.D., Katch, F.I., and Katch, V.L., “Essentials of Exercise Physiology, 2nd Edition, 2000, with permission].

Prediction Equations

Adult Women: Density = 1.0994921- 0.0009920 (X3) + 0.0000023 (X3) 2 - 0.0001392 (Age)

Note: X3 = Site 2+ Site 8 + Site 4

Adult Men: Density = 1.10993800 - 0.0008267 (X2)0.0000015 (X2) 2 - 0.0002574 (Age)

X2 = Site 10 + Site 9 + Site 8

Eq. 14.1

The Sites Listed in the Formulas and Charts Are as Follows:

Common Skinfold Sites			
The most common skinfold sites are the triceps, subscapular, suprailiac, abdominal, and upper thigh. An average of two or three measurements are made at each site on the right side of the body with the subject standing. The following photos show the anatomical location for the most frequently measured skinfold sites.			
	Site 1 (S1) – Subscapula: Oblique fold just below the bottom tip of the scapula.		Site 2 (S2) – Triceps: Vertical fold at the posterior midline of the upper arm, halfway between the tip of the shoulder and the tip of the elbow; elbow remains extended in a relaxed position.
	Site 4 (S4) – Suprailiac (iliac crest): Slightly oblique fold just above the hipbone (crest of the ileum); the fold follows the natural diagonal line.		Site 8 (S8) – Thigh: Vertical fold at the midline of the thigh, two-thirds of the distance from the middle of the patella (kneecap) to the hip.
	Site 9(S9) – Abdomen: Vertical fold 1 inch to the right of the umbilicus (navel).		Site (S10) – Chest: From the front crease of the armpit to the nipple, measure way up; using same angle, take a pinch.

Use of Skinfold Data

Skinfolds provide meaningful information about body fat and its distribution. There are essentially two ways to use skinfolds. Use the skinfold measurements in equations or charts to determine percent body fat. Use skinfold measurements to determine changes in subcutaneous fat distribution of the body.

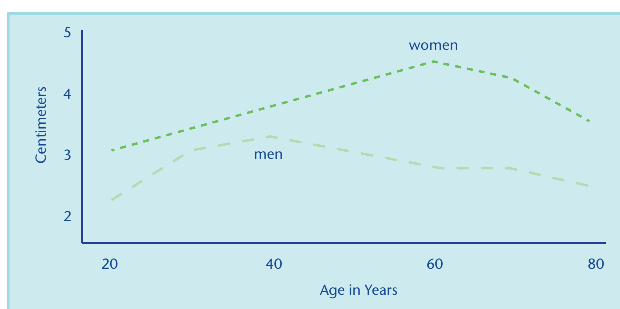


Figure 14.1 Average Sum of Skinfolds for Adults 18 to 79 Years of Age. (H.W. Stoudt, A. Damon, R.A. McFarland & J. Roberts. "Skinfolds, body girths, biacronial diameter, and selected anthropometric indices of adults." Vital and Health Statistics, Series 11. 1973 (47).

Percentage of Body Fat?

Percent body fat is an estimate of the percent of total body weight (mass) that is fat. "Normal" values for percent fat vary somewhat from report to report. However, the following tables are a compilation of a number of studies and may help you interpret your results (adapted from Katch & McArdle 1977). Care should be taken with respect to the low end of the scale. Clients should be advised against too low a body fat. For males, 5 to 10 percent can be considered minimum, whereas 10 to 15 percent is a minimum for females, which should be confirmed by the athlete's physician and team medical policy. In addition, be aware that it is common for sports governing organizations and schools to have lower limits for minimum percentage body fat levels of athletes. Body fat levels that are too low can have adverse health effects for men and women.

Male		**Female**	
USA Averages	Interpreting Results*	USA Averages	Interpreting Results*
20% Younger (Under 30)	Elite Athletes 5-10%** Good 11-14%	24.8% Younger (Under 30)	Elite Athletes 10-15%** Good 16-19%
25% Older (Over 30)	Acceptable 15-17% Too Fat 18-19% Obese 20% & up	31.2% Older (Over 30)	Acceptable 20-24% Too Fat 125-29% Obese 30% & up
*Applies to adults only. **Some medical problems cause low% fat. If you suspect a health problem, consult a physician.			

Percent Fat Estimates for Women, Sites 2, 4 & 8 Sum of Triceps, Suprailium & Thigh Skinfolds*									
Sum of Skinfolds (mm)	Age of the Last Year								
	Under 22	23-27	28-32	33-37	38-42	43-47	48-52	53-57	Over 58
23–25	9.7	9.9	10.2	10.4	10.7	10.9	11.2	11.4	11.7
26–28	11.0	11.2	11.5	11.7	12.0	12.3	12.5	12.7	13.0
29–31	12.3	12.5	12.8	13.0	13.3	13.5	13.8	14.0	14.3
32–34	13.6	13.8	14.0	14.3	14.5	14.8	15.0	15.3	15.5
35–37	14.8	15.0	15.3	15.5	15.8	16.0	16.3	16.5	16.8
38–40	16.0	16.3	16.5	16.7	17.0	17.2	17.5	17.7	18.0
41–43	17.2	17.4	17.7	17.9	18.2	18.4	18.7	18.9	19.2
44–46	18.3	18.6	18.8	19.1	19.3	19.6	19.8	20.1	20.3
47–49	19.5	19.7	20.0	20.2	20.5	20.7	21.0	21.2	21.5
50–52	20.6	20.8	21.1	21.3	21.6	21.8	22.1	22.3	22.6
53–55	21.7	21.9	22.1	22.4	22.6	22.9	23.1	23.4	23.6
56–58	22.7	23.0	23.2	23.4	23.7	23.9	24.2	24.4	24.7
59–61	23.7	24.0	24.2	24.5	24.7	25.0	25.2	25.5	25.7
62–64	24.7	25.0	25.5	25.5	25.7	26.0	26.7	26.4	26.7
65–67	25.7	25.9	26.2	26.4	26.7	26.9	27.2	27.4	27.7
68–70	26.6	26.9	27.1	27.4	27.6	27.9	28.1	28.4	28.6
71–73	27.5	27.8	28.0	28.3	28.5	28.8	29.0	29.3	29.5
74–76	28.4	28.7	28.9	29.2	29.4	29.7	29.9	30.2	30.4
77–79	29.3	29.5	29.8	30.0	30.3	30.5	30.8	31.0	31.3
80–82	30.1	30.4	30.6	30.9	31.1	31.4	31.6	31.9	32.1
83–85	30.9	31.2	31.4	31.7	31.9	32.2	32.4	32.7	32.9
86–88	31.7	32.0	32.2	32.5	32.7	32.9	33.2	33.4	33.7
89–91	32.5	32.7	33.0	33.2	33.5	33.7	33.9	34.2	34.4
92–94	33.2	33.4	33.7	33.9	34.2	34.4	34.7	34.9	35.2
95–97	33.9	34.1	34.4	34.6	34.9	35.1	35.4	35.6	35.9
98-100	34.6	34.8	35.1	35.3	35.5	35.8	36.0	36.2	36.5
101-103	35.3	35.4	35.7	35.9	36.2	36.4	36.7	36.9	37.2
104-106	35.8	36.1	36.3	36.3	36.8	37.1	37.3	37.5	37.8
107-109	36.4	36.7	36.9	37.1	37.4	37.6	37.9	38.1	38.4
110-112	37.0	37.2	37.5	37.7	38.0	38.2	38.5	38.7	38.9
113-115	37.5	37.8	38.0	38.2	38.5	38.7	39.0	39.2	39.5
116-118	38.0	38.3	38.5	38.8	39.0	39.3	39.5	39.7	40.0
119-121	38.5	38.7	39.0	39.2	39.5	39.7	40.0	40.2	40.5
122-124	39.0	39.2	39.4	39.7	39.9	40.2	40.4	40.7	40.9

Percent fat calculated by the formula of Siri30.

Percent fat = [(4.95/Body Density)-4.5] x 100

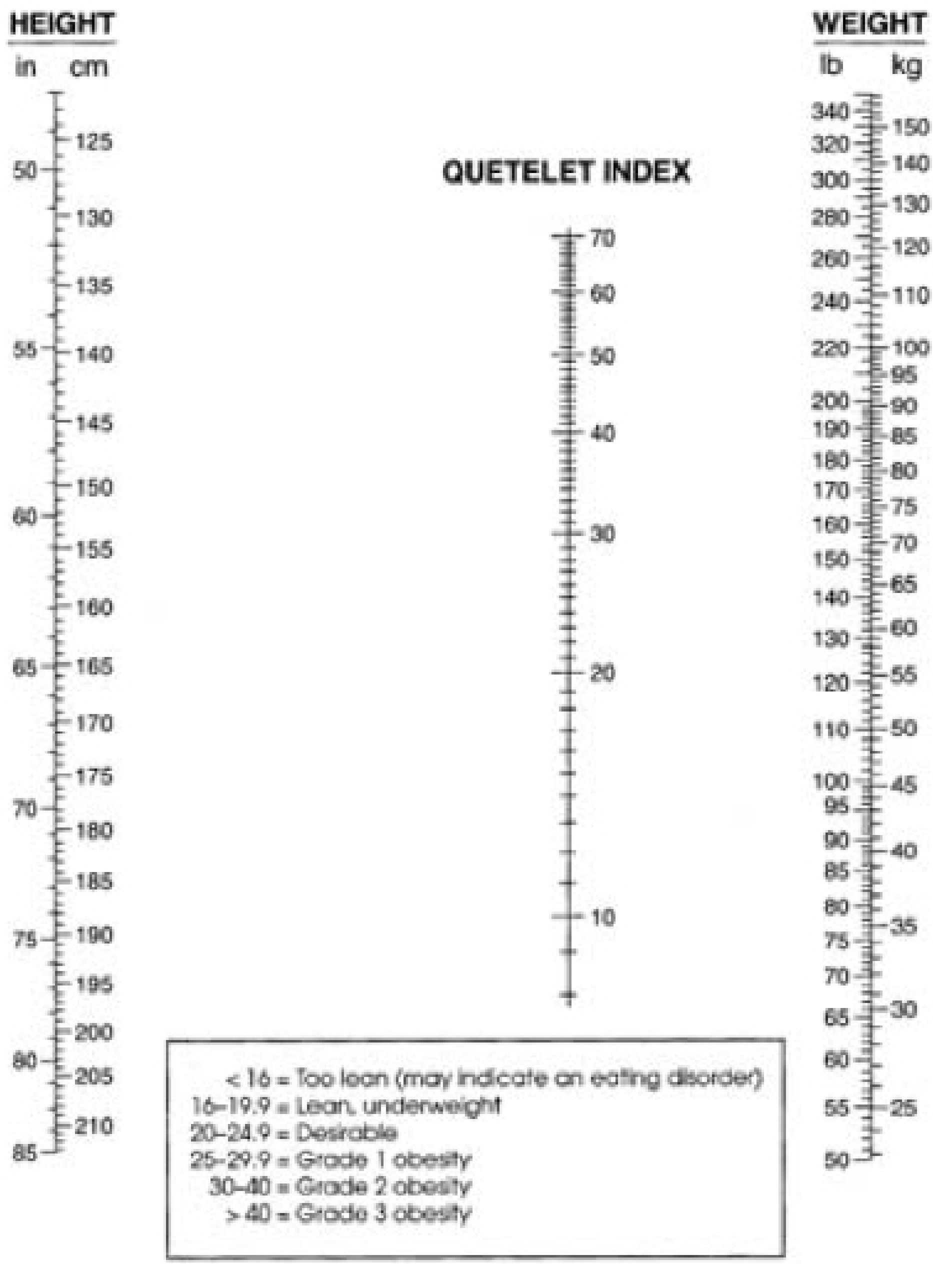
Percent Fat Estimates for Men, Sites 8, 9, & 10 Sum of Chest, Abdominal, & Thigh Skinfolds									
Sum of Skinfolds (mm)	Age of the Last Year								
	Under 22	23-27	28-32	33-37	38-42	43-47	48-52	53-57	Over 58
8-10	1.3	1.8	2.3	2.9	3.4	3.9	4.5	5.0	5.5
11-13	2.2	2.8	3.3	3.9	4.4	4.9	5.5	6.0	6.5
14-16	3.2	3.8	4.3	4.8	5.4	5.9	6.4	7.0	7.5
17-19	4.2	4.7	5.3	5.8	6.3	6.9	7.4	8.0	8.5
20-22	5.1	5.7	6.2	6.8	7.3	7.9	8.4	8.9	9.5
23-25	6.1	6.6	7.2	7.7	8.3	8.8	9.4	9.9	10.5
26-28	7.0	7.6	8.1	8.7	9.2	9.8	10.3	10.9	11.4
29-31	8.0	8.5	9.1	9.6	10.2	10.7	11.3	11.8	12.4
32-34	8.9	9.4	10.0	10.5	11.1	11.6	12.2	12.8	13.3
35-37	9.8	10.4	10.9	11.5	12.0	12.6	13.1	13.7	14.3
38-40	10.7	11.3	11.8	12.4	12.9	13.5	14.1	14.6	15.2
41-43	11.6	12.2	12.7	13.3	13.8	14.4	15.0	15.5	16.1
44-46	12.5	13.1	13.6	14.2	14.7	15.3	15.9	16.4	17.0
47-49	13.4	13.9	14.5	15.1	15.6	16.2	16.8	17.3	17.9
50-52	14.3	14.8	15.4	15.9	16.5	17.1	17.6	18.2	18.8
53-55	15.1	15.7	16.2	16.8	17.4	17.9	18.5	19.1	19.7
56-58	16.0	16.5	17.1	17.7	18.2	18.8	19.4	20.0	20.5
59-61	16.9	17.4	17.9	18.5	19.1	19.7	20.2	20.8	21.4
62-64	17.6	18.2	18.8	19.4	19.9	20.5	21.1	21.7	22.2
65-67	18.5	19.0	19.6	20.2	20.8	21.3	21.9	22.5	23.1
68-70	19.3	19.9	20.4	21.0	21.6	22.2	22.7	23.3	23.9
71-73	20.1	20.7	21.2	21.8	22.4	23.0	23.6	24.1	24.7
74-76	20.9	21.5	22.0	22.6	23.2	23.8	24.4	25.0	25.5
77-79	21.7	22.2	22.8	23.4	24.0	24.6	25.2	25.8	26.3
80-82	22.4	23.0	23.6	24.2	24.8	25.4	25.9	26.5	27.1
83-85	23.2	23.8	24.4	25.0	25.5	26.1	26.7	27.3	27.9
86-88	24.0	24.5	25.1	25.7	26.3	26.9	27.5	28.1	28.7
89-91	24.7	25.3	25.9	25.5	27.1	27.6	28.2	28.8	29.4
92-94	25.4	26.0	26.6	27.2	27.8	28.4	29.0	29.6	30.2
95-97	26.1	26.7	27.3	27.9	28.5	29.1	29.7	30.3	30.9
98-100	26.9	27.4	28.0	28.6	29.2	29.8	30.4	31.0	31.6
101-103	27.5	28.1	28.7	29.3	29.9	30.5	31.1	31.7	32.3
104-106	28.2	28.8	29.4	30.0	30.6	31.2	31.8	32.4	33.0
107-109	28.9	29.5	30.1	30.7	31.3	31.9	32.5	33.1	33.7

Percent fat calculated by the formula of Siri30.

Percent fat = [(4.95/Body Density)-4.5] x 100

Simple Formulas for Calculating Percent Bodyfat

The nomogram to the right is slightly less accurate than other anthropometric measurement formulas are. However, they will allow you to calculate a quick approximation of percent body fat for men and women. Mark the chart for each site indicated and draw a connecting line between them. Your percent body fat is where the connecting line crosses the center column.



Body Mass Index (BMI)

The following will provide an overview of BMI

From the Division of Nutrition, Physical Activity, and Obesity, National Center for Chronic Disease Prevention and Health Promotion

An important fact to emphasize that is well known to health professionals who work with athletic people is that the BMI value can be high for athletes with higher-than-average muscle mass and low body fat. Therefore, BMI has limitations for athletes as a predictor of body composition, in particular, excess body fat determination.

What is BMI?

BMI is a person's weight in kilograms divided by the square of height in meters. BMI does not measure body fat directly, but research has shown that BMI is moderately correlated with more direct measures of body fat obtained from skinfold thickness measurements, bioelectrical impedance, densitometry (underwater weighing), dual energy X-ray absorptiometry (DXA), and other methods. Furthermore, BMI appears to be as strongly correlated with various metabolic and disease outcome as are these more direct measures of body fatness. In general, BMI is an inexpensive and easy-to-perform method of screening for weight category; underweight, normal or healthy weight, overweight, and obesity.

Body mass index (BMI): BMI is a measure of body weight relative to height. The BMI tool uses a formula that produces a score often used to determine if a person is underweight, at a normal weight, overweight, or obese. For adults, a BMI of 18.5 to 24.9 is considered healthy (or "normal"). A person with a BMI of 25 to 29.9 is considered overweight, and a person with a BMI of 30 or more is considered obese.

How is BMI used?

A high BMI can be an indicator of high body fatness. BMI can be used as a screening tool but is not diagnostic of an individual's body fatness or health.

To determine whether a high BMI is a health risk, a health-care provider would need to perform further assessments. These assessments might include skinfold thickness measurements; evaluations of diet, physical activity, and family history; and other appropriate health screenings[10].

What are the BMI trends for adults in the United States?

The prevalence of adult BMI greater than or equal to 30 kg/m^2 (obese status) has greatly increased since the 1970s. Recently, however, this trend has leveled off, except for older women. Obesity has continued to increase in adult women ages 60 years and older.

Why is BMI used to measure overweight and obesity?

BMI can be used for population assessment of overweight and obesity. Because calculation requires only height and weight, BMI is inexpensive and easy to use for clinicians and for the general public. BMI can be used as a screening tool for body fatness but is not diagnostic.

What are some of the other ways to assess excess body fatness besides BMI?

Other methods to measure body fatness include skinfold thickness measurements (with calipers), underwater weighing, bioelectrical impedance, dual-energy X-ray absorptiometry (DXA), and isotope dilution. [1,2,3] However, these methods are not always readily available, and they are either expensive or need to be conducted by highly trained personnel. Furthermore, many of these methods can be difficult to standardize across observers or machines, complicating comparisons across studies and time periods.

How is BMI calculated?

BMI is calculated the same way for both adults and children. The calculation is based on the following formulas:

Calculating BMI for Adults and Children	
Measurement Units	**Formula and Calculation**
Kilograms and meters (or centimeters)	**Formula: weight (kg) / [height (m)]2** With the metric system, the formula for BMI is weight in kilograms divided by height in meters squared. Because height is commonly measured in centimeters, divide height in centimeters by 100 to obtain height in meters. Example: Weight = 68 kg, Height = 165 cm (1.65 m) **Calculation: 68 ÷ (1.65)2 = 24.98**
Pounds and inches	**Formula: weight (lb) / [height (in)]2 x 703** Calculate BMI by dividing weight in pounds (lbs) by height in inches (in) squared and multiplying by a conversion factor of 703. Example: Weight = 150 lbs, Height = 5’5” (65”) **Calculation: [150 ÷ (65)2] x 703 = 24.96**

How is BMI interpreted for adults?

For adults 20 years old and older, BMI is interpreted using standard weight status categories. These categories are the same for men and women of all body types and ages.

The standard weight status categories associated with BMI ranges for adults are shown in the following table.

Interperting BMI for Adults | Standard Weight Status Catgories Associated with BMI	
BMI	**Weight Status**
Below 18.5	Underweight
18.5–24.9	Normal or Healthy Weight
25.0–29.9	Overweight
30.0 and Above	Obese

For example, here are the weight ranges, the corresponding BMI ranges, and the weight status categories for a person who is 5' 9".

Height	Weight Range	BMI	Weight Status
5'9"	124 lbs or less	Below 18.5	Underweight
	125 lbs to 168 lbs	18.5 to 24.9	Normal or Healthy Weight
	169 lbs to 202 lbs	25.0 to 29.9	Overweight
	203 lbs or more	30 or higher	Obese

Is BMI interpreted the same way for children and teens as it is for adults?

BMI is interpreted differently for children and teens than for adults, even though it is calculated using the same formula as adult BMI. Children and teens' BMI need to be age- and gender-specific because the amount of body fat changes with age, and the amount of body fat differs between girls and boys. The CDC BMI-for-age growth charts accounts for these differences and visually show BMI as a percentile ranking. These percentiles were determined using representative data of the US population of 2- to 19-year-olds that was collected in various surveys from 1963–1965 to 1988–1994 [11].

Obesity among 2- to 19-year-olds is defined as a BMI at or above the 95th percentile of children of the same age and gender in this 1963–1994 reference population. For example, a 10-year-old boy of average height (56 inches) who weighs 102 pounds would have a BMI of 22.9 kg/m^2. This would place the boy in the 95th percentile for BMI – meaning that his BMI is greater than that of 95 percent of similarly aged boys in this reference population – and he would be considered to have obesity.

How good is BMI as an indicator of body fatness?

The correlation between the BMI and body fatness is fairly strong,[1,2,3,7] but even if two people have the same BMI, their levels of body fatness might differ[12].

In general,

- At the same BMI, women tend to have more body fat than men do.
- At the same BMI, blacks have less body fat than do whites,[13,14] and Asians have more body fat than do whites do.[15]
- At the same BMI, older people, on average, tend to have more body fat than younger adults do.
- At the same BMI, athletes have less body fat than do nonathletes.

The accuracy of BMI as an indicator of body fatness also appears to be higher in persons with higher levels of BMI and body fatness[16]. Though a person with a very high BMI (e.g., 35 kg/m^2) is very likely to have high body fat, a relatively high BMI can be the result of either high body fat or high **lean body mass** (muscle and bone). A trained health-care provider should perform appropriate health assessments to evaluate an individual's health status and risks.

Lean body mass: all of a body's tissues apart from the body fat: the bones, muscles, organs, blood, and water. Also called fat-free mass.

If an athlete or other person with a lot of muscle has a BMI higher than 25, is that person still considered to be overweight?

According to the BMI weight status categories, anyone with a BMI between 25 and 29.9 would be classified as overweight, and anyone with a BMI above 30 would be classified as obese.

However, athletes may have a high BMI because of increased muscularity rather than increased body fatness. In general, a person who has a high BMI is likely to have body fatness and would be considered overweight or obese, but this may not apply to athletes. A trained health-care provider should perform appropriate health assessments to evaluate an individual's health status and risks.

What are the health consequences of obesity for adults?

People who are obese are at increased risk for many diseases and health conditions, including the following:

- All causes of death (mortality)
- **High blood pressure (Hypertension)**
- High LDL cholesterol, low HDL cholesterol, or high levels of triglycerides (Dyslipidemia)
- Type 2 diabetes
- Coronary heart disease
- Stroke
- Gallbladder disease
- Osteoarthritis (a breakdown of cartilage and bone within a joint)
- Sleep apnea and breathing problems
- Chronic inflammation and increased oxidative stress [19,20]
- Some cancers (endometrial, breast, colon, kidney, gallbladder, and liver)
- Low quality of life
- Mental illness such as clinical depression, anxiety, and other mental disorders [21,22]
- Body pain and difficulty with physical functioning [23]

Note: for cited references, see the reference section in the Appendix.
Page last reviewedand reviewed: May 15, 2015. Content source: Division of Nutrition, Physical Activity, and Obesity, National Center for Chronic Disease Prevention and Health Promotion

www.cdc.gov/healthyweight/assessing/bmi/adult_bmi/index.html

High blood pressure: your blood pressure rises and falls throughout the day. An optimal blood pressure is less than 120/80 mmHg. When blood pressure stays high—greater than or equal to 140/90 mmHg—you have high blood pressure, also called hypertension. With high blood pressure, the heart works harder, your arteries take a beating, and your chances of a stroke, heart attack, and kidney problems are greater. Uncontrolled high blood pressure may lead to blindness, heart attacks, heart failure, kidney disease, and stroke. Prehypertension is blood pressure between 120 and 139 for the top number, or between 80 and 89 for the bottom number.

Body Types (Somatotype)

The way your body looks is a result of your genetics and environmental factors such as training and nutrition. The genetic factor has dominant influence on your body structure, inside and out. The scientist W. H. Sheldon devised a system of classifying the different human body types and called this system "somatotype." With this system, humans can be classified in three body types:

- Mesomorphic or muscular body type
- Ectomorphic or slim, linear body type
- Endomorphic or fat, round body type

Sheldon's system uses a somatotype number with three digits, on a scale from 1 to 7. The first digit refers to the degree of endomorphy, the second digit refers to the degree of mesomorphy, and the third digit refers to the degree of ecotmorphy. An extreme endomorph has the somatotype 711, an extreme mesomorph has the somatotype 171, and an extreme ectomorph has the somatotype 117.

Most individuals have a dominant somatotype and also display some characteristics of the other two. An average person may fall somewhere around a 333 or a 444 rating. This system is useful because it helps you understand your genetic predisposition.

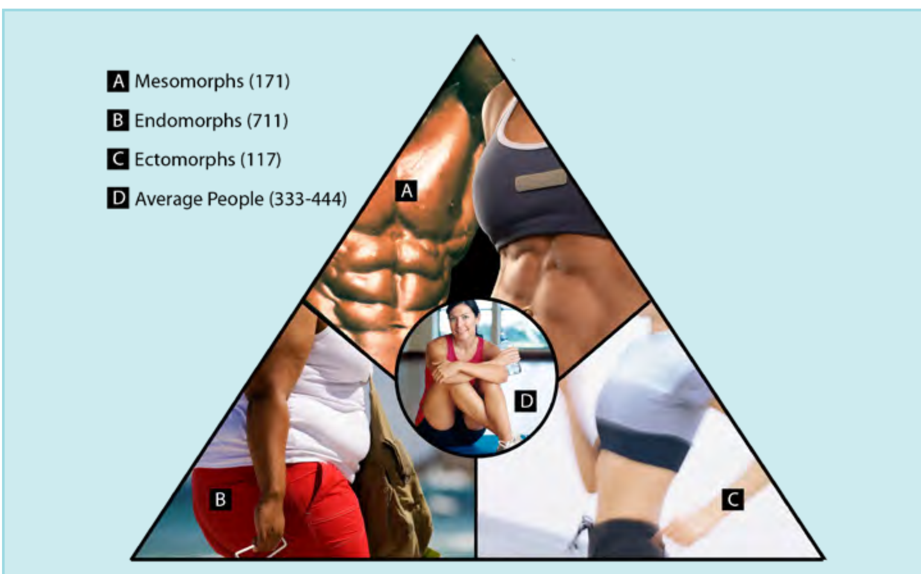


Figure 14.2. Sheldon's Somatotype Distribution Triangle. Note that elite athletes nearly always fall in the mesomorphic sector of the triangle.

For example, on a pound for pound body-weight basis, ectomorphs usually require more calories. Mesomorphs are next in line, and endomorphs demand the fewest calories.

If you are a determined, competitive athlete, you should have your somatotype determined by a trained individual. Elite world-class athletes usually have a mesomorphic rating of 5 to 7, endomorphic of 1 to 3, and ectomorphic of 4 to 1. This indicates that being predominantly mesomorphic is a common trait of elite athletes. This makes sense, as mesomorphs have a higher body composition of muscle mass, which is the primary tissue responsible for athletic performance. This does not mean that ectomorphs or endomorphs cannot become superior athletes; however, they should use training and nutrition methods to build more muscle mass and keep percent body fat within desirable levels for their gender and sport.

CONCLUSION

Determining body composition, somatotype, and other anthropometric measurements will provide useful information for tracking an athlete's progress and determining whether and when there may be nutritional inadequacies or other issues of concern related to training and nutrition programs.

Keywords

Skinfold calipers	Body mass index (BMI)
Skinfold measurement	Lean body mass
Hydrostatic weighing	High blood pressure (Hypertension)

Topics Covered In This Unit

UNIT 15

CALORIE NEEDS AND METABOLISM

Unit Outline

I. **Introduction**

II. **Guide to estimating calorie needs**

III. **Average daily activity level**

IV. **Metabolic equivalent**

V. **Overview of metabolism**

VI. **Homeostasis**
   a. Homeostatic feedback control systems

VII. **Metabolism**

VIII. **Metabolic set point**

IX. **Food and metabolism**
   a. Metabolic testing device example

X. **The environment and metabolism**

XI. **Exercise and metabolic responses**
   a. Aerobic system changes
   b. Anaerobic system changes

XII. **Energy metabolism**

XIII. **Glycogen depletion and metabolism of fatigue**

XIV. **Conclusion**

Learning Objectives

After completing this unit, you will be able to:

- Define and describe terms related to calorie needs and metabolism;
- Calculate estimated daily caloric requirements;
- Understand role of metabolism in the body; and
- Describe the muscle fiber types.

Introduction

How many times has someone asked you, "How many calories should I eat?" The key to answering any such question is *always* going to be related to determining how many calories the person needs. And while we are on the subject, what exactly *are* calories?

Guide to Estimating Calorie Needs

Calories are the unit of measure used to calculate the amount of energy in foods. If you recall, the primary energy yielding nutrients are fats, carbohydrates, and protein. The Calorie (with a big C), or kilocalorie, is the terminology used to represent how much heat-yielding potential there is contained in a food's contents. Technically speaking, one kilocalorie is the amount of heat needed to raise the temperature of 1 kilogram of water 1 degree Celsius. The calorie (with the small c) would then be 1000th of a kilocalorie.

Therefore, the "Calorie or calorie" used in nutrition and on nutrition labeling is technically a kilocalorie. For example, the daily caloric requirements are in the thousands, 2,115 calories per day in the first example. If authors are using the real small calorie convention, then this daily caloric requirement would have been 1,000 times larger or, 2,115,000 calories. Thus you can easily see why the kilocalorie is used instead, to keep the numbers smaller and easier to work with, but can be referred to as calories or Calories depending on the use. Scientific journals and textbooks usually will be more scientific and use the scientific-based terms, but not always.

Another measure of energy used by scientists and internationally is called the kilojoule (kJ). To convert kilocalories to kilojoules, just multiply the kilocalorie number by 4.2. You will commonly encounter the kJ in the scientific literature, used in dietary guidelines from foreign countries outside of North America, and on food packaging from foreign countries outside of North America.

The rate of the body's energy expenditure is sometimes referred to as the "metabolic rate", which is the total daily caloric expenditure. As a starting point, traditional methods of science for measuring metabolic rate use the measurement of oxygen consumption, which will indirectly reflect metabolism because the amount of oxygen used and carbon dioxide exhaled is a direct result of how much energy is being expended. Sophisticated technology is required to use these laboratory techniques. Therefore, the following calculations and charts listed below are provided to serve as a handy reference tool for estimating daily caloric requirements.

Just as with the determination of body composition, all these energy expenditure techniques have a margin of error in them. Keep this in mind because even the most sophisticated methods may yield daily caloric rates that are too high or too low. That is why it is important to keep track of body composition changes, to fine-tune caloric intake based on the individual's metabolic rate, not just what some chart estimates. Keep in mind that ectomorphs usually will require more energy than the charts estimate, mesomorphs are about what the charts estimate, and endomorphs will usually require less than the charts estimate. Therefore, you may find that you need to make a few hundred calorie (plus or minus) adjustments to maintain the desired body composition and performance goals.

Everybody expends a different amount of energy each day, which depends on many factors such as physical activity and the composition of the diet. However, the basal metabolism, or basal metabolic rate (BMR) remains somewhat constant from day to day. Your BMR is the rate at which the body expends energy for maintenance activities, such as keeping the body alive, organ function, and so on. Your BMR is lowest when sleeping; however, most methods measure your BMR when awake, but under controlled conditions of resting and room temperature. Your BMR is therefore an estimate of the number of calories you'd burn over 24 hours while lying down, but not sleeping. Your actual metabolic rate is estimated by adding the caloric cost of all the activities you engage in throughout the day to your BMR. A rough estimate of BMR is as follows:

Men's BMR in calories =
1 × Body weight in kilograms ×24 hours

Women's BMR in calories =
0.9 × Body weight in kilograms × 24

Eq. 15.1

These formulas are reasonably accurate for people with average levels of body fat (i.e., 20 percent and 28 percent for men and women, respectively). One kg (kilogram) equals 2.2046 pounds. The higher your body fat percentage, the fewer calories you will burn (lower activity level, and less muscle to burn calories). The lower your body fat percentage, the more calories you'll burn. (Bigger muscles burn more calories than little ones do.) Energy requirements above the BMR will depend on your activity level, and can be as low as 130 percent of your BMR to over 200 percent of your BMR as listed in the charts below.

Thus, it becomes much easier to eliminate fat by increasing your metabolic rate and not overeating. You do this by increasing both your muscle mass and your activity level. You can (and SHOULD) gain muscle mass and lose fat simultaneously. Never sacrifice muscle tissue during the fat-loss process. Instead, build more muscle to burn more calories. You'll lose more fat faster, and you will be more likely to keep it off. The following methods provide more accurate determinations of BMR and daily energy expenditure.

Average Daily Activity Level

The hour-by-hour approach is the best way to estimate your daily calorie needs, but it is also the most involved. Once you know your average BMR for 24 hours, you can estimate your BMR for an hour by dividing by 24. After that, all you really need to do is add the number of calories your activity level demands. But a few factors mitigate, not the least of which is your body fat percentage versus your lean mass (bigger muscles burn more calories than little ones do). In addition to the detailed hourly calorie requirement method, a Daily Calorie Requirement Guide is also provided. In either case, the information in the following chart is used. Just follow the step-by-step instructions to make the calculations.

First determine your percent body fat using one of the methods described in Unit 14.

Key to Reading the Charts Below			
Lean Factor	Clinical Description	Lean Factor Percent Body Fat Levels	Multiplier
1	Lean	Men 10% - <14% Women 14% - <18%	100% (1.0)
2	Normal	Men 14% - <20% Women 18% - <28%	95% (0.95)
3	Clinically Obese	Men 20% - 28% Women 28% - 38%	90% (0.90)
4	Chronically Obese	Men over 28% Women over 38%	85% (0.85)

Then determine your lean factor from the chart above. For this example, let's use a woman who weighs 130 pounds, with 28 percent body fat. This would give her a lean factor of 3. This lean factor is then used in the Daily Caloric Requirement Guide that follows. For the below example, you need to use the lean factor multiplier also listed in the above table, which would be 90 percent (0.9).

Example: Follow these steps when determining your client's or your own calorie needs:

For each of the 24 hours in one of your "average" days, determine your energy expenditure by adding or subtracting your activity's caloric cost to (from) your BMR. Let's use a clinically obese female in our example:

Body weight	130 pounds (58.5 kilograms)
Lean Factor	3 (clinically obese – use 0.9 Lean Factor Multiplier)
Daily BMR	0.9 x 24 x 58.5 = 1263.6 calories
Hourly BMR	1264 calories / 24 = 52.37 calories/ hour
Lean Factor	52.37 calories/hour x .9 = 47.4 rounded to 47 calories per hour
Adjusted BMR	

Then, using the information in the Energy Expenditure Guide and the 47 calories per hour BMR, you can determine the estimated calories per hour used. An example of this is illustrated in the Example of Estimating Daily Caloric Expenditure Using the Hourly Method table.

Example of Estimating Daily Caloric Expenditure Using the Hourly Method

Hour	Activity	Percent of BMR	Calories Used
Midnight to 1 a.m.	Sleeping	- 22%	47 x .78 = 37
1-2 a.m.		- 22%	47 x .78 = 37
2-3 a.m.		- 22%	47 x .78 = 37
3-4 a.m.		- 22%	47 x .78 = 37
4-5 a.m.		- 22%	47 x .78 = 37
5-6 a.m.		- 22%	47 x .78 = 37
6-7 a.m.		- 22%	47 x .78 = 37
7-8 a.m.	Light Activity	270%	47 x 2.7 = 127
8-9 a.m.	Moderate Activity	360 %	47 x 3.6 = 169
9-10 a.m.		360 %	47 x 3.6 = 169
10–11 a.m.	Light Activity	270%	47 x 2.7 = 127
11 am – Noon	Moderate Activity	360 %	47 x 3.6 = 169
Noon - 1 p.m.		360 %	47 x 3.6 = 169
1-2 p.m.		360 %	47 x 3.6 = 169
3-4 p.m.		360 %	47 x 3.6 = 169
4-5 p.m.		360 %	47 x 3.6 = 169
5-6 p.m.	All-out training	720%	47 x 7.2 = 388
6-7 p.m.	Moderate Activity	360 %	47 x 3.6 = 169
7-8 p.m.	Light Activity	270%	47 x 2.7 = 127
8-9 p.m.	Moderate Activity	360 %	47 x 3.6 = 169
9-10 p.m.	Very Light Activity	120%	47 x 1.2 = 56
10-11 p.m.		120%	47 x 1.2 = 56
11 PM - Midnight	Sleeping	- 22%	47 x .78 = 37
			Daily Total = 2,825 Calories

Another effective way to estimate average daily caloric requirements is to use the Daily Calorie Requirements Guide provided below. This method is not as exact as the hour-by-hour approach is, but it is quick and relatively accurate. To use the Daily Calorie Requirement Guide, choose a total body weight closest to your own. For example, if you weigh 217 pounds, choose the 220-pound weight class. Each weight class on the table also has the average BMR of a male and female of that weight listed in the first column on the left. After finding your weight class, use your Lean Factor to select the correct row. Then at that bottom of the guide, look at the different Average Daily Activity Level descriptions and choose one that best fits your activity for that day. Note that this uses different percentages than does the Energy Expenditure Guide used in the hour-by-hour method.

Energy Expenditure Guide		
Women	Men	Activity
-22%	-20%	Sleeping
-0.1%	0%	Lying down completely relaxed but not sleeping (this is your "basal metabolic rate.")
180%	200%	Very Light: Sitting, studying, talking, little walking or other activities.
270%	300%	Light: Typing, teaching, lab/shop work, some walking.
360%	400%	Moderate: Walking, jogging, gardening-type job.
450%	500%	Heavy: Heavy manual labor such as digging, tree felling, climbing.
540%	600%	Exceptionally Heavy: Fitness-oriented weight training, aerobic dance, cycling, or similar vigorous activities.
630%	700%	Sports: Vigorous sports competition such as football, racquetball, tennis, or other extended-play sports activities.
720%	800%	All-Out Training: Extremely high-intensity weight training with little rest between sets or exercises.
810%	900%	Extended Maximum Effort: Extremely high-intensity and high-duration sports competition such as triathlon, cross-country skiing, or marathon.

Daily Calorie Requirement Guide											
Refer to notes at end of chart for use. This chart is more generalized than is the previous hour-by-hour method but serves as a handy, quick reference to determine approximate daily caloric needs.											
Total Weight & BMR	**Lean Factor**	**Average Daily Activity Level**									
		130%		**155%**		**165%**		**200%**		**230%**	
		M	**F**	**M**	**F**	**M**	**F**	**M**	**F**	**M**	**F**
100 lbs M = 1091 F = 982	1	1418	1277	1691	1522	1800	1620	2182	1964	2509	2259
	2	1347	1213	1606	1446	1710	1539	2073	1866	2384	2146
	3	1276	1149	1521	1370	1620	1458	1964	1768	2258	2033
	4	1205	1085	1437	1294	1530	1377	1858	1669	2133	1920
110 lbs M = 1200 F = 1080	1	1560	1404	1860	1674	1980	1782	2400	2160	2760	2484
	2	1482	1334	1767	1590	1881	1693	2280	2052	2622	2360
	3	1404	1264	1674	1501	1782	1604	2160	1944	2484	2236
	4	1326	1193	1581	1423	1683	1515	2040	1836	2346	2111
120 lbs M = 1309 F = 1178	1	1701	1531	2029	1826	2160	1944	2618	2356	3010	2709
	2	1616	1454	1928	1735	2052	1847	2487	2238	2860	2574
	3	1531	1378	1826	1643	1944	1750	2356	2120	2709	2438
	4	1446	1301	1725	1552	1836	1652	2225	2003	2559	2303
130 lbs M = 1418 F = 1276	1	1843	1659	2198	1978	2340	2105	2836	2552	3261	2935
	2	1751	1576	2088	1879	2223	2000	2694	2424	3098	2788
	3	1659	1493	1978	1780	2106	1895	2552	2297	2935	2641
	4	1567	1410	1868	1681	1989	1789	2411	2169	2772	2495

Total Weight & BMR	Lean Factor	Average Daily Activity Level									
		130%		155%		165%		200%		230%	
		M	F	M	F	M	F	M	F	M	F
140 lbs M = 1527 F = 1375	1	1985	1788	2367	2131	2520	2269	3054	2750	3512	3163
	2	1886	1699	2249	2024	2394	2156	2901	2613	3336	3005
	3	1787	1608	2130	1917	2268	2041	2749	2474	3161	2847
	4	1687	1520	2012	1811	2142	1929	2596	2338	2985	2689
150 lbs M = 1636 F = 1473	1	2127	1915	2536	2283	2699	2430	3272	2946	3763	3388
	2	2021	1819	2409	2169	2564	2309	3108	2799	3575	3219
	3	1914	1724	2282	2055	2429	2187	2945	2651	3387	3049
	4	1808	1628	2156	1941	2294	2066	2781	2504	3199	2880
160 lbs M = 1745 F = 1571	1	2269	2042	2705	2435	2879	2592	3490	3142	4014	3613
	2	2156	1940	2570	2313	2735	2462	3316	2985	3813	3432
	3	2042	1838	2435	2191	2591	2332	3141	2827	3613	3251
	4	1929	1736	2299	2070	2447	2203	2967	2671	3412	3071
170 lbs M = 1855 F = 1669	1	2412	2170	2875	2587	3061	2754	3710	3338	4267	3839
	2	2291	2062	2731	2458	2908	2616	3525	3171	4054	3647
	3	2171	1953	2588	2329	2655	2479	3339	3005	3840	3456
	4	2050	1845	2444	2199	2602	2341	3154	2837	3627	3263
180 lbs M = 1964 F = 1767	1	2553	2297	3044	2739	3241	2916	3928	3534	4517	4064
	2	2425	2182	2892	2602	3079	2770	3732	3357	4291	3861
	3	2298	2068	2740	2466	2917	2625	3535	3182	4065	3659
	4	2170	1952	2587	2328	2755	2479	3339	3004	3839	3454
190 lbs M = 2073 F = 1865	1	2694	2425	3213	2891	3420	3077	4146	3730	4768	4290
	2	2559	2304	3052	2746	3249	2923	3939	3544	4530	4076
	3	2424	2183	2892	2603	3078	2770	3731	3358	4291	3862
	4	2290	2061	2731	2457	2907	2615	3524	3171	4053	3647
200 lbs M = 2182 F = 1964	1	2837	2553	3382	3044	3600	3241	4364	3928	5019	4517
	2	2695	2425	3213	2892	3420	3079	4146	3732	4768	4291
	3	2553	2298	3044	2739	3240	2916	3928	3535	4517	4065
	4	2411	2170	2875	2587	3060	2755	3709	3339	4266	3839
210 lbs M = 2291 F = 2062	1	2978	2681	3551	3196	3780	3402	4582	4124	5269	4743
	2	2829	2547	3373	3036	3591	3232	4353	3918	5006	4506
	3	2680	2412	3196	2876	3402	3062	4124	3711	4742	4269
	4	2531	2279	3018	2717	3213	2892	3895	3505	4479	4032

Total Weight & BMR	Lean Factor	Average Daily Activity Level									
		130%		155%		165%		200%		230%	
		M	F	M	F	M	F	M	F	M	F
220 lbs M = 2400 F = 2160	1	3120	2808	3720	3348	3960	3564	4800	4320	5520	4968
	2	2964	2668	3534	2668	3762	2668	4560	4104	5244	4720
	3	2808	2527	3348	3023	3564	3207	4320	3888	4968	4471
	4	2652	2387	3162	2846	3366	3029	4080	3672	4692	4223
230 lbs M = 2509 F = 2258	1	3262	2935	3889	3500	4140	3726	5018	4516	5771	5193
	2	3099	2788	3695	3325	3933	3540	4767	4290	5482	4933
	3	2936	2642	3500	3150	3726	3353	4516	4065	5193	4674
	4	2603	2495	3306	2975	3519	3167	4265	3839	4905	4414
240 lbs M = 2618 F = 2356	1	3403	3063	4058	3652	4320	3887	5236	4712	6021	5419
	2	3232	2910	3855	3469	4104	3693	4974	4476	5720	5148
	3	3063	2756	3652	3287	3888	3499	4712	4241	5419	4877
	4	2893	2604	3449	3104	3672	3304	4451	4005	5118	4606
250 lbs M = 2727 F = 2455	1	3545	3192	4227	3805	4500	4051	5454	4910	6272	5647
	2	3368	3032	4016	3615	4275	4285	5181	4665	5958	5365
	3	3191	2971	3804	3424	4050	3645	4090	4418	5645	5080
	4	3013	2713	3593	3234	3825	3443	4636	4174	5331	4800
260 lbs M = 2836 F = 2553	1	3687	3319	4396	3957	4679	4212	5672	5106	6523	5872
	2	3503	3153	4176	3759	4445	4001	5388	4851	6197	5578
	3	3318	2986	3956	3561	4211	3790	5105	4594	5871	5284
	4	3134	2821	3737	3363	3977	3580	4821	4340	5545	4991
270 lbs M = 2945 F = 2651	1	3829	3446	4565	4109	4859	4374	5890	5302	6774	6097
	2	3638	3274	4337	3904	4616	4155	5596	5037	6435	5792
	3	3446	3101	4109	3698	4373	3936	5301	4771	6097	5487
	4	3255	2929	3880	3493	4130	3718	5007	4507	5758	5182

Metabolic Equivalent

Metabolic equivalent (MET) is a term used related to energy. For example, 1 MET is defined as the energy to lie/sit quietly. It is equivalent to a metabolic rate of consuming 3.5 mL O_2/kg/minute, the rate of energy expenditure at rest. Looking at it another way, 1 MET can also mean 1 kcal/kg/hour. Therefore, under conditions of physical activity, the MET values will increase, as 1 is a resting value, reflecting no activity.

Furthermore, an MET is the ratio of the rate of energy expended during an activity to the rate of energy expended at rest. For example, 1 MET is the rate of energy expenditure while at rest. A 4 MET activity expends four times the energy used by the body at rest.

MET-Minutes, is another aspect referred to that is related to the MET approach. For example, if a person does a 4 MET activity for 30 minutes, then 4 × 30 = 120 MET-minutes, or 2.0 MET-hours of physical activity. A person could also achieve 120 MET-minutes by doing an 8 MET activity for 15 minutes. Numerous health benefits have been related to exercise type and duration.

Various government guidelines now include some exercise recommendations in terms of METS. For example, the USA Physical Activity Guidelines report mentions that a dose-response relationship exists between physical activity and health benefits. A range of 500 to 1,000 MET-minutes of physical activity per week provides substantial benefit, and amounts of activity above this range have even more benefit. Amounts of activity below this range also have some benefit. The dose-response relationship continues even within the range of 500 to 1,000 MET-minutes, in that the health benefits of 1,000 MET-minutes per week are greater than are those of 500 MET-minutes per week. MET terminology can also be encountered relating to athletes.

Overview of Metabolism

The unit on digestion discussed how the body procures nutrients for growth, maintenance, energy, repair, and life sustenance. For these functions to be accomplished, an astounding number of chemical reactions constantly occur. Each reaction must be carefully controlled to prevent overproduction or underproduction of the desired end product of that particular metabolic phase. This section addresses how the body processes these nutrients to perform these tasks and provides the crucial points of energy metabolism.

As pointed out in previous units, the body consists of trillions of cells, which are organized into tissues, organs, and systems. All the body's components work together in a highly organized manner to maintain a balance. Distinct physiological control mechanisms are self-adjusting. These controls are constantly turning on and off and adjusting their rate of reaction to keep the body in a state of relative equilibrium. Hormone production, body temperature, and heartbeat are all part of this tightly controlled human system.

Homeostasis

In the early twentieth century, the American physiologist Walter Bradford Cannon became credited for coining the term homeostasis to refer to the processes that maintain a constant internal body environment. A good example of homeostasis is the method by which the body maintains a constant temperature of 98.6 degrees Fahrenheit. If physical exertion or external heat causes the body temperature to rise, the brain sends a signal to increase the rate of sweating. Heat is carried away in the evaporating sweat. If body temperature begins to drop due to a cold external environment, shivering begins to generate heat to keep the body temperature at that critical 98.6 degrees F.

Homeostatic Feedback Control Systems

For homeostasis to work, there must be feedback systems that various physiological functions turn off and on. In the two cases just mentioned, imagine if the body kept on sweating or shivering, which would happen if there were no on/off mechanisms. Other metabolic functions under homeostatic control include:

- Hormone production and concentration level maintenance;
- Maintenance of serum oxygen levels and carbon dioxide levels;
- pH balance in the blood and cells;
- Water content of cells and blood;
- Blood glucose levels and other nutrient levels in the cell; and
- Metabolic rate.

The concept of homeostasis is of special interest to the athlete. Indeed, you are in equilibrium with the environmental stimuli imposed on you. Think for example, how your muscles change in response to different training regimens. If you spend most of your time lifting heavy weights, your muscles will grow larger. A shift in your homeostasis has occurred. The simple action of weightlifting causes more protein synthesis in the muscles being exercised with weights. Hormone levels change to accommodate this growth. Muscle fibers increase in size and can store more adenosine triphosphate (ATP) and creatine phosphate (CP), the two energy-supplying molecules used up during explosive power exercise. However, if you choose to run several miles per day, your muscles will take a different form, develop a higher endurance capacity, stimulate the formation of more fat-burning slow-twitch muscle fibers, and develop a higher capacity to use oxygen in energy production.

Nutrient intake is an important factor that can affect your homeostatic balance. Eating too much of the wrong foods, or too little of the right foods, can cause homeostasis to shift. Too much fat and calories, and your body becomes fat. Not enough protein, and your muscles break down. Not enough carbohydrates, and you will feel tired sooner. To achieve optimum homeostasis and metabolism, eating the right nutrients in the right amounts at the right times is vital.

Metabolism

The many biochemical processes that compose the body's metabolism are categorized into two general phases: anabolism and catabolism. From the start, it must be understood that anabolism and catabolism occur simultaneously and continuously. However, the two differ in magnitude depending on the level of activity or rest and on when the last meal was eaten.

To build biomolecules and sustain life, the body needs energy. The body gains its energy from the breakdown of nutrients like glucose and fatty acids. Thus, to construct molecules, there must be molecular destruction occurring simultaneously to provide the energy required to drive these biochemical reactions. When anabolism exceeds catabolism, net growth occurs. When catabolism exceeds anabolism, the body experiences a net loss of substances and body tissues and may lose weight.

Anabolism includes the chemical reactions that combine different biomolecules to create larger, more complex ones. The net result of anabolism is that new cellular material is produced, such as enzymes, proteins, cell membranes, new cells, and growth of the many tissues. That energy is stored in the form of glycogen and/or fat and in muscle tissue. Anabolism is necessary for growth, maintenance, and repair of tissues.

Catabolism: the chemical reactions that break down complex biomolecules into simpler ones for energy production.

Catabolism is the term used to describe the chemical reactions that break down complex biomolecules into simpler ones for energy production. A recent trend in sports nutrition has emerged focusing on "anti-catabolic" training and nutrient intake. For example, when the muscles are strenuously training and the muscle fibers are damaged, cortisol is released at higher levels, which will speed up the breakdown of body tissues. There is some indication that nutrients like the amino acid L-glutamine reduces the effects of cortisol, which results in less tissue breakdown—**anti-catabolic** action. Antioxidants, and a host of phytochemicals, along with good nutrient intake can also have an anti-catabolic effect. Through the reduction of the rate of catabolic actions and substances, the net amount of anabolism is increased, resulting in faster recovery, higher levels of performance, and increased growth rates.

Anti-catabolic: describing a substance that prevents catabolism.

Metabolism includes only the chemical changes that occur within tissue cells in the body. It does not include those changes to substances that take place in the digestion of foods in the gastrointestinal system. A healthy metabolism needs many nutrients to function optimally. A slight deficiency of even one vitamin can slow down metabolism and cause chaos throughout the body. The body builds thousands of enzymes to drive your metabolism in the direction influenced by activity and nutrition. Thus, when you are training several hours a day, you must make sure that your diet contains the nutrients it needs to feed the many **metabolic pathways.**

Metabolic pathway: a sequence of metabolic reactions.

Metabolic Set Point

From the discussion of homeostasis and metabolism above, you can see that the body is a tightly run collection of many biochemical reactions. During the intensive study of weight loss, it was discovered that the body seeks to maintain a certain base rate of metabolism, which has come to be called the metabolic set point (which results in the basal metabolic rate). This set point is controlled by genetics and the environmental factors. Researchers have demonstrated that you can change your metabolic set point through dietary means and physical activity.

The metabolic set point is the average rate at which your metabolism runs and will result in a body composition set point. People with a slow metabolism seem to store fat easily, whereas people with a fast metabolism seem to be able to eat and never get fat. Your metabolic set point can be influenced by the external environment (climate), nutrition, exercise, and other factors. Studies have demonstrated that when individuals go on low-calorie diets, the body's metabolic set point becomes lower to conserve energy. It actually resets itself to burn fewer calories, thereby conserving energy. Exercise tends to keep the metabolic rate up, and more aerobic exercise tends to cause the body to burn more fat for energy.

Food and Metabolism

The type of food eaten can also influence metabolism. Diets low in fat and high in protein and carbohydrates can increase the basal metabolic rate. The processing of the excess protein seems to require more energy. Fat reduction diets should be low in fat and higher in protein. Some studies have shown that certain substances like caffeine also increase your metabolic rate. Other plant compounds, like ephedrine, found in the herb Ma Huang, have a thermogenic effect similar to that of caffeine. There are many supplements that contain guarana to supply caffeine and Ma Huang to supply ephedrine. They are sold as metabolic boosters, also referred to as thermogenic aids. Thermogenesis occurs when the body produces more heat in response to ingestion of certain food compounds or exercise. In other words, thermogenesis increases your metabolic rate above normal. Although increased caffeine intake is not generally recommended, studies have demonstrated a significant loss of fat can be influenced by caffeine intake.

One question commonly asked is which nutrients does your body generate energy from – lipids or carbohydrates? Like most topics discussed herein, it is not an easily answered question because of the many variations from person to person and the limitations on performing good controlled studies on people. However, a method of determining the "fuel mix" being used has been developed, called the Respiratory Quotient (RQ), which gives us a way to measure the relative amounts of fats, carbohydrates, and proteins being burned for energy.

The respiratory quotient is a measure of the ratio of the volume of carbon dioxide expired to the volume of oxygen consumed. Because the amount of oxygen used up for the combustion of fat, carbohydrate, and protein will be different, differences in the RQ will indicate which nutrient source is being predominantly used for energy purposes. The formula for calculating RQ is

$$\textbf{RQ = Volume of } CO_2 \textbf{ expired/ volume of } O_2 \textbf{ utilized.}$$

Eq. 15.2

The RQ for carbohydrates is 1.0, whereas the RQ for fat is 0.7. Fat has a lower RQ value because fatty acids require more oxygen for oxidation than the amount of carbon dioxide produced. The RQ for energy production from protein is about 0.8. The average person at rest will have an RQ of about 0.8; however, this is from using a mixture of fatty acids and carbohydrates for energy production, not from protein as the number might indicate. Remember, protein/amino acids are not usually used for energy. In a normal diet, containing carbohydrate, fat, and protein, about 40 to 45 percent of the energy is derived from fatty acids, 40 to 45 percent from carbohydrates, and 10 to 15 percent from protein. However, this rate of energy production will vary depending on the diet, physical activity, and level of physical training.

$\dot{V}O_2$ max: the maximum rate at which oxygen can be consumed.

Research indicates that when the diet is high in carbohydrates, the RQ is higher, and therefore more energy is being produced from carbohydrates. When the diet is low in carbohydrates and higher in fat, then more energy is produced from fat. Additionally, training intensity will affect the energy source during exercise. Exercise rate below 60 percent of maximum oxygen uptake **($\dot{V}O_2$ max)** results in RQ of about 0.8, which indicates an equal portion of energy derived from fatty acids and carbohydrates. As training intensity increases above 60% $\dot{V}O_2$ max, more carbohydrate is used for energy. Exercise intensity at 100% VO max (which can only be sustained for minutes) yields an RQ of 1. You must also keep in mind that amino acids, in particular the BCAAs, are also being used for energy during exercise and at rest—perhaps as much as 10 percent or more during exercise.

In general, physical conditioning lowers the RQ, which means more energy is being obtained from fatty acids in the trained individual. However, more energy is also being obtained from protein in the trained individual. Carbohydrate is always being used for energy and the fuel mixture varies depending on the composition of the diet and type of training (anaerobic or aerobic, or a combination thereof). For example, when the RQ of untrained individuals versus trained individuals during exercise was compared, the RQ of the untrained individuals was 0.95, and the RQ of the trained individuals was 0.9. This means that although both groups were using mostly carbohydrate for fuel during exercise, the trained individuals were using a higher amount of fatty acids for energy. At rest, fatty acids are the predominant energy source in most people; as exercise begins, carbohydrate use increases. High-intensity exercise uses more carbohydrate, whereas low- to moderate-intensity exercise uses fatty acid and carbohydrate for energy. Although this discussion of RQ is very brief, you can see that the energy substrate utilization of the body is quite varied, and both composition of the diet and intensity of physical activity will determine which energy substrates are used. Therefore, it is easy to see why different sports require different dietary considerations.

Metabolic Testing Device Example

Metabolic exercise testing is traditionally conducted in a research laboratory or specialized testing facility, using expensive equipment. However, now with the development of portable metabolic testing units, certain metabolic testing is now practical in the gym or in private fitness trainer studios. The CardioCoach is an example of a metabolic testing unit for $\dot{V}O_2$ max testing but also provides additional test data related to resting metabolic rate, exercising metabolic rate, O_2, and CO_2 and therefore provides actual individual data about energy expenditure and RQ. The CardioCoach has also been subjected to independent research testing to validate accuracy; citations can be found in the reference section.

With portable metabolic testing technology, fitness trainers and other health professionals can collect and analyze these important metabolic measurements to gain insights into a client's metabolic functioning related to energy expenditure, anaerobic threshold, aerobic threshold, metabolic rate, rate of recovery, RQ, and $\dot{V}O_2$ max. With a program of retesting, tracking changes of these metabolic measurements in response to athletic training and nutrition programs will provide useful information about what is working to produce progressive improvements and to detect when progress may be slower than expected. Applied exercise physiology!

The Environment and Metabolism

The outside environment will also influence metabolic rate. When you are exposed to a progressively colder climate, your body will increase its metabolic rate to keep the body temperature constant and to prevent shivering. Shivering is invoked when the core temperature of the body begins to drop from being in the cold. Shivering is a series of involuntary muscle contractions triggered to create heat in the body, like turning on a furnace. When exposed to higher-than-average cold conditions for a few days, the body increases its basal metabolic rate to run hotter than average to compensate for being in a colder climate. When things begin to warm up, even a 60-degree F day can seem extremely hot because your metabolic rate is still running at a fast rate. After several days of acclimation to the hot climate, your metabolic rate will decrease, and 80 degrees F will feel as hot as the 60 degrees F day did a few months earlier.

Exercise and Metabolic Responses

Exercise will stimulate a series of metabolic responses that affect the body's anatomy, physiology, and biochemical makeup. Here are some of the changes stimulated by endurance exercise:

- Increased muscle glycogen storage capacity
- Increased muscle mitochondria density
- Increased resting ATP content in muscles
- Increased aerobic enzymes
- Increased slow twitch muscle fiber percent
- Decreased fast twitch muscle fiber percent
- Decreased muscle size, when compared to strength training
- Increased cardiac output
- Decreased resting heart rate
- Decreased body fat
- Increased Krebs cycle enzymes
- Increased capillaries

The magnitude of these changes is driven primarily by the type of exercise undertaken: anaerobic or aerobic. The type and duration of exercise will physically stimulate muscles to develop more fast- or slow-twitch muscle fibers and in turn dictate the primary energy mix used. High-intensity exercise simulates fast-twitch muscle fiber development, whereas low-intensity exercise results in slow-twitch muscle fiber development. A series of hormonal changes also occur on an overall basis during exercise and during non-exercising periods. These changes also are benefited and facilitated by a nutrient profile that matches the type of metabolic flux.

Aerobic System Changes

Aerobic training greatly increases the body's functional capacity to transport and use oxygen and to burn fatty acids during exercise. Some of the major changes measured as a result of aerobic exercise include:

- Increased mitochondria density in slow twitch muscle fiber, which results in higher energy production from fatty acids. Maximum oxidative capacity develops in all fiber types;
- Higher aerobic capacity;
- Increase in trained muscle capacity to utilize and mobilize fat, resulting from higher amounts of fat metabolizing enzymes, and increased blood flow;
- Greater development of slow-twitch muscle fibers; and
- Increased myoglobin, which is an iron-protein compound in muscle that acts to store and transport oxygen in the muscles

Anaerobic System Changes

Anaerobic training greatly increases the body's functional capacity for development of explosive strength and maximization of short-term energy systems. Some of the major changes measured as a result of anaerobic exercise include

- Increased size and number of fast-twitch muscle fibers;
- Increased tolerance to higher levels of blood lactate;
- Increases in enzymes involved in the anaerobic phase of glucose breakdown (glycolysis);
- Increased muscle resting levels of ATP, CP, creatine, and glycogen content; and
- Increased growth hormone and testosterone levels after short bouts (45 to 75 minutes) of high-intensity weight training.

Energy Metabolism

Energy metabolism is a series of chemical reactions that result in the breakdown of foodstuffs (carbohydrate, fat, protein) by which energy is produced, used, and given off as heat. Roughly, the body is about 20 percent efficient at trapping energy released. About 80 percent is released as heat, which explains why your body heats up quickly when you exercise. A closer look at your muscle anatomy reveals that the mode of energy storage and energy systems used is related to your physical activity.

Physical activities can be classified into four basic groups, based on the energy systems that are used to support these activities. They are as follows:

- **Strength-Power.** Energy from immediate ATP stores. Shot put, power lift, high jump, golf swing, tennis serve, and throwing. About 0–3 seconds of all-out effort;
- **Sustained-Power.** Energy from immediate ATP and CP stores. Sprints, fast breaks, football line man. About 0–10 seconds of near maximum effort;
- **Anaerobic Power-Endurance.** ATP, CP, and Lactic Acid. A 200–400 meter dash, 100-yard swim. About one to two minutes; and
- **Aerobic-Endurance.** Aerobic oxidative energy. Over two-minute events.

In power events, which last a few seconds or less, the muscles depend on the immediate energy system, namely ATP and CP reserves. In speed events, the immediate and non-oxidative (glycolytic) energy sources are used. In endurance events, the immediate and non-oxidative energy sources are used, and the oxidative energy mechanisms become a more important source of energy. ATP and CP are replenished from energy derived from complete breakdown of glucose, fatty acids, and some proteins.

ATP is the molecule that stores energy in a form that can be used for muscle contractions. Energy production then revolves around rebuilding ATP molecules after they are broken down for energy utilization. The human metabolism can make ATP in several ways, which correlate to the three main categories of energy use.

To better understand how each of these energy systems relate to each other, let's take a look at what happens when muscles contract. First, the immediate energy systems. The brain sends a signal along the nerves, which triggers a release of calcium ions in the muscles, which stimulates the muscles to contract, and in the process, the high-energy molecule ATP (adenosine triphosphate) releases energy and is reduced to adenosine diphosphate plus one phosphate atom. In this way, the immediately available ATP stores are depleted extremely rapidly, the first few seconds of a maximum muscle contraction.

The second immediate source of cellular energy is creatine phosphate (CP). There are several more times CP molecules in the cell than ATP. Creatine phosphate serves to instantaneously regenerate ATP molecules. Therefore, the ATP that is broken down to ADP during muscle contraction is restored to the high energy ATP by CP. The third immediate energy system enables the cell to regenerate ATP from two ADP molecules, resulting in one ATP and one AMP (adenosine monophosphate) molecule. This immediate energy source is depleted in a matter of seconds under conditions of all-out effort, under conditions of maximum muscle contractions.

Some Useful Metabolism-Related Terms

ATP — Adenosine Triphosphate. Primary energy storehouse molecule used in the human body. It is used in many biosynthetic processes which require energy and is essential for muscle contraction.

CP — Creatine Phosphate (also, phosphocreatine). Found in muscle tissue, where it is an energy source for muscle contraction. CP stores are used as a means to immediately replenish ATP, and fuel high intensity muscle contractions. (Together this immediate source of energy from resting levels of ATP and CP is referred to the phosphagen system.)

Glycolysis — The metabolic process that creates energy via splitting a molecule of glucose to form either pyruvic acid or lactic acid and produce some ATP molecules.

Krebs Cycle — This is part of the oxidative portion of energy production where carbon chains from the breakdown of glucose, fatty acids, and protein are used for more ATP production. This takes place in the mitochondria.

Glycogenolysis — The cellular breakdown of stored glycogen for energy use.

It is interesting to note that the storage capacity of ATP and CP in a cell is quickly reached for a particular muscle size. To increase the amount of ATP and CP on hand, the muscle fibers must increase in size. This is why power athletes get big muscles. The workload demands that more ATP and CP are on hand. To meet this demand, the muscle fibers increase in size, causing the entire muscle to get big. When you train, different energy systems are conditioned to work best at the particular workload imposed on the muscles.

As the immediate energy supply is quickly depleted through high intensity physical activity, the non-oxidative energy source kicks in. The non-oxidative system is a major contributor of energy during 4 to 50 seconds of effort. Non-oxidative metabolism (glycolysis) involves the breakdown of glucose to regenerate ADP into ATP. Muscle tissue is densely packed with non-oxidative enzyme systems. Chemically, what happens is that the glucose molecule is split in half, and energy is released. This energy is enough to regenerate 2 ATP molecules and leave two pyruvate molecules. In general, these pyruvate molecules are immediately converted to lactic acid molecules. The amount of free glucose is generally low in the cells, so glucose is derived from the breakdown of glycogen.

Fast-twitch muscle fibers, those associated with strength and size, are also referred to as fast glycolytic muscle fibers because they house the metabolic machinery to get quick energy through fast glycolysis pathways. The fast twitch fibers have a low capacity for oxidative metabolism and are instead set up to run glucose through their fast glycolysis pathways. Lactic acid then builds up because it is being produced too rapidly to enter into the oxidative pathways. Lactic acid is then cleared from the muscle, fed into the blood stream, taken to the liver, and there made into glucose and glycogen. Glycolysis takes place in the cytoplasm of the cell.

For physical activities lasting more than 2 minutes in duration, the oxidative metabolic pathways produce the majority of energy to maintain muscle contractions. Potential oxidative energy sources include glucose, glycogen, fats, and amino acids. Oxidative energy production takes place in the mitochondria of the cells. Far more energy is produced when glucose is completely broken down in the mitochondria. Glucose is still first split in half by glycolysis. The pyruvate molecules then enter into the mitochondria where they are completely broken down. The **oxidative pathways** are called the Krebs cycle and electron transport. Fatty acids, from fat, are a major energy source during endurance events. The processes of fat utilization are activated more slowly than carbohydrate metabolism and proceed at a lower rate. Fatty acids are activated and combined with the molecule carnitine, which enables them to be transported into the mitochondria.

Oxidative pathways: the systems that supply energy for low-intensity, high-duration activities lasting more than approximately three or four minutes, such as marathon running and aerobic dance. They include oxidative glycolysis and beta oxidation.

Glycogen Depletion and Metabolism of Fatigue

Glycogen is essential to performance for both anaerobic and aerobic activities. Muscles being strenuously exercised will rely on glycogen to power these strength generating muscle contractions. In endurance exercise, while the primary fuel is fatty acids, glycogen is also utilized. In fact, fat catabolism is believed to work better when carbohydrates are being metabolized. Research on long-term exercise and work performance all indicate the onset of fatigue when glycogen is depleted. This again underscores the importance of adequate carbohydrate intake and **glycogen replenishment**.

Glycogen replenishment: the refilling of the body's glycogen stores.

Glycogen depletion: the draining of the body's glycogen stores.

Glycogen depletion is just one factor that contributes to the onset of exercise fatigue, including neuromuscular fatigue. This occurs when a decrease in muscle contraction and force output occurs. The following lists other factors that an athlete experiences related to fatigue.

- ATP and CP depletion, faster than rate of formation
- Metabolic acidosis, decrease in pH, associated with an increase in acid forming hydrogen ion concentration (H+)
- Alterations in central nervous system neurotransmitters, such as dopamine and serotonin
- Neural activity decrease
- Ionic imbalances, such as with calcium, potassium, and sodium
- Oxygen depletion, reduction of aerobic energy production

<table>
<tr><th colspan="5">Body Composition, Metabolic Rate Summary Chart</th></tr>
<tr><td colspan="5">Useful reference information that can be used for nutrition planning and other purposes relying on using these measurements.</td></tr>
<tr><td>Body Weight:</td><td>Lean Factor:</td><td>LF Multiplier:</td><td rowspan="3">Males
S8 (Thigh):
S9 (Abdomen):
S10 (Chest):
S1 (subscapula):</td><td rowspan="3">Females
S2 (Triceps):
S4 (Suprailiac):
S8 (Thigh):</td></tr>
<tr><td>% Body Fat</td><td>Body Fat Mass</td><td rowspan="2">Protein Requirement from page Chapter 4</td></tr>
<tr><td>% Lean Body Weight</td><td>Lean Body Weight</td></tr>
<tr><td colspan="5">BMR</td></tr>
<tr><td>130%</td><td>155%</td><td>165%</td><td>200%</td><td>230%</td></tr>
</table>

CONCLUSION

We need energy to maintain the many metabolic processes occurring in the human body. Under conditions of athletic training, energy demands increase. As muscle fibers develop in response to the training stimuli, the body's energy utilization can change. This creates dynamic nutrition intake demands that a sports nutrition program must be customized to satisfy, supplying the athlete's nourishment requirements from food and dietary supplements.

Keywords

Catabolism

Anti-catabolic

Metabolic pathway

Oxidative energy systems

$\dot{V}O_2$ max

Glycogen replenishment

Glycogen depletion

Topics Covered In This Unit

UNIT 16

DIETARY GUIDELINES FOR AMERICANS

Unit Outline

I. Introduction

II. Why dietary guidelines?

III. Dietary Guidelines (DGs)

a. Key recommendations: Components of healthy eating patterns

IV. DASH Diet

a. Health benefits of the DASH eating plan – study results

i. DASH trial

ii. DASH-sodium trial

iii. Premier trial

b. Following the DASH eating plan

V. Conclusion

Learning Objectives

After completing this unit, you will be able to:

- Define and describe terms related to the Dietary Guidelines for Americans;
- Discuss the core elements of healthy eating;
- Determine the dietary shifts needed to align with health-eating patterns;
- Identify points to consider for sports nutrition applications; and
- Be aware of the DASH diet and health benefits.

Introduction

Although the dietary guidelines are not specifically designed for sports nutrition purposes, they are useful to know about to integrate healthy nutrition practices into a sports nutrition program and are useful to keep athletes eating healthy in the off-season and to develop health nutrition practices that will benefit health throughout life.

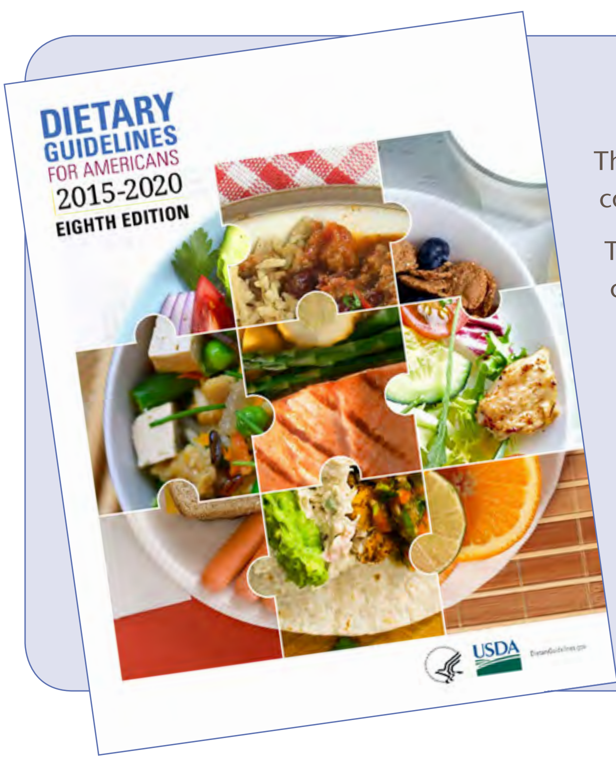
Note that a copy of the 2015–2020 Dietary Guidelines is contained in the Appendix for handy reference use and to gain familiarity. This unit will review a summary level of the Dietary Guidelines, and you are directed to review the entire Dietary Guidelines in the Appendix as part of this unit's study.

The following information in this unit will provide overview information of the Dietary Guidelines, including sports nutrition considerations.

Why Dietary Guidelines?

The main purpose of the Dietary Guidelines is to inform the development of federal food, nutrition, and health policies and programs. The primary audiences are policy makers and nutrition and health professionals, not the general public.

The Dietary Guidelines is a critical tool for professionals to help Americans make healthy choices in their daily lives to help prevent chronic disease and enjoy a healthy diet. It serves as the evidence-based foundation for nutrition education materials that are developed by the federal government for the public. For example, federal dietary guidance publications are required by law to be consistent with the Dietary Guidelines. The guidelines are also used to inform USDA and HHS food programs, such as USDA's national School Lunch Program and School Breakfast Program,



The first half of the 122-page Dietary Guidelines contains chapters related to various nutrition topics.

The second half of the Dietary Guidelines contains the Dietary Guidelines Appendix with many useful tables covering foods, nutrient sources, and calorie intake charts.

In addition to nutrition, the Dietary Guidelines also contain information about physical activity guidelines for Americans. A glossary is included as well.

which feed more than 30 million children each school day, and the Special Supplemental Nutrition Program for Women, Infants, and Children (WIC), which uses the Dietary Guidelines as the scientific underpinning for its food packages and nutrition education program with about 8 million beneficiaries.

At HHS, the Administration on Aging implements the Dietary Guidelines through the Older Americans Act Nutrition Services programs (i.e., nutrition programs for older adults), with about 5,000 community-based nutrition service providers who together serve more than 900,000 meals a day across the United States. Other departments, such as the Department of Defense (DOD) and the Department of Veterans Affairs, also use the Dietary Guidelines to inform programs. The Dietary Guidelines also may be used to inform the development of programs, policies, and communication by audiences other than the document's principal audiences. These audiences, which share the common goal of serving the general public, include businesses, schools, community groups, media, the food industry, and state and local governments.

The 2015–2020 Dietary Guidelines translate science into succinct, food-based direction that can be relied upon to help Americans choose foods that provide a healthy and enjoyable diet. Its recommendations are ultimately intended to help individuals improve and maintain overall health and reduce the risk of chronic disease—its focus is disease prevention.

The Dietary Guidelines is not intended to be used to treat disease. Regardless of an individual's current health status, nearly all people in the United States could benefit from shifting choices to better support healthy eating patterns. Thus, the Dietary Guidelines may be used or adapted by medical and nutrition professionals to encourage healthy eating patterns for their patients.

Dietary Guidelines (DGs)

The DGs is organized in a progressive approach, starting with core concepts, followed by details. The following are considered the five crucial elements of the DGs. Comments are added with respect to sports nutrition programs.

1. **Follow a healthy eating pattern across the lifespan.** All food and beverage choices matter. Choose a healthy **eating pattern** at an appropriate calorie level to help achieve and maintain a healthy body weight, support nutrient adequacy, and reduce the risk of chronic disease. [Comment: Can be applied to a sports nutrition program.]

2. **Focus on variety, nutrient density, and amount.** To meet nutrient needs within calorie limits, choose a variety of nutrient-dense foods across and within all food groups in recommended amounts. [Comment: Can be applied to a sports nutrition program.]

3. **Limit calories from added sugars and saturated fats and reduce sodium intake.** Consume an eating pattern low in added sugars, saturated fats, and sodium. Cut back on foods and beverages higher in these components to amounts that fit within healthy eating patterns. [Comment: with respect to saturated fats, sports nutrition programs should also keep these in check; with respect to sodium, athletes typically require higher than average sodium intakes to compensate for sodium and other electrolytes lost by sweating and other physical activity related losses, but should strive to avoid excessive intake beyond what is needed; with respect to added sugars, most energy sports drinks contain added sugars, so minimizing the use of these sugary sports nutrition products should be considered, and making a shift to healthier choices when possible, such as fruit and other suitable healthy carbohydrate choices.]

4. **Shift to healthier food and beverage choices.** Choose nutrient-dense foods and beverages across and within all food groups in place of less healthy choices. Consider cultural and personal preferences to make these shifts easier to accomplish and maintain. [Comment: can be applied to a sports nutrition program.]

5. **Support healthy eating patterns for all.** Everyone has a role in helping create and support healthy eating patterns in multiple settings nationwide, from home to school to work to communities. [Comment: can be applied to a sports nutrition program.]

Eating pattern (also called "dietary pattern"): the combination of foods and beverages that constitutes an individual's complete dietary intake over time. This may be a description of a customary way of eating or a description of a combination of foods recommended for consumption. Specific examples include USDA Food Patterns and the Dietary Approaches to Stop Hypertension (DASH) Eating Plan. (See USDA Food Patterns and DASH Eating Plan.)

Whole fruits: (Pg. 79) all fresh, frozen, canned, and dried fruit but not fruit juice.

The following figure shows how personal, social, organizational, and environmental contexts and systems interact powerfully to influence an individual's diet and physical activity behaviors and patterns and illustrate how diverse health outcomes result from this dynamic interplay. This was developed and presented in the "Scientific Report of the 2015 Dietary Guidelines Advisory Committee." It provides a model of interrelated factors related to an individual's diet and physical activity and behaviors for health promotion and disease prevention across the lifespan. Of interest to fitness trainers and other health practitioners is a clear role in this model approach. This model is important to consider when working with athletes on- and off-season.

Diet and Physical Activity, Health Promotion and Diease Prevention at Individual and Population Levels across the Lifespan.

Key Recommendations: Components of Healthy Eating Patterns

The Dietary Guidelines' Key Recommendations for healthy eating patterns should be applied in their entirety, given the interconnected relationship that each dietary component can have with others. As illustrated later in this chapter, there is more than one way to put these recommendations into action; this is exemplified by the three eating patterns that translate and integrate the key recommendations into an overall healthy way to eat.

Key Recommendations Include

Consume a healthy eating pattern that accounts for all foods and beverages within an appropriate calorie level.

A healthy eating pattern includes: [2]

- A variety of vegetables from all of the subgroups—dark green, red, and orange; legumes (beans and peas), starchy, and other
- Fruits, especially **whole fruits**
- Grains, at least half of which are whole grains
- Fat-free or low-fat dairy, including milk, yogurt, cheese, and/or fortified soy beverages
- A variety of protein foods, including seafood, lean meats and poultry, eggs, legumes (beans and peas), and nuts, seeds, and soy products
- Oils

A healthy eating pattern limits:

- Saturated fats and trans fats, added sugars, and sodium

Key recommendations that are quantitative are provided for several components of the diet that should be limited. These components are of particular public health concern in the United States, and the specified limits can help individuals achieve healthy eating patterns within calorie limits:

- Consume less than 10 percent of calories per day from added sugars [3]
- Consume less than 10 percent of calories per day from saturated fats [4]
- Consume less than 2,300 milligrams (mg) per day of sodium [5]
- If alcohol is consumed, it should be done so in moderation—up to one drink per day for women and up to two drinks per day for men—and only by adults of legal drinking age. [6]

Notes: [2] Definitions for each food group and subgroup are provided throughout the chapter and are compiled in Appendix 3. USDA Food Patterns: Healthy U.S.-Style Eating Pattern.

[3] The recommendation to limit intake of calories from added sugars to less than 10 percent per day is a target based on **food pattern modeling** and national data on intakes of calories from added sugars that demonstrate the public health need to limit calories from added sugars to meet food group and nutrient needs within calorie limits. The limit on calories from added sugars is not a Tolerable Upper Intake Level (UL) set by the Institute of Medicine (IOM). For most calorie levels, there are not enough calories available after meeting food group needs to consume 10 percent of calories from added sugars and 10 percent of calories from saturated fats and still stay within calorie limits.

[4] The recommendation to limit intake of calories from saturated fats to less than 10 percent per day is a target based on evidence that replacing saturated fats with unsaturated fats is associated with reduced risk of cardiovascular disease. The limit on calories from saturated fats is not a UL set by the IOM. For most calorie levels, not enough calories are available after meeting food group needs to consume 10 percent of calories from added sugars and 10 percent of calories from saturated fats and still stay within calorie limits.

[5] The recommendation to limit intake of sodium to less than 2,300 mg per day is the UL for individuals ages 14 years and older set by the IOM. The recommendations for children younger than 14 years of age are the IOM age- and gender-appropriate ULs (see Appendix 7. Nutritional Goals for Age-Sex Groups Based on Dietary Reference Intakes and Dietary Guidelines Recommendations).

[6] It is not recommended that individuals begin drinking or drink more for any reason. The amount of alcohol and calories in beverages varies and should be accounted for within the limits of healthy eating patterns. Alcohol should be consumed only by adults of legal drinking age. There are many circumstances in which individuals should not drink, such as during pregnancy. See Appendix 9. Alcohol for additional information.

Some Terms to Eat By

Several terms are used to operationalize the principles and recommendations of the 2015–2020 Dietary Guidelines. These terms are essential to understanding the concepts discussed herein:

Eating pattern—The combination of foods and beverages that constitute an individual's complete dietary intake over time. Often referred to as a "dietary pattern," an eating pattern may describe a customary way of eating or a combination of foods recommended for consumption. Specific examples include **USDA Food Patterns** and the Dietary Approaches to Stop Hypertension (DASH) Eating Plan.

Nutrient dense—A characteristic of foods and beverages that provide vitamins, minerals, and other substances that contribute to adequate nutrient intakes or may have positive health effects, with little or no solid fats and added sugars, refined starches, and sodium. Ideally, these foods and beverages also are in forms that retain naturally occurring components, such as dietary fiber. All vegetables, fruits, whole grains, seafood, eggs, beans and peas, unsalted nuts and seeds, fat-free and low-fat dairy products, and lean meats and poultry—when prepared with little or no added solid fats, sugars, refined starches, and sodium—are nutrient-dense foods. These foods contribute to meeting food group recommendations within calorie and sodium limits. The term "nutrient dense" indicates the nutrients and other beneficial substances in a food have not been "diluted" by the addition of calories from added solid fats, sugars, or refined starches, or by the solid fats naturally present in the food.

Variety—A diverse assortment of foods and beverages across and within all food groups and subgroups selected to fulfill the recommended amounts without exceeding the limits for calories and other dietary components. For example, in the vegetables food group, selecting a variety of foods could be accomplished over the course of a week by choosing from all subgroups, including dark green, red, and orange; legumes (beans and peas), starchy, and other vegetables.

Dash Diet (Dietary Approaches to Stop Hypertension)

DASH is a flexible and balanced eating plan that helps achieve a heart-healthy eating style for life. It has been brought to your attention in this unit for a few reasons. Fitness trainers and other health professionals taking this Sports Nutrition course will find knowing about clinically proven healthy diets useful. Although the Dietary Guidelines are based on an array of evidence from many scientific studies, evolving from update to update every five years, the DASH diet itself has undergone a variety of clinical research studies, noting it is based on the Dietary Guidelines.

The DASH eating plan requires no special foods and instead provides daily and weekly nutritional goals. This plan recommends:

- Eating vegetables, fruits, and whole grains
- Including fat-free or low-fat dairy products, fish, poultry, beans, nuts, and vegetable oils
- Limiting foods that are high in saturated fat, such as fatty meats, full-fat dairy products, and tropical oils such as coconut, palm kernel, and palm oils
- Limiting sugar-sweetened beverages and sweets

Based on these recommendations, the following table gives examples of daily and weekly servings that meet DASH eating plan targets for a 2,000-calorie-a-day diet.

Daily and Weekly DASH Eating Plan Goals for a 2,000 Calorie-a-Day Diet	
Food Group	**Daily Servings**
Grains	6–8
Meats, poultry, and fish	6 or fewer
Vegetables	4–5
Fruit	4–5
Low-fat or fat-free dairy products	2–3
Fats and oils	2–3
Sodium	2,300 mg*
Food Group	**Weekly Servings**
Nuts, seeds, dry beans, and peas	4–5
Sweets	**5 or fewer**
*1,500 milligrams (mg) sodium lowers blood pressure even further than 2,300 mg sodium daily.	

Health Benefits of the DASH Eating Plan – Study Results

Three NHLBI-funded trials showed the health benefits of the DASH diet, such as lowering high blood pressure and LDL (bad) cholesterol in the blood, and shaped the final DASH eating plan recommendations.

- DASH (Dietary Approaches to Stop Hypertension Trial): The DASH diet lowers blood pressure and LDL (bad) cholesterol compared with a typical American diet alone or a typical American diet with more fruits and vegetables.
- DASH-Sodium (DASH Diet, Sodium Intake, and Blood Pressure Trial): The DASH diet lowers blood pressure better than a typical American diet at three daily sodium levels does. Combining the DASH diet with sodium reduction gives greater health benefits than the DASH diet alone does.
- PREMIER clinical trial: People can lose weight and lower their blood pressure by following the DASH eating plan and increasing their physical activity.

Food pattern modeling: (Pg. 79) the process of developing and adjusting daily intake amounts from food categories or groups to meet specific criteria, such as meeting nutrient intake goals, limiting nutrients or other food components, or varying proportions or amounts of specific food categories or groups. This methodology includes using current food consumption data to determine the mix and proportions of foods to include in each group, using current food composition data to select a nutrient-dense representative for each food, calculating nutrient profiles for each food group using these nutrient-dense representative foods, and modeling various combinations of foods and amounts to meet specific criteria.

USDA Food Patterns: a set of eating patterns that exemplify healthy eating, which all include recommended intakes for the five food groups (vegetables, fruits, grains, dairy, and protein foods) and for subgroups within the vegetables, grains, and protein foods groups. They also recommend an allowance for intake of oils. Patterns are provided at 12 calorie levels from 1,000 to 3,200 calories to meet varied calorie needs. The Healthy U.S.-Style Pattern is the base USDA Food Pattern. See: Healthy U.S.-Style Eating Pattern, Healthy Mediterranean-Style Eating Pattern, and Healthy Vegetarian Eating Pattern.

DASH Trial

This trial included 459 adults, some with and without confirmed high blood pressure, and compared three diets including 3,000 mg daily sodium:

- Typical American diet (higher in sodium, saturated fats, and calories; lower in fiber, fruits, and vegetables, and some essential nutrients)
- Typical American diet plus more fruits and vegetables
- DASH diet

None of the plans were vegetarian or used specialty foods. After two weeks, participants who added fruits and vegetables to a typical American diet or those on the DASH diet had lower blood pressure than did those who followed a typical American diet alone. However, the participants on the DASH diet had the greatest effect of lowering their high blood pressure.

Follow-up reports from the DASH trial showed that in addition to improving blood pressure, the DASH diet also lowered LDL cholesterol levels. High blood pressure and elevated LDL cholesterol are two major risk factors for cardiovascular disease.

DASH—Sodium Trial

This trial randomly assigned 412 participants to a typical American diet or the DASH diet. While on their assigned diet, participants were followed for a month at a high daily sodium level (3,300 mg) and two lower daily sodium levels (2,300 mg and 1,500 mg). Reducing daily sodium lowered blood pressure for participants on either diet. However, blood pressures were lower for participants on the DASH diet versus a typical American diet. Blood pressure decreased with each reduction of sodium. These results showed that lowering sodium intake and eating the DASH diet is more beneficial for lowering blood pressure than is following the DASH diet alone.

PREMIER Trial

The PREMIER trial included 810 participants who were placed into three groups to lower blood pressure, lose weight, and improve health. The groups included:

- Advice-only group, did not receive counseling on behavior changes
- Established treatment plan, including counseling for six months
- Established treatment plan, plus counseling and use of the DASH diet

After six months, blood pressure levels declined in all three groups. The two groups that received counseling and followed a treatment plan had more weight loss than the advice-only group. However, participants in the established treatment plan who followed the DASH diet had the greatest improvement in their blood pressure.

Following the DASH Eating Plan

The DASH eating plan is intended to be easy to follow using common foods available in grocery stores. The plan includes daily servings from different food groups. The number of servings depends on daily calorie (energy) needs. The following table estimates the number of servings from each food group that a person could have to meet the prescribed goals.

Note that serving quantities are per day, unless otherwise noted.

DASH Eating Plan—Number of Food Servings by Calorie Level					
Food Group	**1,600**	**1,800**	**2,000**	**2,600**	**3,100**
Grains [a]	6	6	6–8	10–11	12–13
Vegetables	3–4	4–5	4–5	5–6	6
Fruits	4	4–5	4–5	5–6	6
Fat-free or low-fat dairy products [b]	2–3	2–3	2–3	3	3–4
Lean meats, poultry, and fish	3–4 or fewer	6 or fewer	6 or fewer	6 or fewer	6–9
Nuts, seeds, and legumes	3–4 per week	4 per week	4–5 per week	1	1
Fats and oils [c]	2	2–3	2–3	3	4
Sweets and added sugars	3 or less per week	5 or less per week	5 or less per week	≤2	≤2
Maximum sodium limit [d]	2,300 mg/day	2,300 mg/day	2,300 mg/day	2,300 mg/day	2,300 mg/day

a Whole grains are recommended for most grain servings as a good source of fiber and nutrients.

b For lactose intolerance, try either lactase enzyme pills with dairy products or lactose-free or lactose-reduced milk.

c Fat content changes the serving amount for fats and oils. For example, 1 Tbsp regular salad dressing = one serving; 1 Tbsp low-fat dressing = one-half serving; 1 Tbsp fat-free dressing = zero servings.

d The DASH eating plan has a sodium limit of either 2,300 mg or 1,500 mg per day.

DASH Eating Plan—Serving Sizes, Examples, and Significance			
Food Group	**Serving Sizes**	**Examples and Notes**	**Significance of Each Food Group to the DASH Eating Plan**
Grains [a]	1 slice bread 1 oz dry cereal [b] ½ cup cooked rice, pasta, or cereal [b]	Whole wheat bread and rolls, whole wheat pasta, English muffin, pita bread, bagel, cereals, grits, oatmeal, brown rice, unsalted pretzels and popcorn	Major sources of energy and fiber
Vegetables	1 cup raw leafy vegetable ½ cup cut-up raw or cooked vegetable ½ cup vegetable juice	Broccoli, carrots, collards, green beans, green peas, kale, lima beans, potatoes, spinach, squash, sweet potatoes, tomatoes	Rich sources of potassium, magnesium, and fiber
Fruits	1 medium fruit ¼ cup dried fruit ½ cup fresh, frozen, or canned fruit ½ cup fruit juice	Apples, apricots, bananas, dates, grapes, oranges, grapefruit, grapefruit juice, mangoes, melons, peaches, pineapples, raisins, strawberries, tangerines	Important sources of potassium, magnesium, and fiber
Fat-free or low-fat dairy products [c]	1 cup milk or yogurt 1½ oz cheese	Fat-free milk or buttermilk; fat-free, low-fat, or reduced-fat cheese; fat-free/low-fat regular or frozen yogurt	Major sources of calcium and protein
Lean meats, poultry, and fish	1 oz cooked meats, poultry, or fish 1 egg	Select only lean; trim away visible fats; broil, roast, or poach; remove skin from poultry	Rich sources of protein and magnesium

DASH Eating Plan—Serving Sizes, Examples, and Significance, continued			
Food Group	**Serving Sizes**	**Examples and Notes**	**Significance of Each Food Group to the DASH Eating Plan**
Nuts, seeds, and legumes	1/3 cup or 1½ oz nuts 2 Tbsp peanut butter 2 Tbsp or ½ oz seeds ½ cup cooked legumes (dried beans, peas)	Almonds, filberts, mixed nuts, peanuts, walnuts, sunflower seeds, peanut butter, kidney beans, lentils, split peas	Rich sources of energy, magnesium, protein, and fiber
Fats and oils [d]	1 tsp soft margarine 1 tsp vegetable oil 1 Tbsp mayonnaise 2 Tbsp salad dressing	Soft margarine, vegetable oil (canola, corn, olive, safflower), low-fat mayonnaise, light salad dressing	The DASH study had 27% of calories as fat, including fat in or added to foods
Sweets and added sugars	1 Tbsp sugar 1 Tbsp jelly or jam ½ cup sorbet, gelatin dessert 1 cup lemonade	Fruit-flavored gelatin, fruit punch, hard candy, jelly, maple syrup, sorbet and ices, sugar	Sweets should be low in fat

[a] Whole grains are recommended for most grain servings as a good source of fiber and nutrients.

[b] Serving sizes vary between ½ cup and 1¼ cups, depending on cereal type. Check the product's Nutrition Facts label.

[c] For lactose intolerance, try either lactase enzyme pills with dairy products or lactose-free or lactose-reduced milk.

[d] Fat content changes the serving amount for fats and oils. For example, 1 Tbsp regular salad dressing = one serving; 1 Tbsp low-fat dressing = one-half serving; 1 Tbsp fat-free dressing = zero servings.

http://www.nhlbi.nih.gov/health/health-topics/topics/dash/followdash

CONCLUSION

From this overview, it is apparent how useful the DGs and DASH Diet can be for a variety of fitness and athletic clients. In addition to the credibility of being developed by Health and Human Services and being clinically proven, there is still room for some knowledgeable fine-tuning to best meet a client's individual requirements.

It is interesting to note the multiple benefits of the DASH Diet include help with losing weight, improving health, lowering blood pressure, and lowering the bad LDL cholesterol. The unit addressing sports nutrition approaches will elaborate on adjusting the DASH Diet and Dietary Guidelines for athletic performance.

Keywords

- Eating pattern
- Food pattern modeling
- USDA Food Patterns
- Whole fruits

PART THREE
Fine Tuning Your Performance

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Topics Covered In This Unit

UNIT 17

SPORTS NUTRITION APPROACH CONCEPTS AND EXAMPLES

Unit Outline

I. **Introduction**

II. **Sports nutrition legal aspects**

III. **Intent of examples and guidelines**

IV. **Sports nutrition is a skill**

V. **What about the many, many different diet approaches**

VI. **Limitations of research studies**

VII. **Sports nutrition plan approaches**
   - a. Dietary Guidelines (2015–2020) and the Dynamic Nutrition Approach
   - b. Daily training session versus athletic event nutrition
   - c. ISSA's 1-2-3 eating rule of thumb

VIII. **The dynamic nutrition approach, a bio-energetic model to performance nutrition**
   - a. How does exercise affect muscle fiber development and composition?
   - b. Sports nutrition supplements are part of the dynamic nutrition approach
   - c. Nutrition conditioning of athletes
   - d. Rationale behind the different athlete-type sports nutrition plan examples
   - e. Dynamic Nutrition athlete-type eating plan examples
   - f. Percentages versus amounts per pound/kilogram of body weight
   - g. Macronutrients – some summary points
   - h. Water/hydration
   - i. Electrolytes
   - j. Carbohydrates
     - i. PDP: pre-during-post exercise, training, workouts, events, and competitions.
     - ii. Pre-event meal/sports nutritionals
     - iii. Carbohydrate intake during long duration events and training sessions
     - iv. Post-event or post-exercise meal
   - k. Protein
     - i. What about protein intake during training sessions or athletic events?
   - l. Fats
   - m. Meal timing and training timing
     - i. "Clock approach" meal scheduling examples
   - n. Sports nutrition fine-tuning is ongoing

IX. **Food lists**

X. **Conclusion**

Learning Objectives

After completing this unit, you will be able to:

- Define and describe key terms related to sports nutrition approaches and concepts;
- Understand the Dynamic Nutrition Approach; and
- Discuss the Athlete-Type nutrition examples.

Introduction

The Dynamic Nutrition Approach is a scientifically founded nutrition model, which addresses the many aspects of nutrition, and provides a logical approach to follow based on exercise physiology, anatomy, and biochemistry of athletes. As you have read about in previous units, as with any scientific model, there is always room for growth related to any new discoveries and modification based on an individual athlete's specific needs. This is a vital consideration: any examples, guidelines, models, or other approaches in this course or other publications need fine-tuning to meet the specific needs of an athlete. What the Dynamic Nutrition Approach can offer is a framework to build a personalized sports nutrition plan from, with an awareness of the previously stated limitations and of the need for personalization and under a physician's and/or other health professionals' supervision.

For example, consider two athletes from different sports, an American football lineman weighing 300 pounds and a marathon runner weighing 150 pounds. The Dynamic Nutrition Approach provides sports nutrition examples for both types of athletes who have differences in nutritional requirements. This approach is dynamic in several ways that are reviewed in this unit, to provide a starting point example to build from and to personalize calories, macronutrients, micronutrients, and ergogenic bioactive substances. Note that the Dynamic Nutrition Approach is meant for healthy athletic adults and is not intended to treat any disorder or replace the advice of an athlete's physician, nutritionist, or another health practitioner.

Furthermore, the foods and number of meals in the examples are not intended to be followed exactly but do provide a potential starting point to build a personalized nutrition program from. Instead of five meals/snacks (eating occasions) used in the examples, some athletes may determine that spreading out their daily food intake requires six meals/snacks (eating occasions) per day. In addition, each athlete will have different food preferences that need to be considered. Remember that a major reason the many prescribed diets in books fail is that after a few weeks of people trying to follow them, they may give up simply because they do not like the foods in these plans, and they do not have the expert understanding or supervision to make food substitutions. Moreover, it is important to note that the percentages of macronutrients in plan examples can be fine-tuned based on an individual's exact requirements determined by qualified expert examination. Similar to creating an effective personalized training program, the crucial word is "dynamic." Any information in this unit or other units is not intended for any adults with diseases or women who are pregnant or lactating or for people with other health conditions that require extra and/or special medical attention.

Sports Nutrition Legal Aspects

When you deal with others' health, a variety of legal issues exist that most fitness trainers and other health professionals are aware of. ISSA-certified fitness trainers are educated about many of these issues and procedures to address them, including liability insurance, client forms and disclosures, doctor approvals, team approvals, and limiting personal training activities within the applicable legal boundaries that may apply for health professionals. Similar and additional legal issues related to sports nutrition can range from local, state, and federal health professional requirements to sports organization rules to lawsuit case law-based concerns for example. Although there may be a general position that developing and prescribing a sports nutrition program or providing input on an existing nutrition program of an adult client in good health, without diseases, may be permitted by non-licensed health professionals, this is something that should be verified in your location/venue.

Check with your liability insurance company about these issues and practice limitations and how to best effectively communicate concerns to your adult clients that protect your mutual interests from an insurance coverage standpoint, in addition to the other parties who may be involved. Suggestions or recommendations about sports nutrition products can be of legal concern, too. Consultation with the athlete's team compliance officer and team-published rules regarding sports nutrition guidelines and prohibitions should be gathered and reviewed to be knowledgeable about an athlete client's team and other legal requirements.

It is typical for athletic/fitness centers and athletic teams to have doctors and other licensed health professionals involved with the athlete training program development and activities. Working under the supervision of the team and/or clients doctor is important because doctors are the best equipped to identify via testing and, from their training, any health concerns that might arise—including but not limited to nutritional imbalances or deficiencies that could occur during intensive athletic training or stem from a person's special needs. However, realistically, no guarantee of 100 percent safety and efficacy can be made for sports example nutrition approaches and products. There may be known and unknown health hazards related to food allergies, food intolerances, food sensitivities, microbial contamination, and chemical contamination, for example, that typically need to be considered. In addition, the demands of an adult athlete's training program and daily schedule can impose time constraints for achieving adequate nutrition intake—potential mission impossible conditions that hinder achieving an optimum sports nutrition program. Training schedule modifications can be worth investigating, as athletes typically have training programs that are unbalanced and/or excessive. "Optimum" training and nutrition programs for athletic performance are the goal, not excessive or extreme programs that can be counterproductive and even unhealthy, for example, too much resistance training or too much caffeine.

Effective communications with clients entails that the clients realize that a sports nutrition program takes time to develop at that, at times, some trial and error can be expected. Foods, including sports nutrition product suitability and usage, should be determined by the clients, their doctors, and with consultation with their team and sports organizations to determine these products are legal, safe, and effective. A starting point can be to first evaluate an athlete's training and nutrition program, to determine whether there are any obvious areas of concern with the nutrition basics, such as following a healthy diet, adequate caloric intake, carbohydrates, protein, essential fatty acids, water (hydration), vitamins and minerals; and the use of safe, effective, permitted, and otherwise legal sports nutrition products. As the legal and medically supervised sports nutrition program continues to develop, it is a good idea for you to reconfirm legal, regulatory compliance, team rules, and scientific aspects each season. Additionally, it is crucial to clearly communicate to athlete clients about the need to maintain an "(illegal) drug-free" sports training and nutrition program. "Illegal drugs" may include illegal recreational drugs and legal drugs banned by sports organizations.

Intent of Examples and Guidelines

As noted throughout this course, and by independent experts and organizations such as the International Olympic Committee in its Nutrition in Sport Publication (2000), it is difficult and challenging to make specific recommendations that will meet the needs of all individuals in all situations. Therefore, the suggested approach is to formulate general guidelines about sports nutrition, with the understanding that these guidelines need to be adapted to best suit an individual athlete, under qualified health professional supervision. Thus, to summarize, the intent of examples, guidelines, and information from research studies; Health Canada's ingredient monographs; and other independent sources is solely academic and not meant to be used exactly for any individual person. Clinical practice approaches by qualified health professionals can be required to determine the exact sports nutrition needs of an individual, and monitor their health and athletic performance, adjusting individualized sports nutrition programs as need, on a case-by-case basis.

Sports Nutrition Is a Skill

What the thousands of scientific studies conducted over the past decades have shown is that when a person engages in athletic training and competition, the demands of physical activity will create above average nutrition requirements. Then, over the months and years and as the body develops, there are expected to be additional changes, requiring evaluation and updating of the nutrition requirements. Athletic conditioning therefore influences what food and supplements will work best for a specific athletic training program. For example, a marathon runner needs to eat different amounts of protein, carbohydrates, and fat than a power-lifter does. However, all athletes need to follow the rules of healthy eating and modify their dietary intakes so they can achieve maximum performance. It will take an ongoing effort to establish, fine-tune, maintain, and evolve an athlete's sports nutrition program.

It will also take time for fitness trainers and other health professionals to develop sports nutrition skills. It can take years of expert supervised training to become an expert in sports nutrition. If you are new to sports nutrition, working with established experts is a good start. If you are already a sports nutrition expert, building and reconfirming your skills with courses like this and other continuing education efforts will help fine-tune these skills, as will your own research review education efforts.

Forming a local sports nutrition expert group/club can provide additional benefits for your sports nutrition skill development, and it can be fun to share knowledge with colleagues. It is sometimes useful to conduct a retrospective analysis of your approaches, along with being progressive. For example, look at what you were doing previously with your athlete clients and/or personal sports nutrition programs. Then run an analysis to confirm the time-tested sports nutrition practices and products that continue to work best. Doing so will also verify which practices or products did not produce measurable benefits and help you determine what can be applied for future sports nutrition program optimization.

Demystifying Nutrition

By this point in your learning efforts, you have discovered the many facets of nutrition and special considerations related to sports nutrition. You know about the macronutrients, micronutrients, and ergogenic nutrients. You know that a person's individual metabolism and activity levels determine his or her total caloric needs along with the amount of protein, carbohydrates, and fat to be consumed. As you read this unit, you will learn how to synthesize and use your new nutrition knowledge by using the Dynamic Nutrition Approach examples as a starting point to be personalized. Included is a general review of existing nutrition plans you have been introduced to. Look at why they may or may not be valid and answer the question:

Why So Many Diets?

This is the number one question that arises from students and clients related to sports nutrition and weight-loss diets. The answer is a simple one as it relates to weight-loss diets and to what most weight-loss diets share in common.

- First, the many weight-loss diets that currently exist prescribe a daily caloric intake, which is less than the total daily calories used. Following a calorie-restricted (deficient) diet will obviously result in some type of weight loss.
- Second, these fad weight-loss diets provide you with a structured plan to follow. When you have a problem with food control and overeating, structure is your best friend. Therefore, following a structured eating plan, which is low in calories, will result in weight loss.

With thousands of foods to choose from, you can easily see how many diets can exist using various food combinations and dieting angles. However, upon close examination, you'll see that many of these trendy diets may be deficient in important macronutrients and micronutrients. Most of these diets do not provide adequate nutrition and are not meant for individuals in a fitness or athletic training program because of this lack. Theses fad weight-loss diets can be too low in protein or carbohydrates, and some of them are too high in fat. They can also leave the dieter in a poor state of health, with a damaged metabolism from the lack of one or more essential nutrients. For example, fad diets low in protein can cause an unhealthy loss of lean body mass.

Typically, the weight lost from following a low-calorie fad diet consists of water weight, fat, and muscle mass. This is where the problem lies. Loss of muscle mass reduces the body's ability to burn calories. Therefore, when the fad dieter has lost weight, his or her body has a lower capacity to burn calories. As most dieters soon return to their old eating habits, they tend to gain more weight as body fat and can end up having a higher percentage body fat, even if they do not return to their previous weight. When you see what happens to a dieter who takes his or her body through a few cycles of fad diets, you can see why many adults have difficulty losing weight the third, fourth, and fifth times. Unit 18 presents a scientifically based and clinically verified approach to losing fat, one that also preserves and builds up the body's precious lean body mass. The unit also presents some of the nutritional diet aids that scientific studies have discovered can assist in the weight-loss process.

When you apply your new nutritional knowledge to understanding the nutrition plans that exist, you will be able to see what their good and bad points are. Remember, as humans, we can survive on different kinds of diets. But as stated in Unit 1, this course is not about tolerating mere survival diets; it is about applying scientific nutritional knowledge and following a quantitative nutrition plan best suited for healthy athletic performance needs.

What about The Many, Many Different Diet Approaches?

Each time this course was updated, questions arose from students about the various diet approaches published in books and offered as programs. One general answer to these is to apply your nutrition knowledge to determine what these diets supply in terms of total daily calories, amounts of macronutrients and the other essential nutrients, and other beneficial nutrition substances that may promote health and perhaps athletic performance benefits, too. When you break down and analyze the fad diets, you will find that the answers you seek will reveal themselves. When you strip the labels/titles and focus on understanding the nutrients the diets provide, you will see that some elements of these diets may even apply to a sports nutrition program, such as focusing on eating healthy whole foods. However, it's clear from analyzing the many diets over the decades that most are too low in calories; are low in certain essential nutrients required in higher amounts by athletes, usually do not include the ergogenic ingredients, and can be insufficient and/or unbalanced in the required macronutrient profiles and amounts athletes need.

Note that some of these diets may be classified as elimination diets, for example the ones that eliminate a type or types of foods or food substances. There may be many reasons for following these; some are trendy, or some may have a valid medical purpose, like with food allergies or intolerances. These types of issues are ideally addressed by a person's doctor, nutritionist, and other related health professional to accurately determine whether elimination of certain foods is warranted for medical reasons.

Limitations of Research Studies

In terms of the growing body of sports nutrition research and related research studies, some is useful and some not. In many instances, research studies that use human subjects, animals, or test tubes are not necessarily designed or intended to be directly applied to the general population. Carefully read the actual research studies that attract your interest and the ones you are considering for application in a sports nutrition program. This means tracking down a copy of the study mentioned in articles or of an abstract found in a database like PubMed. You can even contact the researchers directly via their e-mail contact to request reprints of the study you are interested in and for follow-up questions. Sometimes they will respond, sometimes not. If not, studies are usually available for purchase online by the journals or from the service that offers a wide array of journal articles.

Another consideration is related to the type of subjects used in the research, for example, type of sport, and what level ability, such as recreational, college, professional, or Olympic. In addition, consider that there are specific types of sports and athletes for certain types of products, such as endurance energy drinks. Although there are certain similarities among athletes of different sports, it is not expected that a 150-pound long-distance athlete will have the same energy requirements or digestion and utilization ability compared with that of a 300-pound football player. Thus, when applying research results among the different athletes, think about how these common sports nutrition areas apply to the specific types of athletes, athlete types, and generally. In other words, not all research and research results are intended to be used and may not apply to everybody.

In addition, be research study-minded when working with clients. After reading several research studies and becoming familiar with the formats and methods, you can take this approach with your clients. For example, when trying a nutritional intervention, like extra carbs or an ergogenic supplement like creatine, create a record-keeping approach to track improvements in athletic performance, exercise performance, or body composition changes to confirm the intervention is working. Before you know it, you may have enough data to publish in an article with ISSA or even to submit to a scientific journal. Teaming up with your colleagues can speed up the process and provide even more evidence via more subjects.

Sports Nutrition Plan Approach Examples

When this course was introduced in the 1990s, the situation regarding viable, scientifically based sports nutrition approaches was bleak, hit-or-miss, and evolving. Sure, there were some books along with massive amounts of misinformation or misapplication in the magazine articles. For example, while not technically an athletic performance sport, bodybuilding training and the associated nutrition and supplement approaches tend to dominate magazines, the Internet, and books. Although people active in the sport of bodybuilding are among the most dedicated types of athletes, building supersized muscles and achieving very low body fat levels are not primary goals in most other

athletic performance sports. However, when non-bodybuilding athletes are on their own, they often use these popularized bodybuilding nutrition and training approaches, which are not the most effective for them to achieve their athletic performance goals. Muscle size and low body fat levels are typically a side effect of a performance athlete's training, not the goal. The functioning and condition of the muscles to achieve the required athletic performance is a crucial goal while simultaneously optimizing muscle size and body fat levels.

Similar to other ISSA pioneering sports and fitness courses, thousands of health professionals throughout the world were influenced by this course and other education efforts by the authors. You will frequently find when reading articles and books that some of these expert authors and researchers have taken this course and are ISSA certified. A consideration when reviewing and evaluating sports nutrition and other nutrition approaches is to apply the scientific principles learned in this and other courses, scientific studies, experience of colleagues, and your direct experience. It is impossible to create a general sports nutrition plan in writing that will be best suited for everybody. Examples in this course, other courses, and elsewhere are typically intended to be starting points that need to be personalized under doctor supervision and with direction of other applicable health and wellness professionals, which fitness trainers are part of, focused on determining an athlete's individual specific needs and personalized nutrition program, and for adequate medical monitoring of health and athletic performance.

Dietary Guidelines (2015–2020) and the Dynamic Nutrition Approach

As presented in Unit 16, healthy nutrition should form the basis of a sports nutrition program. When selecting foods to include in a sports nutrition program to provide the required carbohydrates, protein, fats, fiber, other essential nutrients, and other health-promoting substances, refer to the Dietary Guidelines to refine your selections. Moreover, consider new research findings along with findings implemented in other countries about the health-promoting foods and food substances, including dietary supplements. Research studies examining nutrition status of competitive adult athletes consistently report inadequacy of some essential nutrients and total daily calories. A continual effort must be made by the athlete and health professional team to achieve sports nutrition success. The following box provides a summary of the Key Recommendations of the Dietary Guidelines to consider.

Key Recommendations

Consume a healthy eating pattern that accounts for all foods and beverages within an appropriate calorie level.

A healthy eating pattern includes:

- A variety of vegetables from all of the subgroups—dark green, red and orange, legumes (beans and peas), starchy, and other
- Fruits, especially whole fruits
- Grains, at least half of which are whole grains
- Fat-free or low-fat dairy, including milk, yogurt, cheese, and/or fortified soy beverages
- A variety of protein foods, including seafood, lean meats and poultry, eggs, legumes (beans and peas), and nuts, seeds, and soy products
- Oils

A healthy eating pattern limits:

- Saturated fats
- trans fats
- added sugars
- and sodium

Key recommendations that are quantitative are provided for several components of the diet that should be limited. These components are of particular public health concern in the United States, and the specified limits can help individuals achieve healthy eating patterns within calorie limits:

- Consume less than 10 percent of calories per day from added sugars
- Consume less than 10 percent of calories per day from saturated fats
- Consume less than 2,300 milligrams (mg) per day of sodium

Based on the general Key Recommendations, some healthy sports nutrition dilemmas may arise related to added sugars and salt intake. For example, endurance and other athletes training many hours per day and/or who have long duration events in which they expend high levels of glycogen-depleting energy demands and lose potentially detrimental amounts of electrolytes via large amounts of sweating can require and benefit from simple carbohydrate and electrolyte beverages that result in higher added sugar and higher sodium daily intakes, especially during the athletic preseason and season. In general, most athletes will need higher sodium intakes of more than 2,300 mg per day, as previously reviewed in Unit 8. These issues are something

to consider, especially with athletes who may have family history or personal issues with health concerns related to added sugars and salt (sodium) dietary intake.

In addition, note that some sports nutrition products, like the nutrient powders and bars, may contain “added sugars.” This is something to look for when trying to maintain the balance of healthiest levels of adequate intake. The Dietary Guidelines notes the following regarding added sugars, “Healthy intake: Added sugars include syrups and other caloric sweeteners. When sugars are added to foods and beverages to sweeten them, they add calories without contributing essential nutrients. Consumption of added sugars can make it difficult for individuals to meet their nutrient needs while staying within calorie limits. Naturally occurring sugars, such as those in fruit or milk, are not added sugars. Specific examples of added sugars that can be listed as an ingredient include brown sugar, corn sweetener, corn syrup, dextrose, fructose, glucose, high-fructose corn syrup, honey, invert sugar, lactose, malt syrup, maltose, molasses, raw sugar, sucrose, trehalose, and turbinado sugar.” With a little work, combining whole foods sources, like fruits and no-added-sugar fruit juices, may serve to provide healthier simple carbohydrate sources, as might using the prepared sports nutrition products.

Daily Training Session versus Athletic Event Nutrition

For most sports, daily training dominates in terms of hours of physical activity versus during athletic event/competition days. The basic plan examples are intended as base diet starting point examples for day-to-day training, but can also be suited for competition preparation. In general, for the day of athletic competitions or events, and perhaps the previous day(s) too, higher carbohydrate can benefit most athletes of all types. For some of the model examples, this could mean increasing the daily carbohydrate content by 5 to 10 percent. Aside from helping to keep the body’s glycogen levels saturated and high-energy glucose available to meet the athlete’s energy demands, the higher carbohydrate diet is typically easier to digest and facilitates stomach emptying, which is an important factor for athletic performance. However, note that for some weight-class sports, coaches and athletes sometimes break the rules of sports nutrition by using potentially hazardous methods of dehydration and glycogen depletion to keep body weight lower than normal. These means should be avoided.

Speaking of glycogen, remember that even for sports that are shorter in duration, having the body’s glycogen supplies loaded up has certain metabolic advantages, versus having the body’s glycogen supplies low or depleted. When glycogen supplies are too low and run out during training or athletic competition, the body’s mental and physical performance is impaired, and athletic performance can be compromised/reduced. Immunity can be adversely affected, too. But when glycogen stores are simply low, a metabolic distraction or conflict can be caused in which the glycogen-building biosynthesis pathways are highly active. During physical activity, energy production for peak athletic performance may be impaired. Low body glycogen stores may even have adverse effects, disrupting cognitive function and mood. It is certainly one of the many nutritional balancing acts that needs to be considered for a sports nutrition program.

ISSA's 1-2-3 Eating Rule of Thumb

If you are an ISSA-certified fitness trainer, then you are probably wondering how the 1-2-3 rule fits into this Dynamic Nutrition Approach. This general nutritional intake guideline, of approximately 1 part fats, 2 parts protein, and 3 parts carbohydrates, is valid for most people who are weight training and exercising to lose excess body fat, build muscle, and maintain health. This approach is indeed revolutionary and evolutionary in many ways. (ISSA-certified fitness trainers learn about this in the CFT certification course.) If you follow this simple rule, you and your clients will maintain a diet that is low fat, moderate in protein, and high in carbohydrates, or another way to consider this would be: optimum fat, optimum protein, and optimum carbohydrates for an exercising individual. The lesson of the 1-2-3 rule is to have an easy way to put a priority on your nutritional thinking when purchasing foods, preparing meals, and eating out. This ratio can be modified depending on an individual's sports performance or fitness goals. The 1-2-3 approach is part of the Dynamic Nutrition Approach's foundation.

The Dynamic Nutrition Approach: A Bio-Energetic Model to Performance Nutrition

When athletes train for a sport, they are conditioning muscles to produce strength and contractions that generate motion specific to the physical demands of the sport. For example, a marathon runner needs to display a lower intensity muscular output that can be sustained for long periods. Compare this to the explosive strength needed for a hundred-meter sprinter to run a short distance as fast as humanly possible. In the sprinter, muscles are much larger compared with those of other runners, and there is a high-intensity muscle output over a very short time. This explosive strength generates tremendous power. Therefore, the type of physical conditioning results in promoting athletic performance abilities and shapes the size and bio-energetic conditioning of muscles. Other tissues and systems of the body also respond and develop in a sport-specific way. This affects what type of muscle fibers athletes develop and their metabolic functioning, in other words, anatomy and exercise/sport physiology. These are crucial concepts to consider and will help you in sports nutrition and athletic training and fitness development endeavors.

How does exercise affect muscle fiber development and composition?

Skeletal muscles are composed of two main types of muscle fibers, which are classified as slow-twitch and fast-twitch by exercise physiologists. Slow-twitch muscle fibers are the ones preferentially developed when you undertake long-distance training. This includes walking, running, cycling, or swimming long distances, usually distances that take several or more minutes or longer to accomplish. However, running a mile in under four minutes has highly developed oxidative muscle fiber capacity too. This type of physical conditioning results in shaping muscles that are small and have a great many mitochondria packed into each slow-twitch muscle fiber. The muscle tissues consist of a high proportion of cardiovascular components needed to supply oxygen for aerobic metabolism and quickly clear away metabolic wastes. A well-conditioned oxidative athlete burns a great deal of energy-rich fatty acids for energy and can maintain muscle output for a long period. Glucose is also an important energy source for oxidative athletes, as are amino acids, such as the BCAAs.

Strength athletes require conditioning that will preferentially develop fast-twitch muscle fibers. Fast-twitch muscle fibers are capable of a large output of strength over a short period. However, metabolic waste products build up and cause muscle fatigue to quickly set in and impair strength performance. Fast-twitch muscle fibers have some oxidative capacity, the extent of which depends on training methods. The large muscles of power athletes are conditioned to utilize anaerobic energy pathways, such as the immediate energy systems, which use readily available adenosine triphosphate (ATP) and creatine phosphate (CP). Additionally, energy is derived from glycolysis, which makes energy from muscle glycogen (glucose) to make ATP molecules. Remember, too, that all athletes continually use fatty acids for energy. However, power athletes tend to be more conditioned to use muscle glycogen during exercise. This in one reason strength athletes need to make sure that they are following a lower fat diet compared with the diet of oxidative athletes. In fact, this frustrates many people who are well-conditioned strength-training athletes, who struggle to keep off excess body fat due to their strength athlete anatomy and physiology.

Sports Nutrition Supplements Are Part of the Dynamic Nutrition Approach.

Scientific studies show that in addition to well-known benefits of maintaining proper health, athletes can also enhance physical and mental performance with sports nutrition supplements. Protein supplements offer a convenient and economical way to get daily high-quality protein intake. For strength athletes, several supplements can help achieve optimum muscle growth and repair muscle. For maximum aerobic energy, which is of interest to long-distance athletes, there are special energy drinks that can be used, in addition to special metabolites. Some research even supports the use of supplement nutrition therapy to help reduce pain and inflammation, and to help heal some injuries. Some doctors include nutrition/supplements as part of their treatment programs.

The safety of supplements will always depend on an athlete's specific state of health, tolerance, proper use, and level of physical activity. It is also contingent on the fact that a person is using a "legal" sports nutrition product correctly and following the product's directions, not overdosing, and confirming proper use with a physician and other appropriate health professional. Keep in mind that research studies on supplements may be only performed over short periods—a few weeks or a few—months, with small number of subjects, dozens not thousands, and some research over years using thousands of subjects. This means that the long-term effects of using some supplements may not

Examples of Some Sports Nutrition Specialty Foods and Supplements for Potential Occasional Use Reviewed in Previous Units.	
Typically, one or more of these are used at a time, depending on the type of athletic performance and health goals.	
Carbohydrate/Electrolyte Sports Drinks & Gels	Beetroot Juice/Nitrate
Protein Supplements	Pycnogenol
Meal Replacements	Ginsengs
Nutrition Bars	Caffeine
Multivitamins/minerals	Essential Fatty acids
Probiotics	EPA & DHA
Add Your Additional Items:	

have been determined yet. Note that reference to the Canadian-approved ingredients and monographs has been made in previous units, which brings an additional level of credibility and independent expert review regarding safety and effectiveness and duration of use along with other concerns when applicable.

When taking supplements and some of the other sports nutrition products sold as foods, as a general rule, it is always important to follow the proper usage directions provided on the packaging/labeling, under doctor supervision, and to contact the company directly for additional use information when required. For many of the essential vitamins and minerals, you will find recommended daily values (DV) on the labels. In some instances, certain vitamins and minerals will need to be taken in at least 100 percent of the daily values and sometimes in higher amounts. When it comes to the newer or novel metabolite supplements found on the market such as creatine, although these nutrients are found naturally in the diet and are made and used in the body, more caution is needed for their safe use. It is a wise practice to be under the supervision of a physician, team physician, or other health professional to ensure a safe and effective sports nutrition and supplement program that will work for athletes, not against them.

Caffeine is an example of an ergogenic substance with a long history of use and backed by many clinical studies supporting several potential beneficial effects, which are reviewed in Unit 9. Some general points to reiterate here include the legal and healthy use of caffeine. The legal use relates to being legal under the conditions of the sports organizations and legal products. Healthy use relates to using caffeine on an as-needed basis, under doctor supervision, in appropriate dosage forms and amounts. Because caffeine affects the nervous system and energy use, it is important to make sure athletes are first following optimal nutrition and training programs that result in maximum athletic performance to then rate the extra performance benefits of caffeine and the other ergogenic substances. Otherwise, caffeine use may mask nutrition or training program inadequacies, which could ironically lead to jeopardizing athletic performance and health when the body eventually crashes and needs time to recuperate from inappropriate caffeine use.

Nutrition Conditioning of Athletes

Similar to how the body makes changes in response to physical training and acclimates to environmental conditions, the body can take time to make anatomical, biochemical, and physiological adjustments to nutritional changes that are part of a sports nutrition program. Thus, as total daily caloric intake is increased, it will take time for the body to become efficient at processing the extra nutrients, including higher water intake. This includes eating occasions and any special sports nutrition practices before, during, and after training and events. For example, if a sport event is strenuous and long in duration and is expected to require intake of water and carbohydrate/electrolyte beverages during the event, this should be practiced during training to fine-tune the nutrition intake, and condition the body to process the nutrient intake. Testing different foods or nutrients or supplements may be required depending on how the athlete responds to higher consumption of the foods he or she typically eats and new types foods/supplements being tried.

Gastrointestinal upset, including gas and diarrhea, is an example of one of the common sports nutrition program or product symptoms reported occurring in some people. When gastrointestinal update occurs and is reported by athlete clients, they need to work urgently with the health professional team to resolve the annoying condition, as health and athletic performance can be adversely affected—even with minor gastrointestinal upset conditions. Resolving such types of gastrointestinal upset may include adjusting a sports nutrition program to allow the athlete's gastrointestinal system to acclimate or even avoiding certain foods or products.

Rationale behind the Different Athlete-Type Sports Nutrition Plan Examples

The steps and following table summarize the main types of bio-energetic needs and macronutrient profiles to meet energy, growth, recovery, and performance demands. Keep in mind that these are categories to serve as a starting point and that each athlete can have different needs. However, by using this Athlete-Type bio-energetic sports nutrition model, you may achieve goals more quickly versus undertaking years of unscientific trial and error. This summary also follows the Dynamic Nutrition's Hierarchical approach. In other words, when you are designing a sports nutrition plan, the following approach will make the work

easy for you. Refer to the corresponding units for details about determining some of the items, such as body composition.

Step 1: Determine body composition.

Step 2: Determine daily caloric expenditure range for training and non-training days and for competition days.

Step 3: Define the bio-energetics the sport primarily demands for peak athletic performance, Athlete-Type, Anaerobic – Immediate Energy System, Anaerobic Glycolytic; Anaerobic Glycolytic – Oxidative Glycolytic, and Oxidative. Some examples of sports will follow.

Step 4: Determine daily protein intake estimate and the foods and supplements to achieve it. Remember from your lessons that protein requirements can differ between different athlete-types and among individual athletes.

Step 5: Determine daily carbohydrate estimate and the foods and supplements to achieve it. Remember to plan for carbohydrate beverage intake before, during, and after practice and for sport events as appropriate. Modulate carbohydrate type and amount with meals and snacks to attain specific nutrition goals.

Step 6: Determine fat (essential fatty acids) intake estimate and plan and select foods and cooking methods to achieve it. Keeping fat intake under 30 percent of total daily calories will be an ongoing skill to master. For certain sports, maintaining low fat intake during the season of about 15-20 percent of total daily calories can be challenging and requires extra effort to make sure athletes ingest adequate amounts of the essential fatty acids and linoleic and alpha-linolenic acids. Add healthy sources of essential fatty acids, along with EPA and DHA as required for health.

Step 7: Maintain proper fluid intake estimate to meet daily requirements, as determined by amount of physical activity, environmental factors, and specific athletic training, performance, and health needs.

Step 8: Determine the needs for using special sports nutrition and dietary supplement products.

Step 9: Be consistent. Consistency is the key to a successful sports nutrition program.

Step 10: Make Champions. Being a champion is more than just winning. It is about living a certain lifestyle that leads to winning. This lifestyle includes a constant effort to improve all the factors (planning, physical, mental, athletic training, nutritional, spiritual, medical, social, etc.) that result in being the best an athlete can be. Planning is a major part of success in sports and life. Implementing a plan is one thing; the other is regularly measuring the outcome and identifying both strengths and areas of improvement.

Step 11: Repeat steps 1 to 10 periodically. As an athlete's body develops from training and from year to year aging, his or her body and nutrition requirements can change, even in a short period, so repeating steps 1 to 10 periodically is a good practice. Weekly can be an appropriate starting point, and then adjust appropriately after a collection of data is established for an athlete. Fine-tune the intervals.

Athlete-Type Sports Nutrition Plan Examples	
During Season	**Scientific Rationale of the Athlete-Type Sports Nutrition Plan Examples**
15% Fat 30% Protein 55% Carbohydrates	Anaerobic – Immediate Energy Sports. For individuals in sports in which explosive strength and power is required, immediately available ATP and CP anaerobic energy is used. High protein is required to maintain positive nitrogen balance and repair fragile fast-twitch muscle fibers. Low fat, high carbohydrate intake is suggested because these athletes use mostly muscle glycogen to replenish ATP and CP stores.
20% Fat 25% Protein 55% Carbohydrates	Anaerobic Glycolytic Sports. For individuals in sports in which explosive strength and power is required on a sustained or highly repetitive basis. Muscle glycogen is a primary source of energy for these athletes. High protein is required to maintain positive nitrogen balance and repair fast-twitch muscle fibers.
20% Fat 20% Protein 60% Carbohydrates	Anaerobic Glycolytic – Oxidative Glycolytic Sports. For individuals in sports in which the aerobic pathway is the predominant energy source, but glycolysis is also relied on. Fatty acids and muscle glycogen thus become important energy sources. Moderate protein intake is required to maintain positive nitrogen balance and repair muscle fibers. This is a good daily nutrient intake for cross-training sports or multi-energetic sports and for general health and fitness.
25% Fat 15% Protein 60% Carbohydrates	Oxidative Sports. For individuals in sports in which oxidative endurance is required for long-distance events. Slow twitch muscle fibers predominate. High carbohydrate is required to maintain glycogen stores. As endurance athletes utilize a high amount of fatty acids for energy, moderate dietary fat intake is warranted. Protein intake is lowest for this group of athletes, but is about twice as high as nonathletes.
Comments: Short-term use during athletic season, for healthy adults. Starting point to modify based on individual athlete needs, under qualified health practitioner supervision and approval, such as a doctor. Does not apply to special need sports, such as ultra-endurance and high-altitude sports and sporting events. Actual percent fat, protein, and carbohydrates can vary based on the individual.	

Dynamic Nutrition Athlete-Type Eating Plan Examples

Prescribed diets that are found in books, which include recipes and special foods over several weeks, are difficult to follow. Let's face it: most people try them for a few days, find following them frustrating, and shortly return to their old ways of eating. It seems that unless you are confined to an institution where someone else prepares all your meals every day, it's hard to follow most prescribed diets. Additionally, many of the prescribed diets include foods you do not want to eat, which is another factor for the high failure rate. Finally, when confronted with real-life situations, (eating out, eating at friends' houses, or traveling) it's close too impossible to follow a month-long eating plan that someone else created without knowing a person's individual preferences.

With these issues in mind, look at the following examples. They use daily diet examples and food category lists to assist in selecting foods to meet sport-specific daily fat, protein, and carbohydrate intake goals. The daily diet examples illustrate how to spread out caloric intake on training days and demonstrate example foods to meet sport-specific daily nutrient intake.

There are two caloric examples for each of the four different diet types: 2,500 Calories per day and 3,500 Calories per day. The daily diet examples are dynamic, so you can easily add or subtract foods from these example diets to match your individual daily caloric intake. Individuals with enormous daily caloric requirements, like 5,000 Calories per day, or 7,000 Calories per day, can simply double the amounts of portions in the example 2,500 Calorie and 3,500-Calorie example diets, respectively. You can even modify the number of eating occasions to best suit individual needs, 5 to 6 times per day for example. Here is an example for which tracking body weight and body composition at regular intervals becomes important to determine whether the total daily caloric intake is too much, causing unwanted weight gain, or too little, causing unwanted weight loss—in addition to the other measures of athletic performance and health that are being tracked.

When following a doctor-approved nutrition program, it's expected to deviate somewhat from time to time. Athletes should be taught to start back on the right track at the next meal when this occurs. But to be successful, some planning is required, making sure that the refrigerator and pantry are well stocked with the required foods and supplements. Meeting daily nutrition goals may also mean packing a brown bag meal to take for snacks and meals while out of the house.

The examples are summarized in a convenient format, which can be used when shopping and when eating out. Additionally, the food category lists include common foods to get started. To make the plans work the best, you need to add favorite foods to the list based on a person's food preferences and determine how much of these to eat to meet daily caloric and macronutrient goals. Many grocery foods have the nutrition information you need on their labels in the Nutrition Facts box found on most food products or on the Supplement Facts box found on dietary supplement products.

Another thing to remember when constructing nutrition plans is not to become overly concerned if you find that you cannot exactly get the foods to meet target caloric and macronutrient goals. You should realize that it's OK to be a little flexible. When scientists calculate the energy and macronutrient content of foods, many assumptions are made, and an acceptable range of error is to be expected. This means that when you deal with foods, the nutrition content information is not exact. However, when you deal with dietary supplements, the information is usually more accurate. But remember that a margin of error of plus or minus 10 percent is typical, and even up to a 20 percent margin of error has been known to occur. With some whole foods, even a higher margin of error can occur with caloric and nutrient content.

The example diets demonstrate how to spread out the calories throughout training days. Note that following a 15-30-55 diet does not mean

that each meal consists of 15% fat, 30% protein, and 55% carbohydrates. This is the total daily intake goal. The way the diets are structured focus on eating more carbohydrates around training time of day.

With the practice of ingesting a carbohydrate beverage (or similar sports nutritionals) before, during, and after training sessions and athletic events, an evaluation period may be needed to determine how an athlete's digestive system will respond. Note that it may take a few to several weeks to adjust to doing this. If athletes cannot "stomach" drinking a carbohydrate beverage before and during training or during events, then make sure they take in extra carbohydrates during the pre-training meal, during and directly after training, and for the subsequent meals/snacks to ensure adequate glycogen replenishment. Keep well hydrated during practice sessions by drinking water along with a carbohydrate drink when warranted when sweating is excessive leading to weight loss during the workout.

Here's another point on beverage intake before, during, and after sporting events. For short-term, explosive sports like sprinting, wrestling, high jump, and martial arts, athletes may not need to drink carbohydrate beverages right before or during events, unless a benefit has been determined. Short-term sporting events/competitions usually are not reported to benefit from the glycogen-sparing effects of carbohydrate beverage ingestion. Note however that a psychological benefit may occur from consuming carbohydrate beverages for such athletic events, which generally are not at risk for glycogen depletion, and may benefit an athlete in other ways not directly related to muscle energetics. But for longer duration sports, generally more than an hour long, or during day-long tournaments, most types of athletes can benefit from carbohydrate ingestion

before and during the events. However, for all athletes, during daily practice and training, it is important to maintain carbohydrate beverage intake to maintain glycogen stores, as most training sessions last more than two hours in duration, in addition to taking in water and electrolytes. Finally, if a person finds it hard to stomach ingestion of a certain type of carbohydrate beverage, before and during training or a sporting event, experiment with different brands of drinks and different caloric amounts to evaluate a compatible source of activity-related intake.

When working from the following plan examples, remember that they are for illustration purposes only, and you will need to modify them to meet the exact nutrition and supplement needs of each adult athlete. There is no way to guess total daily and workout or event caloric expenditure in a book without working directly with an athlete. In addition, note that these plans are meant to be used by healthy adults, for only a few months at a time, during the competitive seasons, and could also be suited for other athletic training phases, such as preseason. Most athletes can follow a 20% fat, 20 % protein, and 60% carbohydrate diet on the off-season. But because long-distance athletes tend to train all year, they can stick to their 25% fat, 15% protein, and 60% carbohydrate diet all year, except as otherwise directed by their health practitioners. Moreover, remember that the best macronutrient to eat three hours, plus or minus, before practice and competitions is low fat, moderate protein, and high in carbohydrates; low fiber; easy to digest but with some low to moderate glycemic index behavior for sustained blood glucose levels. Don't wait until right before a competition to determine what pregame meal works best; athletes must work on perfecting their sports nutrition program every day, like they do with their sports training. Each person has a different rate of digestion and assimilation, so individual meal timing and nutrient composition needs to be determined and prove effective well in advance of competitions. Comprehensive record keeping and analysis are required to determine the relationship between peak athletic performance and the sports nutrition program.

This table provides a summary of examples of how the different diets may best meet sport specific nutrition requirements for a year-round training program. The rationale for changing diets during the year in some sports is determined by the intensity of physical activity during the off-season, preseason, and competition season. For example, power athletes not intensively training may not require the same level of protein intake they do when intensively training.

Sport	Off-Season %Fat - %Protein - %Carb	Preseason %Fat - %Protein - %Carb	In-Season %Fat - %Protein - %Carb
Baseball	20-20-60	20-25-55	15-30-55
Basketball	20-20-60	20-20-60	20-25-55
Bodybuilding	20-25-55	15-30-55	10-15/30 to 40/50-55
Bowling	20-20-60	20-25-55	20-25-55
Boxing	20-20-60	15-30-55	15-30-55
Cycling-Sprint/Mid-Dist	20-20-60	20-25-55	20-25-55
Cycl-Long Dist	20-20-60	20-20-60	20-20-60
Dancing, Power	20-20-60	20-20-60	20-25-55
Dancing, Stamina	20-20-60	20-20-60	20-20-60
Equestrian, Power	20-20-60	20-25-55	20-25-55
Equestrian, Mid-Distance	20-20-60	20-20-60	20-20-60
Field Hockey, Power Players	20-20-60	20-25-55	20-25-55
Field Hockey, Mid-Dist. Players	20-20-60	20-20-60	20-20-60
Fitness, Power Exercisers	20-20-60	20-20-60	20-25-55
Fitness, Mid-distance Exercisers	20-20-60	20-20-60	20-20-60
Fitness, Endurance Exercisers	25-15-60	25-15-60	25-15-60
Football	20-20-60	15-30-55	15-30-55
Golf	20-20-60	20-20-60	20-25-55
Gymnastics	20-20-60	20-25-55	15-30-55
Hockey, Ice	20-20-60	20-20-60	20-25-55
Martial Arts	20-20-60	20-25-55	15-30-55
Motor Sports	20-20-60	20-20-60	20-25-55
Powerlifting	20-25-55	15-30-55	10-15/30 to 40/50-55
Racket Sports	20-20-60	20-25-55	20-25-55
Rock Climbing	20-20-60	20-25-55	20-25-55
Skiing, All Downhill Events	20-20-60	20-25-55	15-30-55
Skiing, Mid-Distance	20-20-60	20-25-55	20-25-55
Skiing, Endurance, Long Distance	25-15-60	25-15-60	25-15-60
Soccer, Power Positions	20-20-60	20-25-55	20-25-55
Soccer, Mid-Distance Positions	20-20-60	20-20-60	20-20-60
Swimming, Power/Sprint Events	20-20-60	20-25-55	15-30-55
Swimming, Mid-Distance Events	20-20-60	20-25-55	20-25-55
Swimming, Long-Distance Events	20-20-60	20-20-60	20-20-60
Tennis	20-20-60	20-25-55	20-25-55
Track & Field, Power/Sprint Events	20-20-60	20-25-55	15-30-55
Track & Field, Mid-Distance Events	20-20-60	20-25-55	20-25-55
Track & Field, Long-Distance Events	25-15-60	25-15-60	25-15-60
Triathlon	25-15-60	25-15-60	25-15-60
Volleyball	20-20-60	20-25-55	20-25-55
Weightlifting	20-25-55	15-30-55	10-15/30 to 40/50-55
Wrestling	20-20-60	20-25-55	15-30-55
Athlete 1			
Athlete 2			

15% Fat, 30% Protein, 55% Carbohydrate Athlete-Type Sports Nutrition Plan Examples

The 15% fat, 30% protein, 55% carbohydrate daily nutrition plan can be suitable for massive power athletes, driven by the extremely short-term immediate energy system. Athletes such as football players, powerlifters, sprinters, and bodybuilders will do best following this nutrition plan during the season. When training or competing, these athletes rely primarily on the immediate, and to a lesser extent, the glycolytic energy systems. They have massive muscles, with highly developed fast-twitch muscle fibers. Because of this, these athletes require a high amount of protein to maintain positive nitrogen balance and to repair their fragile fast-twitch muscle fibers. Because muscle glycogen is the primary energy source used for replenishing the ATP and CP stores, a diet that is low in fat and rich in carbohydrates is indicated. It should be low in fat because not much fat is used up during training and competition and rich in carbohydrates because the muscles' supply of glycogen needs to be restored every day, or performance and recovery will be impaired.

Note: Although many athletes are reported to be at risk or deficient in either total daily calories and/or one or more of the essential nutrients, low carbohydrate intake is a top concern. Therefore, as a reminder, the following has been added to each eating occasion in the examples: (Extra carbohydrates as required.) Extra carbohydrates may be required at one or more of the eating occasions depending on whether the total daily intake requirements have been met or whether extra carbs are needed to prepare for long training sessions or events to reduce glycogen use, or post training session or events to replenish glycogen levels.

15% Fat, 30% Protein, 55% Carbohydrate Training Days Examples (for illustration only)	
2,500 Calories Per Day Eating Plan Example 15% Fat, 375 Calories, 42 grams 30% Protein, 750 Cal, 188 grams 55% Carbohydrates, 1,375 Cal, 344 grams	**3,500 Calories Per Day Eating Plan Example** 15% Fat, 525 Calories, 58 grams 30% Protein, 1,050 Cal, 263 grams 55% Carbohydrates, 1,925 Cal, 481 grams
Trainig Days	
Breakfast–Meal Goal: 500 cal, 40g P, 62.5g C, 10g F • Take dietary supplements as required • 2 c. Egg alternative, Fleishmann's Egg Beaters Vegetable Omelet, 200 cal, 28g P 20g C, 0g F • 1 slice Canadian Bacon, 86 cal, 11.3g P, 0.6g C, 3.9g F • 4 oz Boiled potato, no skin, 99 cal, 2.1g P, 22.8g C, 0.1g F • 1/2 T. Butter, 50 cal, 0.1g P, 0g C, 5.7g F • 6 oz Grapefruit juice, 60 cal, 1g P, 15g C, 0g F.	**Breakfast**–Meal Goal: 573 Cal, 51g P, 64g C, 13g F • Take dietary supplements as required • 2 1/2 c. Egg alternative, Fleishmann's Egg Beaters Vegetable Omelet, 250 cal, 35 g P, 25g C, 0gF • 1 slice Canadian Bacon, 86 cal, 12g P, 0g C, 3.9g F • 4 oz Boiled potato no skin, 99 cal, 2.1g P, 22.8 g C, 0.1g F • 2/3 T. Butter, 67 cal, 0.1g P, 0g C, 7.6g F • 12 oz Grapefruit Juice, 120 cal, 2g P, 30g C, 0g F.
Morning Snack–Meal Goal: 225 cal, 30g P,15g C, 5g F • Take dietary supplements as required. • Protein Nutrition Bar, Low Calorie, 225 cal, 30g P, 15g C, 5g F.	**Morning Snack**–Meal Goal: 470, 40g P, 64g C, 6g F • Take dietary supplements as required • Protein Nutrition Bar, Medium Calorie, 470 calories, 40g P, 64g C, 6g F.
Lunch–Meal Goal: 500 cal, 40 g P, 62.5 g C, 10g F • Take dietary supplements as required. • 1 orange, medium, 62 cal, 1.2g P, 15.4g C, 0.2g F • 2 slices, bread, whole grain, 170 cal, 7.8g P, 34.8g C, 3.2g F • 4 oz chicken breast, no skin, 124 cal, 26g P, 0g C, 1.6g F • 1 T. Salad Dressing, oil & vinegar, 45 cal, 0g P, 1g C, 4g F • 2 oz, Lettuce, iceberg, trimmed, 8 cal, 0.6g P, 1.2g C, 0.2g F • 4 oz, broccoli spears (Birds Eye), 30 cal, 4g P, 6g C, 0g F • 2 oz carrot, raw, 24 cal, 0.6g P, 5.8g C, 0.2g F.	**Lunch**–Meal Goal: 573 Cal, 51g P, 64g C, 13g F • Take dietary supplements. • 1 orange, medium, 62 cal, 1.2g P, 15.4g C, 0.2g F • 2 slices, bread, whole grain, 170 cal, 7.8g P, 34.8g C, 3.2g F • 6 oz chicken breast, no skin, 186 cal, 39g P, 0g C, 2.4g F • 1 1/2 T., Salad Dressing, (Seven Seas), oil & vinegar, 68 cal, 0g P, 1.5g C, 6g F • 2 oz, Lettuce, iceberg, trimmed, 8 cal, 0.6g P, 1.2g C, 0.2g F • 4 oz, broccoli spears (Birds Eye), 30 cal, 4g P, 6g C, 0g F • 2 oz carrot, raw, 24 cal, 0.6g P, 5.8g C, 0.2g F.
Pre-Training Snack– 2 1/2 hours before training. • Protein Drink, Low Calorie, 225 cal, 30 g P, 15 g C, 5 g F • THEN BCAAs supplement 30 minutes before workout with water. • Workout carbohydrate sports drink, high calorie, 16 oz during workout, 400 cal, 0g P, 100g C, 0g F.	**Pre-Training Snack**– 2 1/2 hours before training. • Protein Drink, Medium Calorie, 470 cal, 40g P, 64g C, 6g F • THEN BCAAs supplement 30 minutes before workout with water. • Workout carbohydrate sports drink, high calorie, 20 oz during workout, 500 cal, 0g P, 125g C, 0g F.
Dinner–Meal Goal: 650 cal, 48g P, 87.5g C, 12g F • Take dietary supplements. • 1 lean pork chop, (Master Choice), 120 cal, 22g P, 0g C, 4g F • 8 oz, Baked Beans, Barbecue (B&M), 260 cal, 15g P, 48g C, 6g F • 6 oz Spinach, 36 cal, 4.8g P, 6g C, 0.6g F • 1 Tomato, 26 cal, 1g P, 5.7g C, 0.4g F • 8 oz Skim Milk, 86 cal, 8.4g P, 11.9g C, 0.4g F • 4 oz, fruit cocktail, canned, in light syrup, Cal 65, 0.5g P, 16.9g C, 0.1g F.	**Dinner**–Meal Goal: 914 cal, 81g P, 100g C, 20g F • Take dietary supplements. • 2 1/2 lean pork chops, (Master Choice), 300 cal, 55g P, 0g C, 10g F • 8 oz, Baked Beans, Barbecue (B&M), 260 cal, 15g P, 48g C, 6g F • 6 oz Spinach, 36 cal, 4.8g P, 6g C, 0.6g F • 1 Tomato, 26 cal, 1g P, 5.7g C, 0.4g F • 8 oz Skim Milk, 86 cal, 8.4g P, 11.9g C, 0.4g F • 4 oz, fruit cocktail, canned, in light syrup, Cal 65, 0.5g P, 16.9g C, 0.1g F.
Additional meal/snack/sports nutritionals, supplements. (Extra carbohydrates as required).	Additional meal/snack/sports nutritionals, supplements. (Extra carbohydrates as required).
Note that pre-workout and post-workout caloric beverages will add to the total daily caloric intake, as will extra caloric drinks during the workout. Changes are required for each athlete.	

20% Fat, 25% Protein, 55% Carbohydrate Athlete-Type Sports Nutrition Plan Examples

The 20% fat, 25% protein, 55% carbohydrate daily nutrition plan can be suitable for individuals who participate in sports and fitness activities that require explosive strength and power on a sustained or highly repetitive basis. When training for or during competition, these individuals rely primarily on the glycolytic energy systems. Muscle glycogen is their primary source of energy. These individuals need to consume large amounts of protein to maintain a positive nitrogen balance and to repair their fragile fast-twitch muscle fibers.

Note: Although many athletes are reported to be at risk or deficient in either total daily calories and/or one or more of the essential nutrients, low carbohydrate intake is a top concern. Therefore, as a reminder, the following has been added to each eating occasion in the examples (Extra carbohydrates as required): Extra carbohydrates may be required at one or more of the eating occasions depending on whether the total daily intake requirements have been met or whether extra carbs are needed to prepare for long training sessions or events to reduce glycogen use, or post training session or events to replenish glycogen levels.

15% Fat, 25% Protein, 55% Carbohydrate: Examples (for illustration only)	
2,500 Calories Per Day Eating Plan Example 20% Fat, 500 Calories, 56 grams 25% Protein, 625 Calories, 156 grams 55% Carbohydrates, 1375 Calories, 344 grams	**3,500 Calories Per Day Eating Plan Example** 20% Fat, 700 Calories, 78 grams 25% Protein, 875 Cal, 219 grams 55% Carbohydrates, 1925 Cal, 481 grams
Trainig Days	
Breakfast–Meal Goal: 465 Calories, 27g P, 60g C, 13g F • Take dietary supplements as required. • 1 cup Egg alternative, Fleishmann's Egg Beaters Vegetable Omelet, 100 cals, 14g P 10g C, 0g F • 1 slice Canadian Bacon, 86 cals, 12g P, 0g C, 4g F • 4 oz Boiled potato, pulp, 117 cals, 2g P, 28g C, 0g F • 2/3 tbsp Butter, 81 cals, 0g P, 0g C, 9g F • 9 oz Grapefruit juice, 90 cals, 0g P, 22.5g C, 0g F.	**Breakfast**–Meal Goal: 579 cal, 38.5g P, 61g C, 18.5g F • Take dietary supplements as required. • 1 1/2cups Egg alternative, Fleishmann's Egg Beaters Vegeta-ble Omelet, 150 cal, 21 g P, 15g C, 0g F • 1 slice Canadian Bacon, 86 cal, 12g P, 0g C, 4g F • 4 oz Boiled potato pulp, 117 cal, 2g P, 28 g C, 0g F • 1 tbsp Butter, 100 cal, 0g P, 0g C, 11.4g F • 6 oz Grapefruit Juice, 60 cal, 0g P, 15g C, 0g F • 4 oz Milk, 2%, 60 cal, 4g P, 5.5g C, 2g F.
Morning Snack–Meal Goal: 225 cal, 30g P,15g C, 5g F • Take dietary supplements as required. • Protein Nutrition Bar, Medium Calorie, 470 calories, 40g P, 64g C, 6g F.	**Morning Snack**–Meal Goal: 470, 40g P, 64g C, 6g F • Take dietary supplements as required • Protein Nutrition Bar, Low Calorie, 225 cal, 30g P, 15g C, 5g F.
Lunch–Meal Goal: 465 cal, 27g P, 60g C, 13g F • Take dietary supplements as required. • 1 orange, medium, 62 cal, 1g P, 13g C, 0g F • 2 slices, bread, whole grain, 170 cal, 8g P, 34g C, 3g F • 2 oz chicken breast, no skin, 62 cal, 13g P, 0g C, 1g F • 2 tbsps, Salad Dressing, (Seven Seas), oil & vinegar, 90 cal, 0g P, 2g C, 8g F • 2 oz, Lettuce, iceberg, trimmed, 8 cal, 0.5g P, 1.5g C, 0g F • 4 oz, broccoli spears (Birds Eye), 30 cal, 4g P, 6g C, 0g F • 2 oz carrot, raw, 24 cal, 1g P, 6g C, 0g F.	**Lunch**–Meal Goal: 579 cal, 38.5g P, 61g C, 18.5g F • Take dietary supplements as required. • 1 orange, medium, 62 cal, 1g P, 13g C, 0g F • 1 roll, Hoagie, 210 cal, 8g P, 34g C, 5g F • 4 oz chicken breast, no skin, 124 cal, 26g P, 0g C, 2g F • 3 tbsps, Salad Dressing, (Seven Seas), oil & vinegar, 135 cal, 0g P, 3g C, 12g F • 2 oz, Lettuce, iceberg, trimmed, 8 cal, 0.5g P, 1.5g C, 0g F • 4 oz, broccoli spears (Birds Eye), 30 cal, 4g P, 6g C, 0g F • 2 oz carrot, raw, 24 cal, 1g P, 6g C, 0g F.
Pre-Training Snack– 2 1/2 hours before training. • Protein Drink, Low Calorie, 225 cal, 30 g P, 15 g C, 5 g F • THEN BCAAs supplement 30 minutes before workout, with water. • Workout carbohydrate sports drink, high calorie, 16 oz during workout, 400 cal, 0g P, 100g C, 0g F.	**Pre-Training Snack**– 2 1/2 hours before training. • Protein Drink, Medium Calorie, 470 cal, 40g P, 55g C, 10g F • THEN BCAAs supplement 30 minutes before workout with water. • Workout carbohydrate sports drink, high calorie, 20 oz during workout, 500 cal, 0g P, 125g C, 0g F.
Additional meal/snack/sports nutritionals, supplements. (Extra carbohydrates as required).	Additional meal/snack/sports nutritionals, supplements. (Extra carbohydrates as required).
Note that pre-workout and post-workout caloric beverages will add to the total daily caloric intake, as will extra caloric drinks during the workout. Changes are required for each athlete.	
Dinner–Meal Goal: 724 cal, 42g P, 94g C, 20g F • Take dietary supplements as required. • 3 oz Beef, Bottom Round, prime, untrimmed, 192 cal, 17.1g P, 0g C, 13.2g F • 2 oz pasta, 210 cal, 9g P, 41g C, 1g F • 4 oz pasta sauce, (Ragu), Mushroom Thick and Hearty, 100 cal, 2g P, 15g C, 3g F • 12 oz Spinach, 72 cal, 9.6g P, 12g C, 1.2g F • 8 oz Skim Milk, 86 cal, 8.4g P, 11.9g C, 0.4g F • 4 oz, fruit cocktail, canned, in light syrup, Cal 65, 0.5g P, 16.9g C, 0.1g F.	**Dinner**–Meal Goal: 901 cal, 62g P, 98g C, 29g F • Take dietary supplements as required. • 5 oz Beef, Bottom Round, prime, trimmed, 225 cal, 31g P, 0g C, 10.5g F • 2 oz pasta, 210 cal, 9g P, 41g C, 1g F • 1/2 tbsp olive oil, cal 60, 0g P, 0g C, 7g F • 4 oz pasta sauce, (Ragu), Mushroom Thick and Hearty, 100 cal, 2g P, 15g C, 3g F • 12 oz Spinach, 72 cal, 9.6g P, 12g C, 1.2g F • 8 oz Milk, whole, 150 cal, 8g P, 11g C, 8g F • 4 oz, fruit cocktail, canned, in light syrup, Cal 65, 0.5g P, 16.9g C, 0.1g F.

20% Fat, 20% Protein, 60% Carbohydrate Athlete-Type Sports Nutrition Plan Examples

The 20% fat, 20% protein, 60% carbohydrate daily nutrition plan can be suitable for individuals who participate in sports or fitness activities that require explosive strength and power on a sustained or highly repetitive basis. However, although these individuals rely to some extent on the glycolytic energy systems, they also depend primarily on the oxidative energy systems. Fatty acids and muscle glycogen are these individuals' primary fuel sources during activity. Therefore, these athletes need to consume just moderate amounts of protein to maintain positive nitrogen balance and to repair their fragile fast-twitch muscle fibers.

Note: Although many athletes are reported to be at risk or deficient in either total daily calories and/or one or more of the essential nutrients, low carbohydrate intake is a top concern. Therefore, as a reminder, the following has been added to each eating occasion in the examples: (Extra carbohydrates as required.) Extra carbohydrates may be required at one or more of the eating occasions. This will depend on whether the total daily intake requirements have been met, whether extra carbs are needed to prepare for long training sessions or events to reduce glycogen use or for post training sessions or events to replenish glycogen levels.

20% Fat, 20% Protein, 60% Carbohydrate: Examples (for illustration only)

2,500 Calories Per Day Eating Plan Example	**3,500 Calories Per Day Eating Plan Example**
20% Fat, 500 Calories, 56 grams 20% Protein, 500 Cal, 125 grams 60% Carbohydrates, 1500 Cal, 375 grams	20% Fat, 700 Calories, 78 grams 20% Protein, 700 Cal, 175 grams 60% Carbohydrates, 2100 Cal, 525 grams
Trainig Days	
Breakfast–Meal Goal: 475 cal, 23.5g P, 67g C, 12.5g F • Take dietary supplements as required. • 3 pancakes, buttermilk, Hungry Jack, prepared, 200 cal, 6g P, 28g C, 7g F • 3 oz ham, fresh, trimmed, 117 cal, 18g P, 0g C, 4.5g F • 8 oz Vegetable juice (V8), 47 cal, 1.3g P, 10.7g C, 0g F • 3 1/2 tbsp Pancake Syrup, (Hungr y Jack), lite, 88 cal, 0g P, 24.5g C, 0g F.	**Breakfast**–Meal Goal: 489 cal, 36g P, 52.5g C, 15g F • Take dietary supplements as required. • 3 pancakes, buttermilk, Hungry Jack, prepared, 200 cal, 6g P, 28g C, 7g F • 4 oz ham, fresh, trimmed, 156 cal, 24g P, 0g C, 6g F • 8 oz skim milk, 86 cal, 8.4g P, 11.9g C, 0.4g F • 2 tbsp Pancake syrup, (Hungry Jack), lite, 50 cal, 0g P, 14g C, 0g F.
Morning Snack–Meal Goals: 270 cal, 12gP, 45gC, 6g F • Take dietary supplements as required • 1 Food Bar, (Earth Grains), Banana apple walnut, 270 cal, 12g P, 45g C, 6g F.	**Morning Snack**–Meal Goals: 440 cal, 16gP, 68gC, 12gF • Take dietary supplements as required. • 1 Food Bar, Pemmician, carob-cocoa, (Bear Valley), 440 cal, 16g P, 68g C, 12g F.
Lunch–Meal Goal: 425 cal, 23.5g P, 67g C, 12.5g F • Take dietary supplements as required. • 1/2 oz American cheese, 55 cal, 3 g P, 0.5 g C, 4.5g F • 1 sandwich roll, 123 cal, 4.5g P, 21.6g C, 3.3 g F • 3 slices, turkey (Tyson), 60 cal, 12g P, 0.9 g C, 1.2g F • 2 oz Iceberg lettuce, trimmed, 8 cal, 0.6g P, 1.2g C, 0.2g F • 3 tablespoon mustard, 30 cal, 3g P, 3g C, 3g F • 2 oz Apricot Dried (Del Monte), 140 cal, 2g P, 35g C, 0g F.	**Lunch**–Meal Goal: 489 cal, 36g P, 52.5g C, 15g F • Take dietary supplements as required. • 1/2 oz American Cheese, 55 cal, 3 g P, 0.5g C, 4.5 g F • 1 sandwich roll, 123 cal, 4.5g P, 21.6 g C, 3.3 g F • 6 slices, turkey (Tyson), 120 cal, 24 g P, 1.8g C, 2.4g F • 2 oz Iceberg lettuce, trimmed, 8 cal, 0.6g P, 1.2g C, 0.2g F • 3 T. mustard, 30 cal, 3g P, 3g C, 3g F • 1 banana, w/o skin, 105 cal, 1.2g P, 26.7g C, 0.6g F.
Pre-Training Snack– 2 1/2 hours before training. • Protein Drink, High Calorie, 548 cal, 30g P, 80g C, 12g F • THEN BCAA's supplement 30 minutes before workout with water. • Workout carbohydrate sports drink, high calorie, 20 oz during workout, 500 cal, 0g P, 125g C, 0g F.	**Pre-Training Snack**– 2 1/2 hours before training. • Protein Drink, Low Calorie, 225 cal, 30g P, 15g C, 5g F • THEN BCAA's supplement 30 minutes before workout with water. • Workout carbohydrate sports drink, high calorie, 16 oz during workout, 400 cal, 0g P, 100g C, 0g F.
Dinner–Meal Goal: 748 cal, 36g P, 106g C, 20g F • Take dietary supplements. as required • 4 oz tuna, bluefin, 164 cal, 26.4 g P, 0g C, 5.6g F • 1 tomato, 4.75 oz, 26 cal, 1g P, 5.7g C, 0.4g F • 8 oz Iceberg lettuce, trimmed, 32 cal, 2.4g P, 4.8g C, 0.8g F • 2 oz onion, trimmed, 22 cal, 0.6g P, 4.8g C, 0.2g F • 3 oz brown rice, 315 cal, 6.9g P, 65.7g C, 2.4g F • 6 oz cauliflower, 42 cal, 23.6g P, 8.4g C, 0.6 g F • 2 T. Salad dressing, (Seven Seas), oil & vinegar, 90 cal, 0g P, 2 g C, 8g F • 3 oz grape juice, 60 cal, 0g P, 15g C, 0g F.	**Dinner**–Meal Goal: 1,034 cal, 57g P, 147g C, 24g F • Take dietary supplements as required. • 6 oz tuna, bluefin, 246 cal, 39.6 g P, 0g C, 8.4g F • 1 tomato, 4.75 oz, 26 cal, 1g P, 5.7g C, 0.4g F • 8 oz Iceberg lettuce, trimmed, 32 cal, 2.4g P, 4.8g C, 0.8g F • 2 oz onion, trimmed, 22 cal, 0.6g P, 4.8g C, 0.2g F • 1 oz garbanzo bean, 103 cal, 5.5g P, 17.2 g C, 1.7g F • 3 oz brown rice, 315 cal, 6.9g P, 65.7g C, 2.4g F • 6 oz cauliflower, 42 cal, 3.6g P, 8.4g C, 0.6 g F • 2 T. Salad dressing, (Seven Seas), oil & vinegar, 90 cal, 0g P, 2 g C, 8g F • 3 oz grape juice, 60 cal, 0g P, 15g C, 0g F.
Additional meal/snack/sports nutritionals, supplements. (Extra carbohydrates as required).	Additional meal/snack/sports nutritionals, supplements. (Extra carbohydrates as required).
Note that pre-workout and post-workout caloric beverages will add to the total daily caloric intake, as will extra caloric drinks during the workout. Changes are required for each athlete.	

25% Fat, 15% Protein, 60% Carbohydrate Athlete-Type Sports Nutrition Plan Examples

The 25% fat, 15% protein, 60% carbohydrate daily nutrition plan can be useful for individuals who participate in aerobic sports or fitness activities. When training or during competition, these individuals rely primarily on oxidative energy systems. Their muscles are composed of highly developed slow-twitch muscle fibers. Because of this, these individuals need to consume large amounts of carbohydrates to maintain their glycogen stores, due to the long duration of training and events. However, fatty acids are their primary source of energy, so they should consume a moderate amount of healthy fats and oils. The amount of protein for this group of individuals is the lowest of the four plans, but is still about two times more than non-athletes require.

Note: Although many athletes are reported to be are risk or deficient in either total daily calories and or one or more of the essential nutrients, low carbohydrate intake is a top concern. Therefore, as a reminder the following has been added to each eating occasion in the examples: (Extra carbohydrates as required.). Extra carbohydrates may be required at one or more of the eating occasions depending if the total daily intake requirements have not been met, or if extra carbs are needed to prepare for long training sessions or events to reduce glycogen use, or post training session or events to replenish glycogen levels.

25% Fat, 15% Protein, 60% Carbohydrate: Examples (for illustration only)	
2,500 Calories Per Day Eating Plan Example 25% Fat, 625 Calories, 69 grams 15% Protein, 375 Cal, 94 grams 60% Carbohydrates, 1500 Cal, 375 grams	**3,500 Calories Per Day Eating Plan Example** 25% Fat, 875 Calories, 97 grams 15% Protein, 525 Cal, 131 grams 60% Carbohydrates, 2100 Cal, 525 grams
Trainig Days	
Breakfast–Meal Goal: 440 cal, 20g P, 50g C, 16.5g F • Take dietary supplements as required. • 3 pancakes, buttermilk, Hungry Jack, prepared, 200 cal, 6g P, 28g C, 7g F • 2 oz ham, fresh, trimmed, 78 cal, 12g P, 0g C, 3g F • 12 oz Vegetable juice (V8), 70 cal, 2g P, 16g C, 0g F • 2 T. Pancake Syrup, (Hungry Jack), lite, 50 cal, 0g P, 14g C, 0g F • 1/2 tablespoon butter, 50 cal, 0.1g P, 0g C, 5.7g F.	**Breakfast**–Meal Goal: 550 cal, 24g P, 70g C, 20.5g F • Take dietary supplements as required. • 3 pancakes, buttermilk, Hungry Jack, prepared, 200 cal, 6g P, 28g C, 7g F • 3 oz ham, fresh, trimmed, 117 cal, 18g P, 0g C, 4.5g F • 12 oz Vegetable juice (V8), 70 cal, 2g P, 16g C, 0g F • 4 T. Pancake Syrup, (Hungry Jack), lite, 100 cal, 0g P, 25g C, 0g F • 2/3 tablespoon butter, 67 cal, 0.1g P, 0g C, 7.6g F.
Morning Snack–Meal goal: 230 cal, 10gP, 45gC, 2.5g F • Take dietary supplements as required. • 1 Power Bar, 230 cal, 10g P, 45g C, 2.5g F.	**Morning Snack**–Meal Goal: 440 cal, 16gP, 68gC, 12g F • Take dietary supplements as required. • 1 Food Bar, Pemmician, carob-cocoa, (Bear Valley), 440 cal, 16g P, 68g C, 12g F.
Lunch–Meal Goal: 440 cal, 20g P, 50g C, 16.5g F • Take dietary supplements as required. • 1 oz American cheese, 110 cal, 6g P, 1g C, 9g F • 1 sandwich roll, 123 cal, 4.5g P, 21.6g C, 3.3 g F • 2 slices, turkey (Tyson), 40 cal, 8g P, 0.6 g C, 0.8g F • 2 oz Iceberg lettuce, trimmed, 8 cal, 0.6g P, 1.2g C, 0.2g F • 2 T. mustard, 20 cal, 2g P, 2g C, 2g F • 2 oz Apricot Dried (Del Monte), 140 cal, 2g P, 35g C, 0g F.	**Lunch**–Meal Goal: 560 cal, 24g P, 70g C, 20.5g F • Take dietary supplements as required. • 1 oz slice American cheese, 110 cal, 6g P, 1g C, 9g F • 1 sandwich roll, 123 cal, 4.5g P, 21.6g C, 3.3 g F • 3 slices, turkey (Tyson), 60 cal, 12g P, 0.9 g C, 1.2g F • 2 oz Iceberg lettuce, trimmed, 8 cal, 0.6g P, 1.2g C, 0.2g F • 2 tbsp mustard, 32 cal, 2g P, 2g C, 2g F • 2 oz Apricot Dried (Del Monte), 140 cal, 2g P, 35g C, 0g F • 1/3 tablespoon safflower oil, 40 cal, 0g P, 0g C, 4.7g F • 6 oz grapefruit juice, 60 cal, 1.0g P, 15g C, 0g F.
Pre-Training Snack– 2 1/2 hours before training. • 1 Food Bar, (Earth Grains), Banana Apple Walnut, 270 cal, 12 g P, 45 g C, 6 g F • THEN BCAA's supplement 30 minutes before workout with water. • Workout carbohydrate sports drink, high calorie, 16 oz during workout, 400 cal, 0g P, 100g C, 0g F.	**Pre-Training Snack**– 2 1/2 hours before training. • Protein Drink, High Calorie, 548 cal, 30g P, 80g C, 12g F • THEN BCAA's supplement 30 minutes before workout with water. • Workout carbohydrate sports drink, high calorie, 20 oz during workout, 500 cal, 0g P, 125g C, 0g F.
Dinner–Meal Goal: 720 cal, 32g P, 85g C, 27.5g F • Take dietary supplements as required. • 3 oz tuna, bluefin, 123 cal, 19.8g P, 0g C, 4.2g F • 1 tomato, 4.75 oz, 26 cal, 1g P, 5.7g C, 0.4g F • 4 oz Iceberg lettuce, trimmed, 16 cal, 1.2g P, 2.4g C, 0.4g F • 2 oz onion, trimmed, 22 cal, 0.6g P, 4.8g C, 0.2g F • 3 oz brown rice, 315 cal, 6.9g P, 65.7g C, 2.4g F • 6 oz cauliflower, 42 cal, 3.6g P, 8.4g C, 0.6 g F • 4 T. Salad dressing, (Seven Seas), oil & vinegar, 180 cal, 0g P, 4 g C, 16g F.	**Dinner**–Meal Goal: 892 cal, 37g P, 112g C, 32g F • Take dietary supplements as required. • 3 oz tuna, bluefin, 123 cal, 19.8g P, 0g C, 4.2g F • 1 tomato, 4.75 oz, 26 cal, 1g P, 5.7g C, 0.4g F • 4 oz Iceberg lettuce, trimmed, 16 cal, 1.2g P, 2.4g C, 0.4g F • 2 oz onion, trimmed, 22 cal, 0.6g P, 4.8g C, 0.2g F • 4 oz brown rice, 420 cal, 9.2g P, 87.6g C, 4g F • 6 oz cauliflower, 42 cal, 3.6g P, 8.4g C, 0.6 g F • 5 T. Salad dressing, (Seven Seas), oil & vinegar, 225 cal, 0g P, 5 g C, 20g F.
Additional meal/snack/sports nutritionals, supplements. (Extra carbohydrates as required).	Additional meal/snack/sports nutritionals, supplements. (Extra carbohydrates as required).
Note that pre-workout and post-workout caloric beverages will add to the total daily caloric intake, as will extra caloric drinks during the workout. Changes are required for each athlete.	

Date:	Type of day: training ❒ or nontraining ❒
Macronutrients ratio to follow: 15:30:55 ❒ 20:25:55 ❒ 20:20:60 ❒ or 25:15:60 ❒	
Daily goals: _________ calories, _________ grams protein, grams carbohydrates, _________ and grams fat	

Breakfast

Meal goals: _________ calories, _________ grams protein, grams carbohydrates, _________ and grams fat

FOOD AND PORTION	CALORIES	PROTEIN (GRAMS)	CARBS (GRAMS)	FAT (GRAMS)
		Meal subtotals		

Supplements taken with or after meal:

Morning Snack

Meal goals: _________ calories, _________ grams protein, grams carbohydrates, _________ and grams fat

FOOD AND PORTION	CALORIES	PROTEIN (GRAMS)	CARBS (GRAMS)	FAT (GRAMS)
		Meal subtotals		

Supplements taken with or after meal:

Lunch

Meal goals: _________ calories, _________ grams protein, grams carbohydrates, _________ and grams fat

FOOD AND PORTION	CALORIES	PROTEIN (GRAMS)	CARBS (GRAMS)	FAT (GRAMS)
		Meal subtotals		

Supplements taken with or after meal:

Afternoon Snack

Meal goals: __________ calories, __________ grams protein, grams carbohydrates, __________ and grams fat

FOOD AND PORTION	CALORIES	PROTEIN (GRAMS)	CARBS (GRAMS)	FAT (GRAMS)
		Meal subtotals		

Supplements taken with or after meal:

Dinner

Meal goals: __________ calories, __________ grams protein, grams carbohydrates, __________ and grams fat

FOOD AND PORTION	CALORIES	PROTEIN (GRAMS)	CARBS (GRAMS)	FAT (GRAMS)
		Meal subtotals		

Supplements taken with or after meal:

GRAND TOTALS	

Notes:

Nutrient/Supplement Intake Worksheet Example			
NUTRIENT / INGREDIENT EXAMPLES	AMOUNTS FROM Supplements/Food		DAILY TOTALS / NOTES
Vitamin A (preformed, such as retinol)			
Beta Carotene			
Vitamin B1 (thiamin)			
Vitamin B2 (riboflavin)			
Vitamin B3 (niacin)			
Vitamin B5 (pantothenic acid)			
Vitamin B6 (pyridoxine)			
Vitamin B12 (cobalamin)			
Biotin			
Folate			
Vitamin C			
Vitamin D			
Vitamin E			
Vitamin K			
Boron			
Calcium			
Chromium			
Copper			
Iodine			
Iron			
Magnesium			
Manganese			
Molybdenum			
Phosphorus			
Potassium			
Selenium			
Sodium			
Zinc			
Protein			

NUTRIENT / INGREDIENT EXAMPLES	AMOUNTS FROM Supplements/Food		DAILY TOTALS / NOTES
Carbohydrates			
Fiber			
Glutamic acid			
Glutamine			
Branched-Chain Amino Acids (BCAAs)			
Fat			
Alpha-linolenic acid			
Docosahexaenoic acid (DHA)			
Eiocosapentaenoic acid (EPA)			
Gamma linolenic acid (GLA)			
Linoleic acid			
Inositol			
Choline			
Pycnogenol ®			
Coenzyme Q10			
L-carnitine			
Beta-Alanine			
Creatine			
Glucosamine			
Chondroitin Sulfate			
BHMB			
Bicarbonate			
Caffeine			
Gamma Oryzanol / Ferulic Acid			
Ginsengs			
Nitrates (e.g., Beet Root)			

Percentages versus Amounts per Pound/Kilogram of Body Weight

A frequent question from students and a topic of debate among experts is about percentages of fats, protein, and carbohydrates versus grams per kilogram of body weight (mass) for determining a sports nutrition diet. The simple answer is that they both have value. In some ways, these two approaches are different sides of the same coin so to speak. Both approaches end up with quantitative amounts. Although both approaches have strong points in support of them and their viability, there is feasibility to use both approaches for double-checking, for analysis, and for calculations.

The percentage approach, based on actual daily calorie expenditure needs, is tied to a metabolic measurement and can make constructing a program an easier task. Percentages based on the actual daily energy expenditure help provide adequate calories and carbohydrates, with protein and fats falling into place. Because the percentage approach has been introduced, it has caught on and can be found being used in various forms by athletic organizations, in scientific research, and in textbooks (McArdle 2007, IOC 2000, Weatherwax-Fall 2006). This includes the trend for sports nutrition programs that are higher carbohydrate, lower fat, and higher protein, relatively speaking. In addition, there are different percentages or percentage ranges for different types of athletes, such as for endurance and strength athletes and multi-energetic sports.

However, the grams per kilogram of body weight or lean body mass is also important, especially for protein as reviewed in Unit 4, which is based on lean body mass. This helps provide a cross-check to the percentage approach. Therefore, using both methods can be useful, especially during the initial stage of determining an athlete's nutrition requirements. One major limitation of the grams per kilogram of body weight approach is variations in the body fat of individuals and having to rely on making estimates of activity and actual caloric expenditure. Furthermore, day-to-day differences in total caloric expenditure based on physical activity / training variations may be challenging to estimate. Some examples of grams per kilogram of body weight will be provided in the following macronutrients section. Grams per kilogram of lean body mass can be considered a preferred approach when body composition data are gathered.

Another issue worth repeating here concerns sports nutrition for day-to-day training/workouts/exercise and for athletic events/competitions. Examples in this unit and others are primarily offered as a guide for day-to-day training sports nutrition. These examples can also serve to build from for pre-competition day and competition day sports nutrition, as noted in the respective units. Interestingly, for some sports, the daily calories can be more for training days than for competitions/events, and for other sports, the daily calories can be more for competitions/events than for training days.

Another point is that as daily caloric intake requirements become very high, further adjustments to the relative intakes of fats, carbohydrates, and protein are required. For example, reducing protein and increasing fats and carbohydrates may be required as high protein intake maxes out. This area of sports nutrition fine-tuning is challenging but worth the effort and can be a major factor for achieving peak athletic performance, in addition to training and other athletic performance factors. Using rates of intake based on body weight or body mass implies that individuals are in good shape, with athletic body fat levels. Some norming of the rates may be needed when dealing with athletes with excess body fat levels, by estimating ideal body weight using normal body fat ranges.

Macronutrients – Some Summary Points

To start, the following reference tables provide a summary of how the different macronutrient percentages result in total daily grams based on various daily caloric intakes. This provides a quick summary that can be used for nutrition planning. Some additional information regarding macronutrients is also included below.

Total Daily Caloric Intake Example Values	**Protein Daily Intake at 15% of Total Daily Calories (Calories and Amount)**	**Protein Daily Intake at 20% of Total Daily Calories (Calories and Amount)**
2,000 Calories	300 Cals, 75 grams	400 Cals, 100 grams
2,500 Calories	375 Cals, 94 grams	500 Cals, 125 grams
3,000 Calories	450 Cals, 113 grams	600 Cals, 150 grams
3,500 Calories	525 Cals, 131 grams	700 Cals, 175 grams
4,000 Calories	600 Cals, 150 grams	800 Cals, 200 grams
Total Daily Caloric Intake Example Values	**Protein Daily Intake at 25% of Total Daily Calories (Calories and Amount)**	**Protein Daily Intake at 30% of Total Daily Calories (Calories and Amount)**
2,000 Calories	500 Cals, 125 grams	600 Cals, 150 grams
2,500 Calories	625 Cals, 156 grams	750 Cals, 188 grams
3,000 Calories	750 Cals, 188 grams	900 Cals, 225 grams
3,500 Calories	875 Cals, 219 grams	1050 Cals, 263 grams
4,000 Calories	1000 Cals, 250 grams	1200 Cals, 300 grams

Protein Daily Intake was calculated as follows, Total Daily Caloric Intake times 0.15, 0.20, 0.25, or 0.30.

Example: 3,000 Calories × 0.20 = 600 Calories.

Protein Daily Intake in grams was calculated as follows, Total Daily Caloric Intake divided by 4 calories per gram. Example: 600 Calories / 4 calories per gram = 150 grams

Total Daily Caloric Intake Example Values	**Carbohydrate Daily Intake at 55% of Total Daily Calories (Calories and Amount)**	**Carbohydrate Daily Intake at 60% of Total Daily Calories (Calories and Amount)**
2,000 Calories	1,100 Cals, 275 grams	1200 Cals, 300 grams
2,500 Calories	1,375 Cals, 374 grams	1,500 Cals, 375 grams
3,000 Calories	1,650 Cals, 413 grams	1,800 Cals, 450 grams
3,500 Calories	1,925 Cals, 481 grams	2,100 Cals, 525 grams
4,000 Calories	2,200 Cals, 550 grams	2,400 Cals, 600 grams
4,500 Calories	2,475 Cals, 619 grams	2,700 Cals, 675 grams

Carbohydrate Daily Intake was calculated as follows, Total Daily Caloric Intake times 0.55 or 0.60.

Example: 3,000 Calories × 0.60 = 1,800 Calories.

Carbohydrate Daily Intake in grams was calculated as follows, Total Daily Caloric Intake divided by 4 calories per gram. Example: 1,800 Calories / 4 calories per gram = 450 grams

Total Daily Caloric Intake Example Values	Fat Daily Intake at 15% of Total Daily Calories (Calories and Amount)	Fat Daily Intake at 20% of Total Daily Calories (Calories and Amount)	Fat Daily Intake at 25% of Total Daily Calories (Calories and Amount)
2,000 Calories	300 Cals, 33 grams	400 Cals, 44 grams	500 Cals, 56 grams
2,500 Calories	375 Cals, 42 grams	500 Cals, 56 grams	625 Cals, 69 grams
3,000 Calories	450 Cals, 50 grams	600 Cals, 67 grams	750 Cals, 83 grams
3,500 Calories	525 Cals, 58 grams	700 Cals, 78 grams	875 Cals, 97 grams
4,000 Calories	600 Cals, 67 grams	800 Cals, 89 grams	1000 Cals, 111 grams
Fat Daily Intake was calculated as follows, Total Daily Caloric Intake times 0.15, 0.20, or 0.25. Example: 3,000 Calories × 0.20 = 600 Calories. Fat Daily Intake in grams was calculated as follows, Total Daily Caloric Intake divided by 9 calories per gram. Example: 600 Calories / 9 calories per gram = 67 grams. Focus on consuming essential fatty acids, EPA, DHA, and other healthy unsaturated fats/oils.			

The following information is intended to provide some summary level information regarding the macronutrients. Refer to the main units for more detailed information. Be mindful that even though a body of scientific research evidence exists for "guidelines" and "examples," each athlete needs his/her sports nutrition program to be customized and refined. Another consideration to keep in mind is that the research evidence may be biased to a certain athlete-type. For example, based on the volume of research, carbohydrate, hydration, and electrolyte intake research during athletic events has historically been conducted on long-distance endurance athletes. Furthermore, the muscle-building and strength-training research using a variety of subjects (untrained, trained, recreational athletes, and elite athletes) with showing increases in strength or muscle mass did not necessarily evaluate for increases in athletic performance outcomes. However, the principles and insights gained from the various research studies may apply to other athletes too, during both athletic events and training sessions.

Another general point concerns pre-, during, and post-training session or athletic event nutrition approaches. No single approach works for everybody the same way, and guideline information is intended to provide concepts and general points of reference that need to be personalized for each athlete and tested to result in optimizing athletic performance. This information should therefore be considered introductory, and these advanced topics can require years of specialized education and experience to master.

Training, which creates the extra nutritional demands of athletes, should be scheduled into two or more shorter sessions per day when possible, versus a very long, exhaustive session that makes it difficult to prevent nutrient depletion. In addition, it is necessary to modulate (alternate) training intensity from day to day (low, medium, and high intensities) to avoid overtraining syndrome and allow for adequate recovery and injury prevention. Of course, event/competition days have established schedules and require the best efforts to provide adequate nutrition intake for peak athletic performance, health, and recovery: this includes athletes bringing along to events an adequate sports nutrition supply. The goals of athletic training are generally for attaining and maintaining the required athletic performance conditioning and skills, plus good health. They are not for dangerously over-working the body or intentionally creating circumstances that prevent or curtail achieving adequate nutrition status that may be counterproductive to an athlete's health and athletic performance.

Water/Hydration

The amount of water a person can ingest at one time and during a certain time frame depends on the size of the stomach, stomach emptying rate, intestinal absorption rate, use in the body, and rate excretion via the kidneys and sweating. Thus, any hydration reference numbers should not be considered suitable for everyone and requires personalization. Water is certainly one of the nutrients for which too much or too little of can have acute (immediate) negative effects on health and athletic performance, and just the right amount is required for optimal hydration resulting in the conditions for optimal athletic performance.

Some practical points to consider once an athlete's daily water intake is established is to have athletes carry water and other suitable beverages with them and consume adequate water throughout the day as required. Trips to the bathroom will also increase and should be planned for. The color of the urine is one indicator of adequate hydration, and appropriate urine color charts can be consulted that may be posted in locker rooms or provided by the team doctor. During rest and low activity, water intake from hour to hour is relatively constant, under similar climate conditions. Water intake increases during physical activity as the rate of sweating and the amount of water lost through the skin increases.

Other noncaloric beverages, such as tea, coffee, or adding lemon juice to water, and caloric/nutrient beverages when appropriate, offer an option to help avoid water consumption fatigue that can occur when just drinking plain water. Drinking multi-nutrient beverages can provide convenience to help with calorie and essential nutrient intake, as athletes can even experience eating fatigue, which leads to caloric and important nutrient deficiencies that lead to symptoms.

Another consideration is during long duration training and events in which hydration plus carbohydrate and electrolytes intake is important. This balancing act can require use of water plus a carbohydrate/electrolytes sports beverage to maintain adequate hydration levels, alternating intake to maximize water intake, carbohydrate intake, and electrolyte intake. This is related to how the stomaching emptying rate is slowed as the concentration of substances in a beverage is increased. More on this in the following section.

But note that realistically during some of the longer athletic events, especially during hotter and more humid climate conditions that increase the rate of sweating, 100 percent of hydration, carbohydrate, and electrolyte replenishment is not always possible. Another dose of reality to be considered is this: should an athlete even be involved in these long duration events that put their health at risk? As a matter of fitness trainer practice, serious thought should be given to determine whether taking on athletes involved in such potentially hazardous sports should be avoided. During the more controlled athletic training sessions, with adequate planning, dehydration and nutrient depletion should be able to be avoided or minimized to avoid unhealthy and athletic performance limiting conditions.

In addition to the various hydration-related information provided in Unit 6, some additional hydration intake guideline examples published in the scientific literature and from team guidelines you may encounter include the following: two to four hours before exercise, 5 to 10 milliliters per kilogram of body weight; rate of water intake in small amounts 150–200 milliliters every 10 to 20 minutes; 15 minutes before exercise, 300 to 800 milliliters when not possible to drink during exercise; during exercise 0.4 to 0.8 liters per hour, or maybe higher; after exercise, at an individual's appropriate rate of fluid intake during a few or more hours to regain water lost that resulted in loss of body weight during exercise, in appropriate divided dosages, which can include hydration from other beverages in addition to water.

As with other sports nutrition consumption issues, take time to determine what is required for each athlete and what rate of intakes best suits each athlete. Seek to perfect the hydration approach during training sessions that will work best during athletic events. Include sodium and other electrolytes as needed, keeping in mind that eating occasions should supply these and other essential nutrients too. However, during training sessions and events that are long in duration and incur a high volume of sweating accompanied by loss of sodium in particular, electrolytes in energy drinks or other appropriate beverages or dosage forms pre-, during, and post-training may be required to prevent electrolyte depletion that is detrimental to heath and or athletic performance. Similar to carbohydrate content in a beverage, electrolyte content can slow down the stomach-emptying rate depending on the total concentration of the beverage, and needs to be factored in.

Electrolytes

Unit 8 presented information about the main electrolytes with daily reference intakes that include sodium, chloride, and potassium. Additionally, other minerals like magnesium and sulfate are sometimes grouped in. Because electrolytes and other essential nutrients are vital for health and performance, the focus on electrolytes for athletes is related to maintaining adequate intake to compensate for increased physical activity and electrolytes that may be excreted in higher amounts via an increased amount of sweating during exercise. Usually meal and supplement intake provides the majority of electrolyte intake. Electrolytes are also a common ingredient in sports drinks used during exercise, which usually contain sodium, chloride and potassium, and carbohydrates. Some sports drinks contain additional minerals, vitamins, amino acids, and other substances, such as caffeine.

Electrolyte depletion can become a concern when inadequate daily intake occurs and possibly during long bouts of exercise or athletic events or any physical activity accompanied by a high rate of sweating and loss of electrolytes via sweat. D. J. Casa and coworkers (2005) noted an example of sodium loss during endurance exercise of about 460 mg/L to 1,840 mg/L during endurance exercise. At this rate of loss, it is possible for an athlete to lose a few to several grams of sodium at high rates of sweating over two or more hours of continuous exercise. As with hydration requirements, estimating electrolyte requirements will involve various measurements and calculations by trained health professionals. This may even include collecting and analyzing the electrolyte content of an athlete's sweat.

Carbohydrates

As carbohydrates, especially glucose, are a primary high-energy substrate for all types of athletes, daily adequate intake is vital for peak athletic performance. For the "anaerobic" and "aerobic" athletes, glucose is the primarily high-energy fuel source. As previously mentioned, during strenuous, short-term strength athletic activities, glucose is a primary fuel for anaerobic energy production. However, glucose is also a primary high-energy fuel for aerobic energy production, too, in addition to the slower metabolized fatty acids and, to a minor extent, amino acids, like the BCAAs. With longer duration aerobic (oxidative) athletic events and training, fatty acids also contribute to energy production; however, glucose helps maintain athletic performance at a higher level. Glucose plus specialized glycose polymers and/or sucrose, and/or some fructose can provide additional energy substrate, especially during the longer duration endurance events, those lasting more than 90 minutes.

Regarding the glycemic index, ingestion of carbohydrate sources and meals in the low to medium GI range will be a good nutrition practice to maintain sustained healthy blood glucose levels. Periodic use of high GI foods and sports nutritionals, like energy drinks, can provide a quicker source of energy when required. But remember that the GI for individual foods can change when added into a mixed food meal with other foods of different GI values. The GI of a mixed meal will generally trend in the direction of reducing GI, especially when lower GI foods are mixed with higher GI foods and when mixed with proteins and fats that slow down the stomach emptying rate.

Regarding some additional carbohydrate intake information, extra carbohydrates for athletes had been acknowledged and practiced for many decades, so an abundance of research and different rates of intakes are published in research and guidelines. For athletes training about two to five hours a day, a range of carbohydrate intake guidelines commonly reported is 6 to 12 grams per kilogram of body weight per day—the lower part of the range for shorter duration training sessions, and smaller athletes, and the upper part of the range for longer duration training, and larger athletes.

PDP: Pre-During-Post Exercise, Training, Workouts, Events, and Competitions

While maintaining consistency from meal to meal (eating occasion to eating occasion) is an essential foundation of a healthy sport nutrition program, pre-, during, and post-exercise nutrition is an area of additional focus. With some exceptions, PDP is similar for most athlete-types for exercise, training, and workouts, but with some differences with athletic events and competitions, for example, long-duration endurance athletic events compared with short-duration strength athlete events.

Yes, for all athletes, an inadequate sports nutrition program from meal to meal and PDP can deplete an athlete's energy supply, electrolytes, protein, and other essential nutrients, leading to reduced physical and mental performance, reduced recovery, and compromised health. Thus, even if meal-to-meal nutrition is "adequate," "inadequate" PDP nutrition can have adverse effects, especially for hydration status, glycogen stores, and electrolytes. Note that when an athletic event or training session is longer in duration and higher in intensity, 100 percent hydration /nutrient depletion prevention is not always possible.

Therefore, the following will serve to summarize some of the major PDP sports nutrition issues. Note that PDP related to exercise, training, and workouts is just as important as PDP that is related to athletic events and competitions is. When athletes neglect training session-related PDP, this may lead to training in a depleted state, resulting in suboptimum athletic performance. PDP related to athletic events and competitions will vary based on the type of sport. Some sports like long endurance events require a comprehensive program of hydration, carbohydrates, and electrolytes, whereas for some sports with athletic events that are short in duration, like a wrestling match or sprinting, going in to the event well-nourished benefits

peak athletic performance and health. However, during a short duration event, sports drinks may not be needed or practical. In addition, some sporting events during which athletes have a fluid swishing around in their stomachs, or even the extra weight, may suffer in terms of athletic performance.

A good starting point for fitness trainers working with athletes is to consult with the PDP that is used by the athlete's team or may be prescribed by other health professionals working with the athlete. In addition to your independent expert review, if the team PDP is adequate, discussing it with your athlete clients and making efforts to encourage them to follow their PDP during training sessions and athletic events are warranted. Additionally, getting feedback from the athletes is vital for determining whether the team-prescribed PDP is resulting in improved training and athletic performance during events, including feedback on any gastrointestinal upset or other issues that need to be resolved for best results. Opportunities for improvement may also be identified for consideration and discussion.

Hypoglycemia: low blood sugar.

It is important to note that athletes may encounter low blood sugar levels at the start of their training or events even when undertaking a reasonable carbohydrate-focused PDP routine. If an athlete encounters diet-induced **hypoglycemia** (or from other reasons), reduced athletic performance can occur when the athletes begin their activities because of the low available energy substrate in the blood and glucose and perhaps due to energy-storing insulin levels competing with energy-liberating glucagon levels. Therefore, how an athlete is expected to respond to a PDP nutrition program needs to be evaluated during training sessions to determine a PDP nutrition program that works best. Note that 100 percent certainty cannot be expected for event days, even when a program has been proven during training sessions. While a few approaches exist that could address energy-draining hypoglycemia, in healthy people, one example would be to, at the start of athletic training or events, have the athlete move around at a warm-up level of activity and to then have him or her start slowly ingesting an appropriate carbohydrate/electrolyte beverage to achieve and maintain a normal blood sugar level. The exercising muscles stimulating glucagon levels along with the exogenous carbohydrate source may overcome the hypoglycemia condition. Changing the timing and composition of the pre-event meal and sports nutritionals may also be warranted if hypoglycemia occurs at the start of training sessions or athletic events. Of course, the team doctor should be consulted to determine the cause and best course of action.

Pre-Event Meal/Sports Nutritionals

Although all athletes should get their pre-event meal composition and timing perfected, this is especially important for athletes undergoing long duration events that may deplete their glycogen supplies during athletic events and training, usually continuous events lasing 90 minutes or more. However, all athletes should strive to time the pre-event meal in a way in which it has cleared their gastrointestinal systems because if food is still being digested, blood and energy will be diverted away from exercising muscles and could also create gastrointestinal upset, resulting in decreased athletic performance.

A major goal of the pre-event meal emphasizes carbohydrates to make sure adequate glycogen stores are present when athletes start their competitions along with blood glucose levels to provide exogenous energy substrate. The pre-event meal therefore should be timed properly so it is completely digested and absorbed in to the body, before the athletic event begins. This may take three hours, plus or minus, assuming the meal is higher in carbohydrates. Ingestion of other sports nutritionals or smaller snacks that are consumed closer to training sessions of events, 60 minutes plus or minus, for example, need to ideally be cleared from the stomach at the start of athletic activity, marked by the warm-up period. Pre-training meals can be similar to pre-event meals in conditioning the digestive system, as can protein and an appropriate healthy fat content, which will not significantly slow down the stomach emptying rate.

Carbohydrate Intake during Long Duration Events and Training Sessions

During events and training sessions, the body uses carbohydrates, fatty acids, and some minor amounts of amino acids for energy. The extent of the proportional energy substrate use will depend on the type of physical activity and duration, with longer duration physical activity increasing the risk of depleting glycogen stores and reducing mental and physical performance. To help to spare the body's internal stores of energy, especially glucose from glycogen, athletes can ingest exogenous energy in the form an energy drink is. Carbohydrate ingestion during events and training sessions usually is accomplished by consuming dilute carbohydrate/electrolyte beverages. Depending on several factors, examples of ranges of carbohydrate beverage intake is about 6 to 12 ounces every 15 to 20 minutes. Carbohydrate beverages need to be diluted; 4 to 8 percent solutions, to empty from the stomach quickly, with the lower percentage drinks usually emptying from the stomach more quickly. This is about what most sports beverages contain, but you can check with the manufacturer to confirm this. Higher percentage solutions may also be suitable depending on the individual's beverage digestion ability during physical activity. Observations suggest that even short duration sport athletes not at risk for glycogen depletion may benefit from sipping small amounts of a carbohydrate energy drink, as doing so may promote neurological benefits. There is even some emerging research using carbohydrate beverage mouth rinsing, which will be interesting to report on in the future as more research develops.

Some additional reference intakes, based on endurance athletes include 30 to 60 grams per hour carbohydrate, for events 1 to 2.5 hours in duration and up to 90 grams per hour carbohydrate for events more than 2.5 hours in duration. These guidelines should be adjusted for each athlete but are starting points found published in the scientific literature. As indicated in the 2017 Trommelen study below, higher rates of exogenous carbohydrate may be possible. (Note that larger team sport and strength athletes may have the potential for higher per hour carbohydrate digestion and utilization rates.)

Regarding the type of carbohydrate, for elite level performance, ones up to a couple to a few hours in duration, glucose-containing beverages will provide the fastest available energy. As studies with endurance athletes have reported exogenous glucose use during events to be about 1 to 1.2 grams per minute, 60 to 72 grams per hour would be a starting point range for just glucose.

Because the intensity of the continuous exercise is low to moderate, and longer in duration, over about two hours, the mixed-carbohydrate source may have an advantage because some recent research indicates that the total amount of ingested carbohydrate per hour that can be used for energy may be at a higher rate of use. This was indicated in test beverages containing high amounts of glucose, sucrose, or fructose (see Trommelen study overview below). Fast digesting glycose polymers are also used in some energy drinks. All athlete needs to evaluate what works best for them individually, especially ultra-endurance athletes who as a group have extremely special event nutrition needs that can only be determined by working directly with a sports nutrition expert.

It is interesting to note that energy requirements during exercise or events are relatively constant, whereas hydration needs can vary depending on rates of sweating, which can vary from day to day. Thus, becoming more sophisticated with fluid, electrolyte, and energy substrate intake during exercise will require making estimates based on climate conditions and expected rates of sweating for each day. This can be challenging for outside sporting events and usually more constant for inside sporting events.

Research efforts are constantly being conducted to fine-tune approaches for maximum use of exogenous energy sources during exercise, such as carbohydrates during events and training sessions. For example, J. Trommelen and coworkers (2017) reported in their research that co-ingestion of glucose plus sucrose and glucose plus fructose resulted in higher oxidation rates compared with ingestion of glucose alone, during 180 minutes of endurance-type cycling exercise using trained male cyclists. The cyclists exercised at a moderate level of intensity. The researchers observed that both the glucose-plus-sucrose and glucose-plus-fructose treatments resulted in higher total oxidation rates, versus just glucose treatments, which reconfirmed previous study results. The increase of oxidation rates was more pronounced during the latter 120 minutes of exercise, which is to be expected. The researchers noted some limitations of this study, such as its not being an exercise performance study, that fructose takes extra energy to be converted into lactate or glucose before being used in exercising muscles, and that a fructose group was not included. An interesting observation was that fatty acid metabolism was highest in the water-only group, and then the next highest was in the glucose-only group, followed by the mixed-carbohydrate groups. Moreover, upper gastric distress scores were highest for glucose only, versus glucose plus sucrose or fructose, and for water only.

Rates of carbohydrate ingestion and oxidation from the study are as follows:

- Rages of ingestion: 1.8 grams per minute glucose; 1.2 grams per minute glucose & 0.6 grams per minute fructose; 0.6 grams per minute glucose & 1.2 grams per minute sucrose. [Total fluid/experimental drinks provided during 180 minutes was about 2.25 liters per subject. Rate of fluid intake was 600 ml during first three minutes of exercise, followed by 150 ml every fifteen minutes.]
- Rates of exogenous carbohydrate oxidation: glucose-only peak oxidation rate was 0.96 grams per minute; glucose & fructose peak-oxidation rate was 1.4 grams per minute; and glucose and sucrose peak-oxidation rate was 1.29 grams per minute. (Note that endogenous carbohydrate oxidation was also estimated and reported in the study.)

An interesting point of these research results is that the exogenous mixed simple carbohydrate intake resulted in higher oxidation rates (energy use) versus those of just glucose. But this highest oxidation rate was less than the 1.8 grams per minute rate of intake.

The researchers review additional measurements and data that can be found by reading the entire study. For example, Figure 2 in their study report provides an illustration of the relative contribution of substrates to total energy expenditure. An interesting trend from the illustration is that when compared with water only, more carbohydrates (endogenous and exogenous) contribute to energy expenditure in all the carbohydrate treatment groups and to less endogenous fat. In addition, the water-only treatment had a higher percentage of endogenous carbohydrate oxidation compared with that of the carbohydrate treatment groups. Thus, ingestion of exogenous carbohydrates helped "spare" or use less endogenous carbohydrate and fat for energy. But remember to keep the added sugars under control by avoiding excessive intake of added sugars.

Post-Event or Post-Exercise Meal

There are some misconceptions about post-exercise eating. One is that there is only a tiny window of opportunity to replenish glycogen; some people are led to think that it is a matter of minutes, but it is longer. It is true that after-exercise glycogen replenishment can be at a higher rate with a post-exercise meal, but the time of this window runs up to a couple of hours, a period in which athletes should be eating as part of their routine. Additionally, glycogen stores can be replenished ongoing from meal to meal when food composition and caloric content is adequate. Therefore, it is beneficial to be able to time post-exercise or post-event meals to be consumed within about one hour after exercise, depending on the workout length and intensity and depending on any post-exercise water and on carbohydrate/protein/electrolyte drinks ingested directly after training/events. This may then require the post-training meal to be in the 30-minute to two-hour range. Some people like to think of post-exercise or post-event supplements and meals as several courses spread out over an hour or more, eating slowly to not overwhelm the stomach. Moreover, consuming a post-workout beverage that contains carbohydrates and protein, first, followed by a complete post-exercise meal will allow for optimal muscle recovery. This will get carbohydrates, protein, and other nutrients into your body fast, in an easy-to-digest hydrated form for rehydration. This is done in addition to ingesting plain water. Some post-training /event carbohydrate and protein supplement intake examples include 15 to 25 grams of high-quality protein and 1 to 1.5 grams per kilogram of bodyweight. This is more important if the post-exercise meal is delayed.

Post-exercise meals or sports nutrition drinks for post-exercise consumption can be high in carbohydrates and moderate in protein, and low in fat, something that will be easily and quickly digested. In addition, high glycemic index carbohydrates will further increase the rate of glycogen replenishment in the post-exercise period. Some athletes may also need to increase their consumption of salty foods to help replace the sodium lost during high sweat-loss exercise or events, along with potassium and other essential vitamins and minerals. This is why the consumption of a complete post-exercise meal with supplements is desirable for optimum nutrient replenishment in general. The GI value of meals following the post-exercise meals are less critical and can range from high to medium to low GI values based on nutritional preference. Generally, for weight loss, or athletes with weight management issues, medium to lower GI meals will promote better appetite control and a higher rate of fat metabolism. Starting by eating carbohydrates first during the meal can favor faster carbohydrate digestion, whereas eating protein first and any mixed macronutrient meal can start to slow down stomach emptying. So even meal to meal, there is potentially a conflict between intake of water and nutrients, based on the rate of stomach emptying and intestinal absorption and assimilation.

Protein

The issue of protein intake can become complicated when including whole proteins and extra amino acid supplementation. In short, the key to maintaining adequate protein intake is to divide the daily high-quality protein intake requirement of an athlete over the several daily eating occasions of meals, snacks and sports nutrition products, which may include consumption of protein drinks and protein bars and high-protein meal replacements. This will provide a steady supply of amino acids to the body's tissues and amino acid pool. Additional specialized supplements previously reviewed include BCAAs, essential amino acid blends, some individual amino acids, and the various protein sports nutrition products with added amino acids and other nutrients and ergogenic substances.

High-quality protein consumption should be emphasized. This can be provided by a combination of conventional healthy protein foods and protein supplements, such as whey, casein, egg, high-quality soy isolates, and various protein combinations. This last item may include fortification with individual amino acids, such as the essential amino acids. The other factor of high-quality proteins is healthy fat content, minimizing protein food sources that are high in saturated fats.

Regarding some additional protein intake information, although it has taken many years for the academic researchers and various sports organizations to break away and recognize that the low RDA protein intake for adults (0.8 grams per kilogram of body weight per day) is not sufficient for athletes, with some still in catch-up mode, the overall trend has been to increase the protein intake guidelines for athletes in the 1.2 to 2 grams per kilogram of body weight per day range, or higher, as a general sports nutrition approach. Note that this course was among the first to establish higher protein intake requirements for athletes, decades ago. In addition, various studies reported a further breakdown based on athlete type, similar to the Dynamic Nutrition Approach. This includes, for example, 1 to 1.6 grams per kilogram of body weight per day for endurance training/exercise; 1.4 to 1.7 grams per kilogram of body weight per day for intermittent stamina type sports; and 1.6 to 2 grams per kilogram of body weight per day for power and strength training/exercise. Regarding even higher protein intake, J. Antonio and coworkers (2015) reported their results of safety and efficacy of a high protein diet of 3.4 grams per kilogram of body weight per day using male and female subjects who were resistance training, during an eight-week treatment period of a high-protein diet and resistance training. J. Antonio and coworkers (2016) also reported on another high protein intake study conducted over a year, in a crossover design. During this study, the high-protein diet was followed for two months, and four months, at a rate of 3.32 grams per kilogram of body weight per day. Among various health parameters tested during the study periods, there were no harmful effects found regarding measures of blood lipids and liver and kidney function. For bodybuilders during contest preparation, E. R. Helms and coworkers (2014) provided evidence-based nutrition recommendations for protein of 2.3 to 3.1 grams per kilograms of lean body weight per day, especially for periods of calorie restriction to help reduce loss of lean body mass.

Remember that short-term use of higher protein diets for athletes is intended to achieve multiple goals in addition to just maintaining positive nitrogen balance. These goals include increasing lean body mass, including muscle mass; preventing loss of lean body mass during high-intensity, long duration training during the preseason and season; lowering body fat; compensating for amino acids that are used for energy; and supporting progressive, compensatory improvements from athletic training. Higher protein diets for healthy athletes should be for short-term use such as a few months to several months and monitored closely by a doctor to determine whether any side effects occur and whether changes to the diet or treatment are needed. Extra water intake can be required with higher dietary protein intake.

What about protein intake during training sessions or athletic events?

As previously reviewed, spacing protein intake over several eating occasions provides a steady supply of amino acids required for growth, maintenance, and other protein/amino acid-related functions. This approach should cover the pre-training and post-training training session/athletic event eating occasions, in addition to eating main meals and/or snacks. This leaves the time at training sessions and during athletic events periods—for these, the sports nutrition focus has usually been on hydration, carbohydrates and electrolytes, and certain ergogenic substances.

There are then two main considerations regarding "protein during," that is, during training sessions and during athletic events. The current consensus published in independent research studies and reviews indicates that protein supplementation during exercise does not appear to promote immediate/acute athletic performance benefits, especially when compared with other nutrients, like carbohydrate, or some of the ergogenic substances previously reviewed (van Loon 2014, Beck 2015, Thomas 2016).

However, in terms of training sessions, there could be potential benefits from some protein intake during exercise with carbohydrates, related to potentially reducing muscle damage, enhancing recovery, and promoting muscle protein synthesis. Potential benefit could be expected for longer duration training sessions that can have greater depletion effects on the amino acid pool, for both endurance and strength sports, assuming this is not at the expense of hydration, electrolyte, and carbohydrate supply. This would need to be determined from working with individual athletes on a cost-benefit evaluation basis, ideally in the off-season or early preseason as to not interfere with athletic performance during the season. Traditionally, it is common among some strength athletes to drink low-concentration protein or protein multi-nutrient- containing beverages during training sessions, especially among athletes with shorter duration training sessions who are not at risk for dehydration or glycogen depletion. Note that while being an advanced specialty topic not covered in this course, it is worth mentioning the potential benefits for ultra-endurance athletes of drinking low-concentration protein or protein nutrient-containing beverages, which along with other nutrients during the long training sessions and athletic events, could help reduce tissue breakdown and promote recovery.

Fats

The term "fat" is frequently used in a way that follows conventional usage, not to mean only saturated fats. An example of conventional usage of the term fats is on food and supplement product labeling, which includes saturated and unsaturated fats. Regarding dietary fats, the focus should be the healthy lipids, including the essential fatty acids, EPA, DHA, and other unsaturated fatty acids.

Controlling total daily fat intake results from emphasizing carbohydrate and protein intake, so fat intake comes in on the low side of the range. Recall that although fats are important, athletes' diets can be too high in fats and inadequate in carbohydrate and protein content. If for individual reasons, fat intake needs to be increased above the basic plan goals, the good news when it comes to fat content is that it is easy to increase it in the diet. Adding healthy oils to foods and in cooking, taking healthy fat supplements, and eating healthy fat food sources like nuts and nut butters, avocados, and oily fish, for example, is fairly straightforward. Just pay attention to how the extra dietary fat affects stomach emptying rate, which may be longer when the fat content of a meal is increased, in addition to other factors.

Meal Timing and Training Timing

Each athlete needs to determine what works best for his or her personal rate of digestion from working with the health professional team. Note that in general, a person's rate of digestion is expected to increase as daily physical activity increases; this is the body's mechanism to make sure the increased nutrition demands can be met. Thus, there can be variation in the amounts consumed per eating occasion and rate of intake from eating occasion to eating occasion. Achieving the optimum intake of total daily calories and required nutrients involves expert evaluation and planning. Sports nutrition coaching is involved, which athletes sometimes refer to as sports nutrition nagging. Even what would seem to be the simplest nutrition factor, adequate hydration, is often deficient for many athletes in training. In addition, if athletes need to eat or drink fluids during their competition, this needs to be part of their training to condition the gastrointestinal system to process nutrition during athletic performance.

Many athletes who do not consume the required fluids, and sometimes the solid sports nutritionals during their training

periods that are required during competitions/ events, experience gastrointestinal upset during competitions from not having properly conditioned the gastrointestinal system. In addition to conditioning an athlete's digestive system during training, this allows for fine-tuning the fluids and foods that promote easy digestion and enhanced athletic performance versus the opposite. Remember that athletic competitions may be a regular season event or daylong or multiple-day tournaments. Then there are the very physical and nutritionally demanding multi-day endurance event sports like the Tour de France that require a very sophisticated sports nutrition program involving daily medical monitoring by highly qualified health professionals.

Calorie and macronutrient modulation is an important part of an athlete's sports nutrition program, which is dynamic in nature. Day to day, caloric intake requirements will typically be different depending on an athlete's training duration and intensity and on other daily physical activity demands, which are sometimes tragically overlooked and can cause detrimental caloric and nutrient deficiencies. Modulating the relative proportions of fat, carbohydrate, and protein, especially before, during, and after training or competitions, is required. Then there is the specialized practice of glycogen supercompensation reviewed in Unit 19, along with the general approach of increasing carbohydrates before and the day of athletic events/competitions.

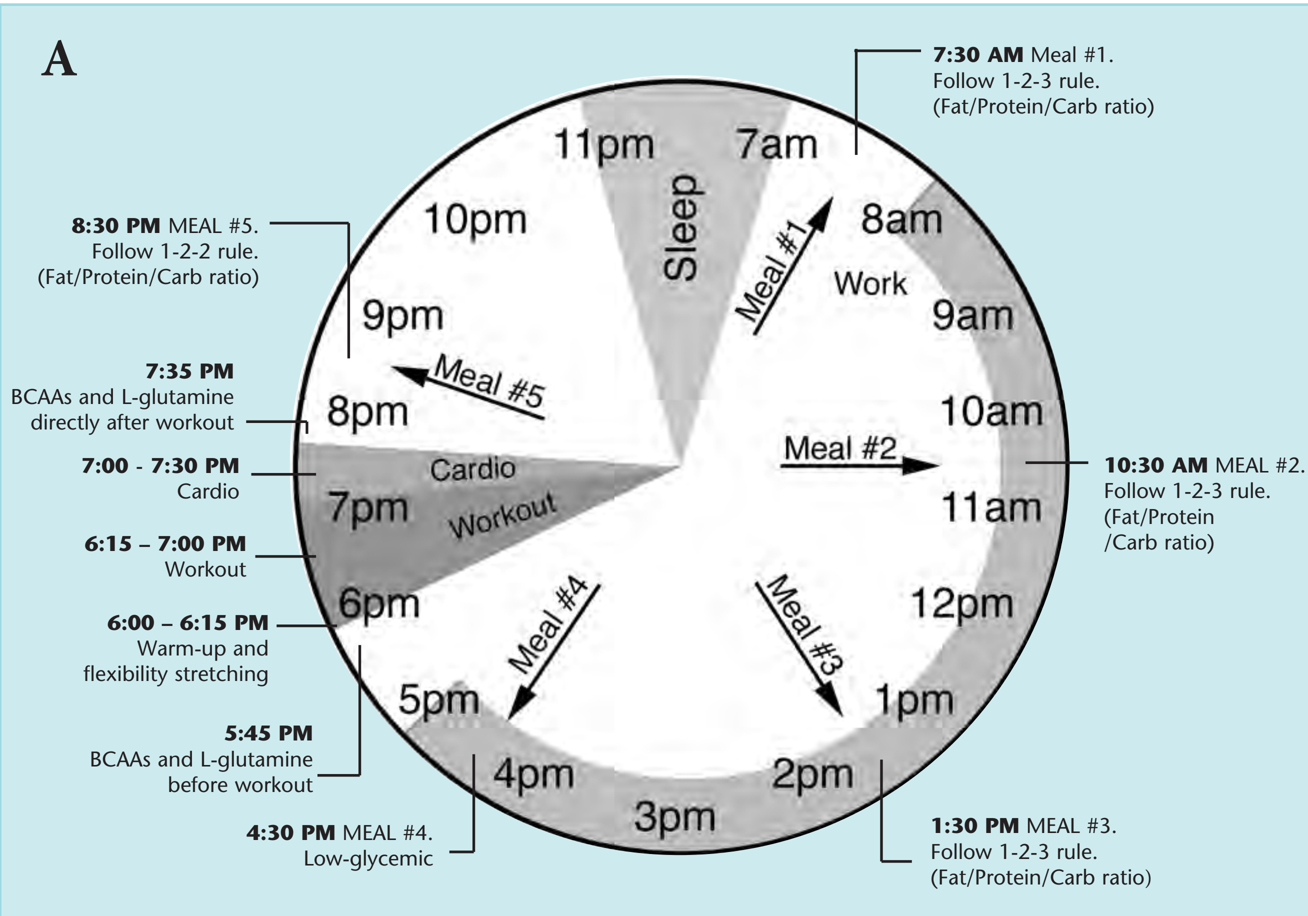
A good starting point example for meal scheduling or timing is the "Clock Approach"

"Clock Approach" Meal Scheduling Examples

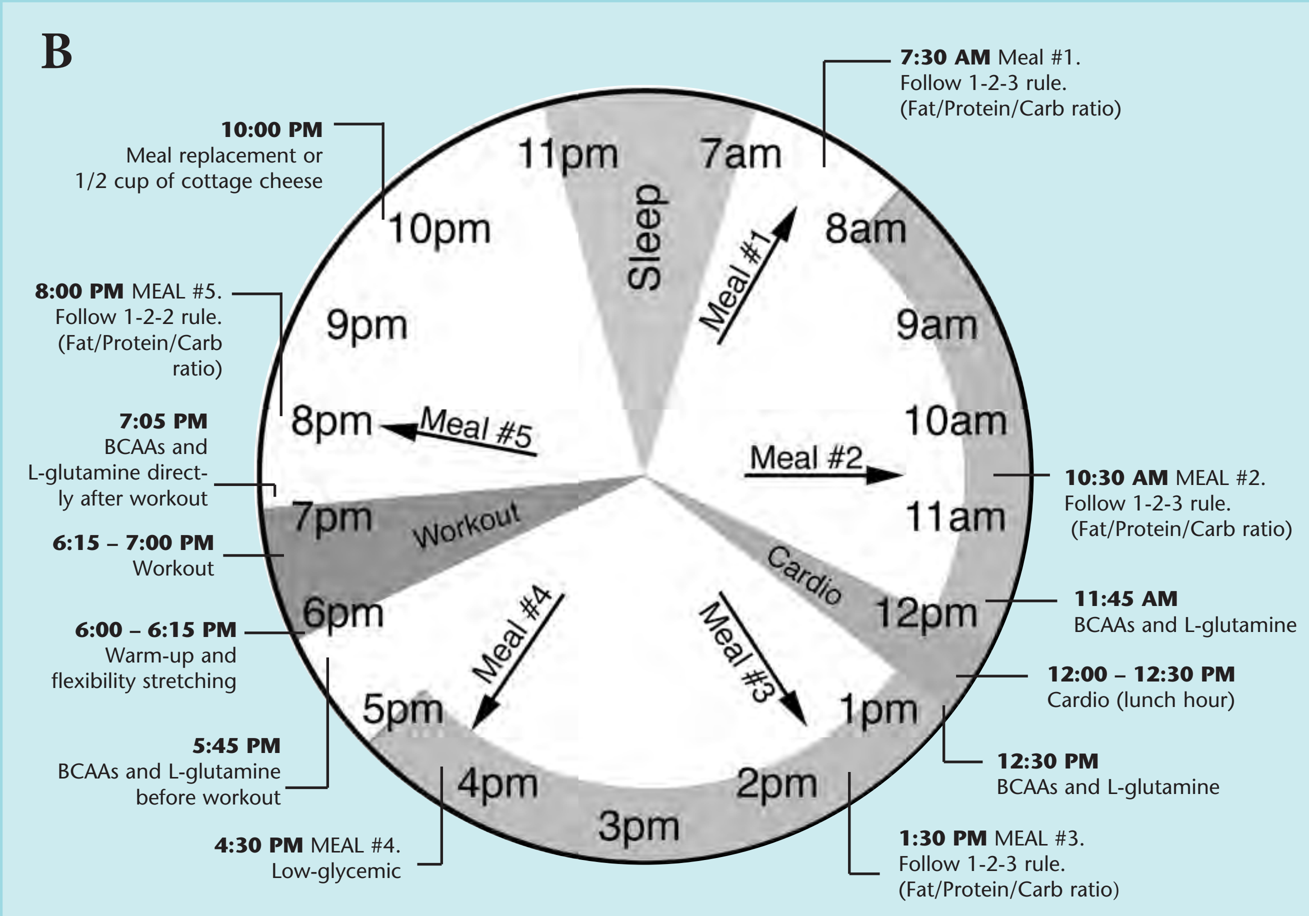
The Clock Approach was developed by Dr. Hatfield to help as a visual aid to align nutrition with training and competition schedules. This can best be done by consuming five or six meals each day. Pay attention to maintaining adequate blood sugar levels. Following a meal, blood sugar will be elevated. This will allow a person to perform physical activity without the loss of energy. Of course, the more intense the physical activity, the quicker these blood sugar levels will drop. If you learn to listen to your body, you will realize that your blood sugar is low and that replenishment is needed.

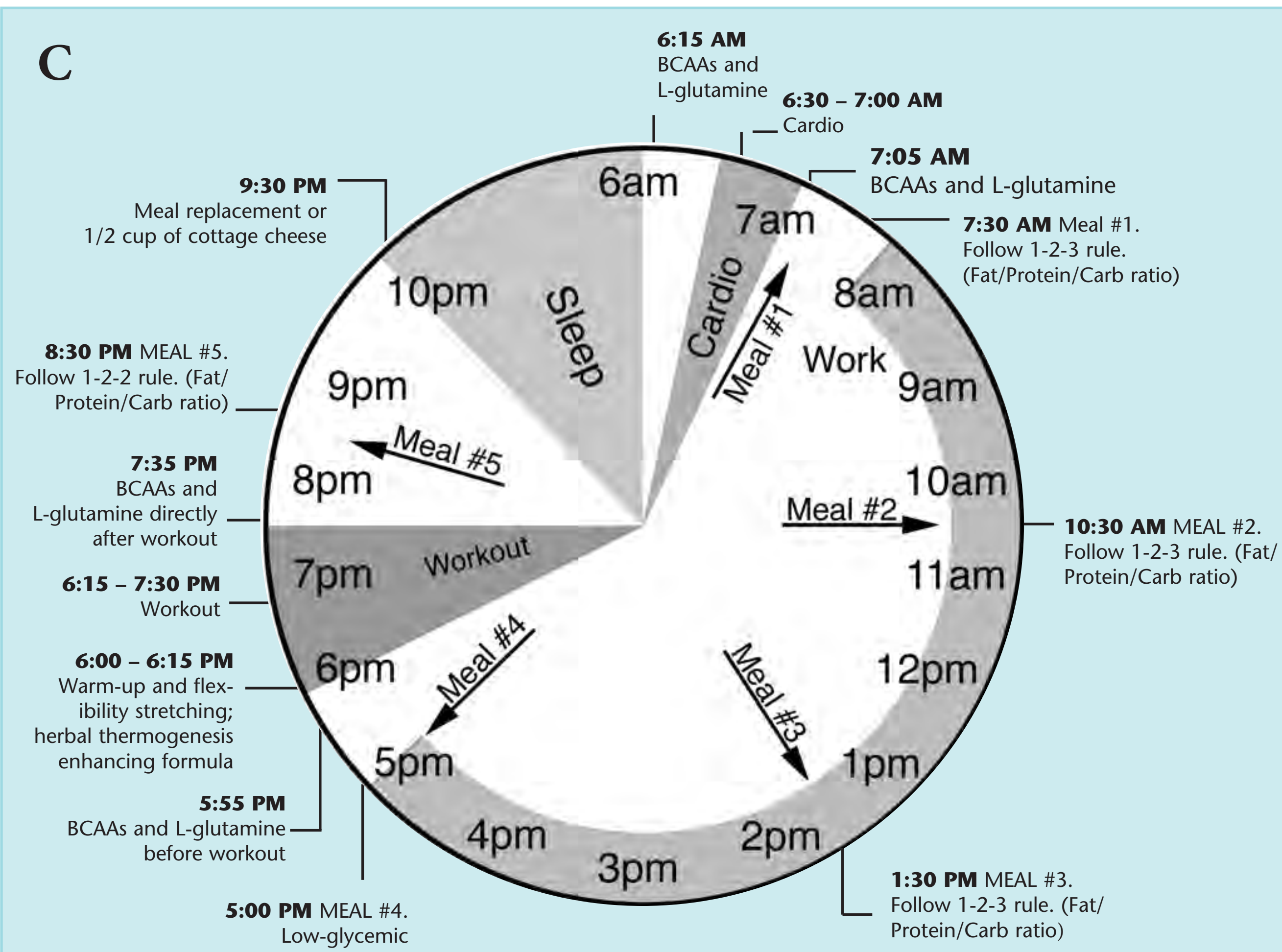
As a starting point, a meal every three or so hours is suggested, which can be plus or minus based on an individuals' rate of digestion and meal composition. Pace caloric intake for the hours following the meal, for example, the meal prior to a low-energy activity or a sedentary activity like sitting will be fewer calories compared with the meal prior to a high-activity athletic training. Simply ask, "What am I going to do in the next three hours?" By carefully evaluating your next three hours of activity, you can determine approximately how many calories to consume at the present meal.

The following Clocks include examples for different numbers of workouts per day, with meals following the 1-2-3 rule of Fat/Protein/Carb ratio, noting that meals can be fine-tuned using the Dynamic Nutrition Approaches for the different athlete-types.



Clock A, above. Clock B top right. Clock C, bottom right.


B
7:30 AM Meal #1.
Follow 1-2-3 rule.
(Fat/Protein/Carb ratio)
10:00 PM
Meal replacement or
1/2 cup of cottage cheese
11pm
7am
Sleep
Meal #1
8am
10pm
8:00 PM MEAL #5.
Follow 1-2-2 rule.
(Fat/Protein/Carb
ratio)
9pm
9am
8pm
Meal #5
10am
Meal #2
7:05 PM
BCAAs and
L-glutamine directly after workout
10:30 AM MEAL #2.
Follow 1-2-3 rule.
(Fat/Protein/Carb ratio)
7pm
Workout
11am
6:15 – 7:00 PM
Workout
Cardio
11:45 AM
BCAAs and L-glutamine
6pm
Meal #4
Meal #3
12pm
6:00 – 6:15 PM
Warm-up and
flexibility stretching
12:00 – 12:30 PM
Cardio (lunch hour)
5pm
1pm
5:45 PM
BCAAs and L-glutamine
before workout
4pm
2pm
12:30 PM
BCAAs and L-glutamine
3pm
4:30 PM MEAL #4.
Low-glycemic
1:30 PM MEAL #3.
Follow 1-2-3 rule.
(Fat/Protein/Carb ratio)


C
6:15 AM
BCAAs and
L-glutamine
6:30 – 7:00 AM
Cardio
7:05 AM
BCAAs and L-glutamine
9:30 PM
Meal replacement or
1/2 cup of cottage cheese
6am
7am
7:30 AM Meal #1.
Follow 1-2-3 rule.
(Fat/Protein/Carb ratio)
10pm
Sleep
Cardio
8am
Meal #1
Work
8:30 PM MEAL #5.
Follow 1-2-2 rule. (Fat/
Protein/Carb ratio)
9pm
9am
Meal #5
7:35 PM
BCAAs and
L-glutamine directly
after workout
8pm
10am
Meal #2
10:30 AM MEAL #2.
Follow 1-2-3 rule. (Fat/
Protein/Carb ratio)
7pm
Workout
11am
6:15 – 7:30 PM
Workout
6pm
Meal #4
Meal #3
12pm
6:00 – 6:15 PM
Warm-up and flexibility stretching;
herbal thermogenesis
enhancing formula
5pm
1pm
5:55 PM
BCAAs and L-glutamine
before workout
4pm
2pm
3pm
5:00 PM MEAL #4.
Low-glycemic
1:30 PM MEAL #3.
Follow 1-2-3 rule. (Fat/
Protein/Carb ratio)

Sports Nutrition Fine-Tuning Is Ongoing

Based on new ingredients, new sports nutrition products, new research discoveries, and new sports nutrition insights, one thing is certain: fine-tuning an athlete's sports nutrition program will be an ongoing effort. Even when the point is reached when 99 percent optimization is achieved, it is that extra 1 percent that could be the championship edge an athlete needs to achieve his or her athletic performance goals. The "Alkalinity Nutrition Factor" information box is a good example of progressive sports nutrition research that goes beyond conventional nutrition thinking.

The Alkalinity Nutrition Factor Throughout this course, and in most conventional thinking about nutrition, the major focus is on achieving daily intake of the essential, semi-essential nutrients, and specialty ergogenic ingredients for optimum health and maximum performance, too. But aside from this essential nutrient focus, an additional line of thinking concerns how diets affect the acidity or alkalinity of the body. Acid-alkaline diets and food factors come arise as a topic in general for health purposes and as related to sports and athletic performance. Books have been and will continue to be written about this subject of growing interest, and research is being conducted as well.

At a simple level of explanation, the idea is, with pH 7 being neutral, the body (body fluids) could be in a healthier condition when on the alkaline side of the pH scale for body fluids (7+) versus the acid side (7-). The thought is that when the body's pH is alkaline, this could be healthier, and when the body's pH is acid, this could be unhealthy. Origins of acid-alkaline balance are thought to be rooted in traditional health approaches dating back thousands of years.

A core point of achieving and maintaining alkalinity is eating the right balance of acid forming foods and alkaline forming foods to maintain a body that is overall alkaline. There are many facets to this, and modern research is slowly but surely being conducted to provide additional evidence to the appropriateness of the alkalinity-forming diet approach. Note that while this is independent of essential nutrients, there is a relationship. For example, body acidity may disrupt calcium in the bones, possibly causing bone calcium to be released to support the body's calcium-based buffering system. Acid body plus inadequate calcium intake is even more of a problem for bone health. Moreover, disruption of calcium ions in the nervous system may be adversely affected from body acidity, one of the possible factors leading to exercise-related fatigue, such as with the lowering of pH in the exercising muscles and the rest of the body.

Speculation aside, the point of bringing this topic to your attention is leading up to a 2015 research study by Susan L. Caciano and coworkers, titled "Effects of Dietary Acid Load on Exercise Metabolism and Anaerobic Exercise Performance." The researchers noted that urine pH relates to dietary acid-base load, and during the study, the alkaline-promoting diet was designed to promote a urine pH greater than or equal to pH of 7.0, and the acid-promoting diet was designed to promote urine pH less than or equal to 6.0. The alkalinity-promoting diet was high in fruits and vegetables and low in meats, grains, and cheese, which can promote systemic acidity. Note too that bicarbonates reviewed in Unit 9 have been proven to promote alkalinity and benefit some types of athletic performance. Furthermore, there is some research examining the alkalinity-promoting effects of the "greens drinks" being sold in health product stores, which are becoming more popular with health-minded people (see Anton 2013 reference for an example). It is important to realize that although this research is interesting, it is considered experimental and evolving, and the research subjects were under close medical supervision in the Caciano 2015 experiment.

It took several days for subjects to achieve either acid or alkaline urine pH from the respective diets. Subjects then underwent anaerobic exercise-performance testing. Anaerobic exercise performance testing consisted of running time-to-exhaustion lasting one to four minutes on a treadmill wherein running speed was constant and the incline was increased until fatigue was achieved in a graded exercise design. The alkaline-promoting diet subjects experienced improvement in anaerobic exercise performance by 21 percent compared to the acid promoting diet subjects.

Food Lists

The foods lists can be used to make food substitutions to the eating plans listed above based on individual athlete requirements. You should also include healthy favorite foods and foods that are readily available. Make additions to these lists to include suitable foods that are the athlete's favorites. Be sure to refer to the Dietary Guidelines document in the appendix. The food lists begin on the next page.

Note that the actual calorie and nutrient content for conventional foods can vary up to 20 percent or more, higher or lower; many agricultural factors contribute to this variation. Nutrient content variation of supplement products tends to be less, due to the high standard of manufacturing and quality control testing requirements.

When possible, choose organic foods, range-fed organic, whole grains, and whole unprocessed foods.

High-Protein Foods: Beef, Lamb, Poultry, Fish, Pork.					
Food	**Serving Size**	**Calories**	**Protein** (Grams)	**Carbs** (Grams)	**Fat** (Grams)
Abalone	3 oz	89	14.5	5.1	0.7
Bacon Alternative (Louis Rich)	1 strip	32	2.4	0.3	2.4
Bacon Bits (Hormel)	1 oz	117	12	1	7
Bacon, Canadian-Style	1 slices	86	11.3	0.6	3.9
Bass, Freshwater	1 oz	32	5.3	0	1
Bass, Sea	1 oz	27	5.2	0	0.6
Beef, Flank, untrimmed	1 oz	51	5.6	0	3
Beef, Bottom Round, prime, trimmed	1 oz	45	6.2	0	2.1
Beef, Bottom Round, prime, untrimmed	1 oz	64	5.7	0	4.4
Beef, Sirloin, prime, trimmed	1 oz	44	6	0	2
Beef, Tenderloin, choice, untrimmed	1 oz	82	5	0	6.7
Beef, Corned (Hillshire Farm)	1 oz	31	6	0	0.4
Beef, Roast, sliced (Healthy Deli)	1 oz	30	6.4	0.2	0.4
Buffalo	1 oz	31	6.1	0	0.5
Bluefish	1 oz	35	5.7	0	1.2
Burger, vegetarian, Harvest Burger (Green Giant)	1 burger	140	18	8	4
Chicken, breast, no skin	1 oz	31	6.5	0	0.4
Chicken, breast, with skin	1 oz	49	5.9	0	2.6
Chicken,sliced,(Tysonhickorysmoked)	1 slice	25	4	0.8	1
Cod	1 oz	23	5	0	0.2
Deer	1 oz	34	6.4	0	0.7
Egg (chicken)	1 large	75	6.3	0.6	5
Egg, white (chicken)	1 large	17	3.5	0.3	0
Egg, Alternative (Fleishmann's) Egg Beaters vegetable omelet	1/2 cup	50	7	5	0
Flounder	3 oz	77	16	0	1
Frankfurter, low fat, (Healthy Choice)	1 frank	70	8	5	2
Halibut	1 oz	31	5.9	0	0.6
Ham, fresh trimmed	1 oz	39	6	0	1.5
Ham, sliced (Kahn's)	1 slice	30	5	1	1
Pork, Tenderloin, trimmed	1 oz	34	5.9	0	1
Pork Chops (Master Choice)	1 chop	120	22	0	4
Tofu, soybean curd cake	1 oz	22	2.3	0.5	1.4
Tuna, bluefin	1 oz	41	6.6	0	1.4
Tuna, canned in soybean oil, solid, drained (Star-Kist)	2 oz	150	13	0	13
Tuna, canned, white, in water, drained, diet (Star-Kist)	2 oz	70	15	0	1
Turkey, light meat, no skin	1 oz	33	6.7	0	0.4
Turkey, dark meat, no skin	1 oz	35	5.7	0	1.2
Turkey, sliced, (Tyson)	1 slice	20	4	0.3	0.4

Foods High In Complex Carbohydrates: Breads, Crackers, Cereals, Grains, Starchy Vegetables, And Starchy Fruits.					
Food	**Serving Size**	**Calories**	**Protein** (Grams)	**Carbs** (Grams)	**Fat** (Grams)
Bagel, Onion 3.5-inch diameter	1 bagel	195	7.5	37.9	1.1
Bagel, Plain 3.5-inch diameter	1 bagel	195	7.5	37.9	1.1
Bagel, Frozen (Lender's)	1 bagel	150	6	30	1
Bagel Chips (Burns & Ricker)	1 oz	130	4	20	4
Biscuit, commercially baked	1 oz	103	1.8	13.8	4.7
Hamburger bun	1 bun	123	3.7	21.6	2.2
Bread, white	1 slice	70	3	13	1
Bread, whole wheat	1 slice	60	3	11	1
Bread, bran	1 oz	100	4	19	1
Bread, French	1 oz	78	2.5	14.7	0.9
Bread, whole grain	1 slice	85	3.9	17.4	1.6
Bread, rye	1 slice	80	3	16	1
Cake, Free & Light frozen (Sara Lee)	1/8 cake	110	2	26	0
Cake, pound, Free & Light (Sara Lee)	1/10 cake	70	1	17	0
Cereal, All Bran extra fiber (Kellogg's)	1 oz	50	4	22	0
Cereal, Basic 4 (General Mills)	3/4 cup	130	3	28	2
Cereal, Corn Flakes	1 oz	110	2.3	24.4	0.1
Cereal, Grape-nuts (Post)	1 oz	101	3.3	23.3	0.1
Cereal MultiGrain Cheerios (General Mills)	1 oz	100	2	23	1
Cracker, saltine (Premium) Fat-free	4 crackers	50	1	12	0
English Muffin, plain (Thomas')	1 muffin	130	4.3	25.4	1.3
Frankfurter bun	1 bun	123	3.7	21.6	2.2
Oatmeal, plain, instant	1 oz	100	5.8	18	2
Roll, Hoagie	1 roll	210	8	34	5
Roll, Kaiser	1 roll	184	7	35.4	2.9
Roll, Sandwich	1 roll	123	4.5	21.6	3.3
Grits, dry (Arrowhead Mills)	2 oz	200	5	43	1
Pancake, buttermilk, (Hungry Jack), prepared, with skim milk, oil, egg whites	3 pancakes	200	6	28	7
Pancake, extra light, (Hungry Jack), prepared with skim milk, oil, egg whites	3 pancakes	170	6	28	4
Pasta linguine and spaghetti, dry	2 oz	210	9	41	1
Popcorn, microwave, (Jiffy Pop), Natural, popped.	4 cups	140	3	17	7
Popcorn, microwave, (Jolly Time), light	3 cups	60	2	12	2
Potato, baked in skin	4 oz	124	2.6	28.6	0.1
Potato, boiled, no skin	4 oz	99	2.1	22.8	0.1
Potato, sweet, baked , pulp only	4 oz	117	2	27.5	0.1
Pretzels, most types	1 oz	110	3	23	1
Rice, Brown, dry	1 oz	103	2.3	22	1
Rice, White, dry	1 oz	105	2	23	0.2

Vegetables and Beans					
Food	**Serving Size**	**Calories**	**Protein** (Grams)	**Carbs** (Grams)	**Fat** (Grams)
Adzuki Bean, raw	1 oz	93	5.6	17.8	tr
Arugula	1 leaf	1	0.1	0.1	0
Baked Beans, canned ,	8 oz	200	10	43	3
Tomato (Campbell's)					
Baked Beans, canned,	8 oz	260	15	48	6
Barbecue (B&M)					
Baked Beans, canned, pea, small (Friends)	8 oz	360	17	62	4
Baked Beans, canned,	8 oz	160	12	38	<1
Showboat (Bush's Best)					
Baked Beans, canned,	8 oz	230	14	50	3
Vegetarian (B&M)					
Black Bean, raw	1 oz	97	6.1	17.7	0.4
Broccoli, fresh, raw, trimmed	1 oz	8	0.8	1.5	0.1
Broccoli, frozen, spears (Birds Eye)	4 oz	30	4	6	0
Cabbage, raw	1 oz	5	0.3	0.9	0.1
Carrot, raw	1 oz	12	0.3	2.9	0.1
Cauliflower, raw	1 oz	7	0.6	1.4	0.1
Celery, raw	1 oz	5	0.2	1	0
Corn, frozen (Health Valley)	1/2 cup	76	2	17	0
Garbanzo Bean, raw	1 oz	103	5.5	17.2	1.7
Lettuce, iceberg, trimmed	1 oz	4	0.3	0.6	0.1
Lettuce, romaine, trimmed	1 oz	5	0.5	0.7	0.1
Lima Bean, raw	1 oz	32	2	5.7	0.2
Lima Bean, frozen (Green Giant)	1/2 cup	80	6	18	0
Onion, raw, trimmed	1 oz	11	0.3	2.4	0.1
Spinach, untrimmed	1 oz	6	0.2	1	0.1
Tomato, 2 3/4inch dia, 4.75 oz	1 tomato	26	1	5.7	0.4
Turkey, sliced, (Tyson)	1 slice	20	4	0.3	0.4

Fruit: Whole Fruits and Sauces					
Food	**Serving Size**	**Calories**	**Protein** (Grams)	**Carbs** (Grams)	**Fat** (Grams)
Apple Sauce (Mott's) Natural	6 oz	80	0	20	0
Apricot pitted	1 oz	14	0.4	3.2	0.1
Apricot Dried (Del Monte)	2 oz	140	2	35	0
Asparagus Frozen (Birds Eye)	3.3 oz	25	3	4	0
Blueberry	1 oz	16	0.2	4	0.1
Fruit Cocktail, canned, in light syrup	4 oz	65	0.5	16.9	0.1
Grapefruit	1/2 fruit	50	1	13	0
Orange	1 med	62	1.2	15.5	0
Pasta Sauce, (Hunt's) Homestyle	4 oz	60	2	10	2
Pasta Sauce, (Ragu), Mushroom Thick and Hearty	4 oz	100	2	15	3

Dairy: Cheese, Milk, Yogurt					
Food	**Serving Size**	**Calories**	**Protein** (Grams)	**Carbs** (Grams)	**Fat** (Grams)
Cheese, American	1 oz	110	6	1	9
Cheese, American Cheddar	1 oz	113	7	0.4	9.3
Cheese, parmesan, grated	1 oz	128	11.6	1	8.4
Cheese, Swiss	1 oz	105	8	1	7.7
Cottage Cheese, large curd	4 oz	117	14.1	3	5.1
Cottage Cheese, large curd, 1%	1 oz	20	3.5	0.8	0.3
Cottage Cheese, large curd, 2%	1 oz	25	3.9	1	0.5
Cream Cheese	1 oz	98	2.1	0.7	9.8
Cream Cheese, fat-free	1 oz	30	6	2	0
Butter, Salted	1 tbsp	100	0.1	0	11.4
Milk, Skim	8 oz	86	8.4	11.9	0.4
Milk, 1%	8 oz	102	8	11.7	2.6
Milk, 2%	8 oz	121	8.1	11.7	4.7
Milk, Whole	8 oz	150	8	11	8
Yogurt, Plain (Dannon), low fat	8 oz	140	10	16	4
Yogurt, Plain (Dannon), nonfat	8 oz	110	11	16	0
Yogurt,MixedBerry(Breyers),low fat	8 oz	250	9	48	2

Spreads and Sauces					
Food	**Serving Size**	**Calories**	**Protein** (Grams)	**Carbs** (Grams)	**Fat** (Grams)
Catsup	1 tbsp	16	0.2	4.1	0.1
Margarine (Land O'Lakes)	1 tbsp	35	0	0	4
Mayonnaise	1 tbsp	100	0	0	11
Mustard	1 tbsp	10	1	1	1
Olive oil	1 tbsp	120	0	0	14
Pancake syrup (Hungry Jack), lite	2 tbsp	50	0	14	0
Pancake syrup (Hungry jack), regular	2 tbsp	100	0	26	0
Safflower oil	1 tbsp	120	0	0	14
Salad Dressing, (Kraft), Blue Cheese "Free"	1 tbsp	16	0	4	0
Salad Dressing, (Kraft), French, reduced calorie	1 tbsp	20	0	3	1
Salad Dressing, (Seven Seas), oil & vinegar	1 tbsp	45	0	1	4
Salad Dressing, (Wish-Bone), Blue Cheese, Chunky	1 tbsp	75	0.4	0.7	7.9
Salad Dressing, (Wish-Bone), Italian	1 tbsp	46	0	1.5	4.5
Steak Sauce, (A1)	1 tbsp	18	0	4	0

Beverages

Food	Serving Size	Calories	Protein (Grams)	Carbs (Grams)	Fat (Grams)
Apple Juice,(Knudsen&Sons),natural	8 oz	85	<1	21	0
Apple Juice (Ocean Spray)	6 oz	90	0	23	0
Apple Grape Juice (Red Cheek)	6 oz	109	0.3	27	0
Banana, w/o skin	1 fruit	105	1.2	26.7	0.6
Cranberry Juice	8 oz	125	<1	31	0
Carbohydrate Sports Drink, low calorie	8 oz	50	0	13	0
Carbohydrate Sports Drink, medium calorie	8 oz	100	0	25	0
Carbohydrate Sports Drink, high calorie	16 oz	400	0	100	0
Grape Juice	6 oz	120	0	30	0
Grapefruit Juice	6 oz	60	1	15	0
Orange Juice	6 oz	120	0	30	0
Vegetable Juice (V8)	6 oz	35	1	8	0

Mixed Foods

Food	Serving Size	Calories	Protein (Grams)	Carbs (Grams)	Fat (Grams)
Beef, corned hash, canned (Libby's)	8 oz	420	19	21	28
Chili, canned w/ chicken (Stagg)	7.5 oz	200	14	21	6
Chili, canned vegetarian (HealthValley)	5 oz	90	10	12	0
Food-bar, banana apple walnut, "Bagel Power Bar" (Earth Grains)	1 bar	270	12	45	6
Food-bar, Pemmician, carob-cocoa (Bear Valley)	1 bar	440	16	68	12
Food-bar, raspberry, fat free (Health Valley)	1 bar	140	3	33	0
Pizza, frozen, Three Cheese (Lean Cuisine)	5.5 oz	330	23	38	10
Protein Drink, low calorie, powder	2 oz	225	30	15	5
Protein Drink, medium calorie	4 oz	470	40	64	6
Protein Drink, high calorie	5 oz	548	30	80	12
Protein Nutrition Bar, low calorie	1 bar	225	30	15	5
Protein Nutrition Bar, medium calorie	1 bar	470	40	64	6
Protein Nutrition Bar, high calorie	1 bar	548	30	80	12
Power Bar	1 bar	230	10	45	2.5

2017 Advice about Eating Fish Guidelines from the FDA and EPA

Although the advice about eating fish, including shellfish, issued by the FDA and EPA focuses on avoiding and/or reducing potentially harmful intake of mercury and is geared toward women of childbearing age, it will be useful for everybody who wants to reduce mercury in his or her diet. The following chart categorizes fish and seafood into three main categories: Best Choices, Good Choices, and Choices to Avoid. Additional information can be found at the FDA's website:

http://www.fda.gov/Food/FoodborneIllnessContaminants/Metals/ucm393070.htm#supporting

Advice About Eating Fish

What Pregnant Women & Parents Should Know

Fish and other protein-rich foods have nutrients that can help your child's growth and development.

For women of childbearing age (about 16-49 years old), especially pregnant and breastfeeding women, and for parents and caregivers of young children.

- *Eat 2 to 3 servings of fish a week from the "Best Choices" list OR 1 serving from the "Good Choices" list.*
- *Eat a variety of fish.*
- *Serve 1 to 2 servings of fish a week to children, starting at age 2.*
- *If you eat fish caught by family or friends, check for fish advisories. If there is no advisory, eat only one serving and no other fish that week.**

Use this chart!

You can use this chart to help you choose which fish to eat, and how often to eat them, based on their mercury levels. The "Best Choices" have the lowest levels of mercury.

What is a serving?

To find out, use the palm of your hand!

For an adult
4 ounces

For children, ages 4 to 7
2 ounces

Best Choices EAT 2 TO 3 SERVINGS A WEEK

OR

Anchovy	Herring	Scallop
Atlantic croaker	Lobster, American and spiny	Shad
Atlantic mackerel	Mullet	Shrimp
Black sea bass	Oyster	Skate
Butterfish	Pacific chub mackerel	Smelt
Catfish	Perch, freshwater and ocean	Sole
Clam	Pickerel	Squid
Cod	Plaice	Tilapia
Crab	Pollock	Trout, freshwater
Crawfish	Salmon	Tuna, canned light (includes skipjack)
Flounder	Sardine	Whitefish
Haddock		Whiting
Hake		

Good Choices EAT 1 SERVING A WEEK

Bluefish	Monkfish	Tilefish (Atlantic Ocean)
Buffalofish	Rockfish	Tuna, albacore/ white tuna, canned and fresh/frozen
Carp	Sablefish	Tuna, yellowfin
Chilean sea bass/ Patagonian toothfish	Sheepshead	Weakfish/seatrout
Grouper	Snapper	White croaker/ Pacific croaker
Halibut	Spanish mackerel	
Mahi mahi/ dolphinfish	Striped bass (ocean)	

Choices to Avoid HIGHEST MERCURY LEVELS

King mackerel	Shark	Tilefish (Gulf of Mexico)
Marlin	Swordfish	Tuna, bigeye
Orange roughy		

*Some fish caught by family and friends, such as larger carp, catfish, trout and perch, are more likely to have fish advisories due to mercury or other contaminants. State advisories will tell you how often you can safely eat those fish.

www.FDA.gov/fishadvice

www.EPA.gov/fishadvice

EPA United States Environmental Protection Agency

FDA U.S. FOOD & DRUG ADMINISTRATION

THIS ADVICE REFERS TO FISH AND SHELLFISH COLLECTIVELY AS "FISH." / ADVICE UPDATED JANUARY 2017

Conclusion

The Dynamic Nutrition Approach offers a comprehensive scientific evidence-based approach, which can be used as a starting point when developing a personalized sports nutrition program, by qualified health professionals, and under the athlete's doctor supervision.

Key Word

Hypoglycemia

Topics Covered In This Unit

Introduction

Athlete body composition change challenges

- The weight-loss misnomer
- First stop the weight gain
- Targeted fat-loss approach
- Fat loss off-season and preseason
- Jump-starting the fat-loss program
- Fat loss during the athletic season (not preferred)
- The gender and age gap when losing weight
- Important rules for making performance nutrition work for an athlete's fat-loss program
- The zigzag method of fat loss

Muscle gain approach

Constructing a custom nutrition plan for fat loss and muscle gain

Conclusion

UNIT 18

FAT LOSS AND MUSCLE GAIN FOR ATHLETES

Uit Outline

Learning Objectives

After completing this unit, you will be able to:

- Define and describe related terms.
- Understand the ZIGZAG method developed by Dr. Fredrick Hatfield, PhD.
- Discuss effective fat loss and muscle gain for athletes.
- Determine weight management programs for healthy adult athletes.

Introduction

In an athlete's career, there may come a time when a modification in body composition is desired, such as weight gain or weight loss. However, as you have learned throughout this book, for maximum athletic performance and results, body composition changes must be specifically targeted. This means that for weight loss, the primary goal is fat loss. For weight gain, increase in muscle mass is the primary goal. As it turns out, the best way for athletes to accomplish these goals is the same for most healthy athletic adults.

There are thousands of products and services on the market for fat loss and muscle gain in the form of books, videos, audio cassettes, magazines, nutritional products, exercise equipment, pre-packaged meals, support groups, and seminars. Billions and billions of dollars are spent each year by people wanting to lose and gain weight. In the process, most people lose out in some way: in time, money, impaired athletic performance, or diminished health and energy.

Clearly, a combined loss of body fat and increase in muscle mass will produce the most desirable results. However, note that for weight-class

Athletic Significance of Fat Loss and Muscle Gain	Fitness Significance of Fat Loss and Muscle Gain
For the athlete wanting to lose body fat and maintain or build muscle mass, taking the correct approach is critical for performance. The approaches presented in this unit have been developed and field tested to confirm that fat loss can be targeted, i.e., without loss in lean body mass, including with many famous athletes. It presents an approach for building lean body mass while losing body fat. Extra body fat will reduce performance levels, just as much as not having enough muscle will. And many athletes find that gaining weight becomes a double-edged sword because they also gain fat. This integrated approach is a solution for athletic applications.	As it turns out, the method developed for athletes to lose body fat is also ideal for everybody—all healthy adults. This approach is easy to implement and will be immediately effective in reducing excess body fat. What differentiates this system from the rest is that it targets fat loss, builds lean body mass in the process, and requires no special foods, just making adjustments in when and how much is eaten and cutting down on eating certain fat-forming foods. After a few days, people can become efficient fat-burning machines. Of course, implementing healthy nutrition practices is desirable, including implementing the 2015–2020 Dietary Guidelines for Americans when practical.

sports, such as wrestling, loss of body fat while maintaining muscle mass/lean body mass may be the most appropriate goal but may vary with each individual athlete. This unit therefore treats these two subjects together, fat loss and muscle/lean body mass gain, providing background information and guidelines that could be used to achieve athletic body composition goals.

Athlete Body Composition Change Challenges

Changes in an athlete's body composition related to muscle gain or fat loss can bring about unwanted decrements in athletic performance and, sometimes, even in health. Therefore, ideally, intentional changes in an athlete's body composition should be planned for during the off-season and early preseason whenever possible. Depending on the amount of muscle gain or fat loss an athlete wants during a particular year, a few to several months may be required for optimum changes in body composition to minimize negative effects on an athlete's anatomy or physiology. Measuring body weight, circumferences, skinfolds, and composition will be required regularly to determine changes in lean body mass and body fat mass. The body fat loss rate should be slow, 0.5 to 1 pound per week, as not to result in loss of lean body mass. By your keeping track of an athlete's body composition, adjustments to the rate of body fat loss can be made, for example, slower rate if lean body mass is also being lost. Over 1 pound of body fat mass loss per week is sometimes possible while maintaining or building lean body mass, but it depends on the body response dynamics of each person to determine what rate of fat reduction is best. As a rule, as the rate of fat loss increases, the chance of loss in lean body increases, and the associated negative metabolic adverse effects increase, too.

Note that the specialized approach developed by Dr. Hatfield, referred to as the ZIGZAG Approach solves this problem by cycling the reduction of calories for a few days, with some days of normal caloric intake, versus chronic negative caloric intake, which can trigger the metabolism to slow down. More information about the ZIGZAG approach is provided in following section of this unit.

Body composition goal changes can include a variety of outcomes, depending on the athlete's goals, for example:

- Reduction of body fat, with maintenance of lean body mass
- Reduction of body fat, with increase of lean body mass
- Increase of lean body mass, with maintenance of body fat
- Increase of lean body mass, with an increase in body fat

In rare instances, athletes may desire a reduction of both body fat and lean body mass, sometimes encountered in weight-class sports, but it should be noted that negative effects on health and athletic performance may occur, and this type of situation should be avoided. Report severe weight-loss attempts to the client's doctor, coach, or other appropriate parties when warranted. Note that a reduction in body weight, body fat, and/or lean body mass can also be a sign of severe under eating, eating disorders, disordered eating, dehydration, or disease, which likely require immediate medical attention.

The Weight-Loss Misnomer

Losing weight has become something of a pastime for many people, and we have discovered a great deal along the way. When you determine the optimum fat-loss approach for athletes, reviewing traditional methods will help shed some light on how to best approach the task. Surprisingly, when researching the facts, it became evident that traditional fat-loss approaches vary and are not intended for athletes. These methods are primarily developed for people who need to lose weight fast for health reasons or for the would-be dieter who wants to trim down to look better.

There are three main ways your body loses weight: dehydration, lean weight loss (from muscle, bone, organs), and fat loss. Dehydration is not a recommended type of weight loss. However, wrestlers and other athletes who need to "make weight" will unavoidably turn to this method as a last-minute resort. Losing a few pounds during the last few hours prior to competition to make it into a specific weight division may not be harmful, assuming the athlete is in a good state of hydration to begin with. In most cases, athletes can have time to rehydrate after the weigh-ins. However, do not rely on dehydration to lose more than a few pounds (usually less than 2 percent of total body weight), and do not stay dehydrated or become dehydrated under circumstances of heat stress or during training or athletic events. Ideally, dehydration to make weight should be avoided and is not recommended but seems to be an unavoidable reality for some athletes.

Lean body mass/muscle mass weight loss can result from cutting back on the calories too much, losing weight too fast, not eating the proper proportions of macronutrients, and not properly exercising. Lean body mass weight loss stems primarily from the breakdown of muscle tissue, but bone and connective tissue can also be reduced in size. This is a very detrimental type of weight loss for the athlete or anybody for that matter. Loss of lean body mass also reduces BMR and jeopardizes body structure and function. If athletes are doing more long duration aerobic exercise during weight loss, this type of exercise may also result in reducing lean body mass due to changes in muscle fiber composition, more of the smaller slow-twitch muscle fibers, and less of the larger fast-twitch muscle fibers. Thus, the body composition change balancing act involves nutrition and training.

For most athletes, increases in lean body mass percentage can accompany a proper fat-loss program. This is a result of losing fat and keeping lean body weight the same, which will result in a lower percent body fat and higher percent lean body mass. Or this is a result of increasing the weight of lean body mass, which will result in a higher increase of lean body mass percentage and lower body fat percentage. An appropriate resistance-training program is typically needed to increase lean body mass during reduction of body fat mass. The key to adjusting body composition should not be dictated by reaching some arbitrary weight goal; it should be determined by reaching a body fat goal that is realistic, that can be reached within the allotted time, and that is related to achieving maximum athletic performance and good health.

In its most basic form, untargeted weight loss can be accomplished by cutting back on food (energy) intake or through outright starvation (not recommended) below what is required by the body for weight maintenance. When caloric intake is less than caloric use from energy expenditure, the body liberates energy from body tissues and stores; fat, glycogen, and muscle tissue. Although reduction of total calories causing a calorie intake deficit can result in weight loss, a significant amount of muscle tissue may be lost in the process if proper methods are not implemented to prevent this.

Anyone familiar with the popular survival television shows has seen how fast a person can lose weight from food and calorie deprivation along with the adverse effects to body function and structure, often resulting in bed (hut) rest a few days into the survival experience. In addition, notice that post-show interviews with the survival participants typically demonstrate rapid weight gain.

Another type of currently popular weight-loss television show example is something like The Big Loser type of show. Scientists have studied the before, during, and after effects of some of the contestants and have reported their findings in scientific journals. One study that gained media attention reported that weigh regain occurred among most of the show participants, even when they adhered to an exercise and diet program to try to maintain the quickly lost and large amount of weight lost during the TV series competition.

An interesting note on powdered meal replacements: meal replacements usually result in an initial drop in weight attributed mostly to loss of water weight and gastrointestinal bulk. Additionally, you may find that a meal replacement diet causes diarrhea, which will cause dehydration and adversely affect performance. The athlete needs to consider maintaining adequate performance levels and maintaining or building muscle mass.

When following a "targeted fat-loss" program, fitness trainers and their clients will be surprised how easy losing fat can be in healthy athletic adults. Put aside your misconceptions that you need to starve to lose fat. In fact, when a program is properly executed, people won't even realize they are on a fat-loss program because they will be eating about the same amount of food as during a weight-maintenance nutrition program. However, note that if the desired body-fat loss is not occurring within two to three weeks, there may be health problem or other issue that requires a medical evaluation to determine why body fat is not being reduced.

First Stop the Weight Gain

A short, simple, and important point is athletes and other clients with excess body fat should "first stop the weight gain" before starting a fat-loss program. During the pre-fat-loss phase, they can focus on achieving weight maintenance for a few to several weeks; establish their fat-loss eating plan; modify food-related behaviors; start an exercise program; and determine whether any weight-loss supplements or even drugs are warranted, under physician supervision; and address any abnormal health issues based on their physicians' examinations.

This "first-stop-the-weight-gain" step can help make the fat-loss program even more successful and easier. A major reason many people rapidly regain the excess body fat they lost is from skipping this first-stop-the-weight-gain." It is unrealistic to reverse a fat-gaining metabolism or weight-maintenance metabolism and switch to a fat-loss metabolism in days or even weeks to achieve long-term success, which includes avoiding body fat regain. The higher the excess body fat and the lower the physical activating of a person, the longer this metabolic switching may take.

Targeted Fat-Loss Approach

Ideally, athletes should plan to make body composition changes during the off-season. This way, the pre/in-season nutrition and training program can focus on maximizing performance. Most championship athletes will follow this approach. Just think of boxers for example. When they are in their prime, they look in shape. When they get fat, they look out of shape and perform poorly. Carrying around extra weight in the form of fat will decrease performance. Rollercoaster fluctuations in your body composition during the season will also adversely affect athletic performance. However, realistically it is common for weight-class athletes such as boxers, weightlifters, powerlifters, and wrestlers to also try to lose weight during the season or up to the day of competitions. Avoiding this approach is best, but the next best approach would be to minimize athlete clients from doing this.

Start by strategically determining body composition goals by referring to the table on the following pages. Plan to reach body composition goals two months before the season begins. This will give an athlete's body a chance to adjust. Depending on the amount of body fat to lose, it may take weeks or months. NEVER try to lose excess fat by using crash diets, starvation diets, or any of the fad approaches common to the weight-loss and sports nutrition industries. For athletes, the fad weight-loss diets can result in losing muscle mass, which means a drop in BMR and athletic performance along with other potential adverse health effects.

Fat Loss Off-Season and Preseason

For losing fat during the off-season, simply follow along with the nutrition guidelines for a particular sport. For example, reduce total daily caloric intake by about 3–4 calories per pound of lean body mass (or lean body weight).

For example,

- If an athlete weighs 195 pounds with 20% body fat, lean body mass is about 156 pounds.
- Therefore, **156 pounds of lean body mass × 4 calories = 624 calories per day.**
- Thus, for a weight-maintenance 3,500 calories per day nutrition plan, subtract 624 calories, which is about 2,876 calories per day for the fat loss program's calorie reduction days.
- Be sure to reevaluate the metabolic needs of the athlete regularly to make adjustments to the calorie calculations based on changes in lean body mass.

As a pound of fat contains 3,500 calories, it will take about six days to lose a pound of fat for the above example. Losing fat at a faster rate will certainly result in a loss of muscle mass, not what athletes want. This moderate fat-loss approach will result in about 4 to 5 pounds of fat lost per month. Subtract the calories evenly from each meal. If the sport-specific nutrition plan has a daily menu that consists of five meals/snacks per day, then reduce each meal/snack by 125 calories **(-625 calories/ 5 meals = -125 calories per meal)** in the above example. It is crucial to keep up with the daily meal schedule. Of course, based on a person's individual situation, caloric reduction per day may be less than the 3 to 4 calories per pound of lean body mass range.

However, for some people, even slow, steady body-fat reduction with a moderate level of calorie restriction, along with lean body mass maintenance or building, might reduce basal metabolic rate. Therefore, this is where the ZIGZAG approach fits in. This can be used from the start of a body fat reduction program, but can be phased in after a few weeks, especially if lean body mass starts to be reduced. Regarding modifications to caloric intake, caloric intake is zigzagged down and up. Thus, in this example, reduce caloric intake for 4 to 5 days, then return to normal caloric intake for 2 to 3 days. Modulating caloric intake may prevent the body's response to lower basal metabolic rate. However, another important factor of the ZIGZAG approach is to include muscle-building resistance (weight) training into the athlete's training program, especially when wanting to building lean body mass. But it can be useful for maintaining lean body mass in association with reducing body fat mass. The resistance-training program should be compatible with an athlete's training program goals.

Furthermore, the calorie reduction should come from excess dietary fats and simple carbohydrates and then complex carbohydrates. These three calorie sources are the fat-causing culprits. Cut back on the high-fat foods, spreads, desserts, pastries, fruit, soda, and other sources of fat, sugar, and alcohol, too. Follow the fat-loss tips and guidelines to reduce consumption of

these calorie sources. In addition, consuming higher proportions of low glycemic index foods can provide additional benefits to a fat-loss program and to health.

Calorie reduction should not come from the essentially required protein intake, and should come only minimally from healthy complex carbohydrates. Protein consumption should stay at the level recommended level based on sport and season needs, also the protein chart in Unit 4 can be used to fine-tune protein needs during fat loss/muscle building cycles. Protein has the bonus of stimulating the thermogenic effect, meaning that it takes the body more calories to process protein then it can derive from the breakdown of protein, in addition to its other essential nutrient benefits.

Additionally, protein/amino acids are generally the last source of energy the body uses, because it saves them for building and repairing tissues and compounds. Complex carbohydrates are very important to maintain blood sugar levels and provide a constant dietary source of high energy. Studies also show that fat burns better when carbohydrates are present in the diet. Also, maintain supplement intake as required.

Regarding additional exercise. Stick to the core strength training and endurance exercise program as determined by the specific sport requirements. For sport training programs that do not include daily aerobic activity, incorporation of 40 minutes of aerobic exercise into the exercise schedule, four to five days per week during fat-loss cycle, may be needed.

Remember, aerobic exercise uses a higher proportion of fatty acids as fuel, whereas strength training uses mostly muscle glycogen. Maintaining a daily exercise program will also help keep up your metabolic rate, maintain or increase lean body mass, and keep up your fat-burning enzyme levels. High-Intensity Interval Training can additionally add benefits depending on the athlete's performance training program.

Regarding establishing the ultimate percentage body fat reduction, and goal percentage body fat mass, this should be accomplished working with the athlete's team and or sport's organization guidelines and doctor.

Jump-Starting the Fat-Loss Program

Rate of fat loss will be determined by individual genetics, body type, metabolism, nutrition, and exercise program. Ectomorphs (naturally lean people) will have the easiest time losing fat but find it hard to gain muscle. Mesomorphs will also able to lose fat easily and can put on muscle mass the easiest. Endomorphs, who tend to carry more body fat, can lose fat at a good rate, but need to make sure to stick to a low-fat nutrition program, keep up on strength and aerobic exercise, and use the Fat Loss Tips, as they will probably benefit from them the most. Endomorphs may also find it beneficial to raise their protein levels up to 25 to 30 percent of total daily calories, which is accommodated by reducing carbohydrate and fat intake. The relative proportions of reducing carbohydrate and fat intake may vary depending on how much fat and carbohydrate each athlete is consuming to start with. It is important to maintain a healthy minimum intake of essential fatty acids. Reduction of carbohydrate intake also needs to be done cautiously as not to jeopardize health or physical performance.

Some individuals may find it helpful to give their fat-loss program a "jump start" by depleting their glycogen system, thereby encouraging greater use of body fat stores. To do this, one approach is to reduce carbohydrates, along with calorie deficit, during the first day or two of the fat-loss program. The reduction of carbohydrates can be similar to what is presented Unit 19 about Glycogen Loading, the depletion phase. Eating plenty of healthy low-calorie, low-starch vegetables and the daily protein required amount should be part of the nutrition program. This should help deplete muscle glycogen stores and cause a loss in water weight, too, that is stored with glycogen. It will also get fat stores liberating fatty acids for energy. Follow this jump-start diet for one or two days; then slowly phase in carbohydrates over the next two to three days. Following this approach should only be considered during the off-season by healthy people under physician approval and supervision. Be aware that depleting glycogen stores will reduce mental and physical performance and, depending on the individual, can cause low blood sugar-associated problems, like dizziness. Therefore, this approach may not be suitable for everyone, and some mild side effects are expected to occur.

Make sure that body composition is measured once a week while on a fat loss program to monitor body composition changes. Additionally, make sure athletes are not losing lean body mass, unless, as in some situations, reduction of lean body mass may be desired along with reduction of body fat mass.

Fat-Loss Tips

- Never skip meals.
- Exercise daily.
- Maximize the thermogenic effect by keeping protein levels up, increasing activity, and taking supplement factors.
- Vigorous resistance training will maintain or increase lean body mass (muscle). Muscle burns calories, which means that, for every pound of muscle gained, you will be burning more calories and increasing the rate of fat loss.
- Do not drastically reduce total daily caloric intake.
- Reduce fat intake to less than 25% of total daily calories.
- Increase foods high in fiber and low GI complex carbohydrates to help satisfy hunger.
- Avoid foods high in salt and fat, such as all processed foods and snack foods.
- Eat fresh foods, organic when possible.
- Do not fry foods or use oil or fat in the cooking process. Instead, bake, broil, boil, grill, or microwave foods.
- Avoid using heavy sauces on foods.
- Read food nutrition labels. Look for foods that have less than 2 grams of fat per 100 calories.
- Eat fat-free foods.
- Eat low-fat protein foods.
- Use low-fat protein supplements to help meet daily protein requirements.
- Eat egg whites as a snack to help reduce hunger pangs at night.
- Do not eat out daily and avoid eating fast foods. These foods are usually high in fat, salt, and calories.
- Eat plenty of low-starch vegetables.
- Do not overeat excess calories at any meal because this will promote fat-storing enzymes and metabolism to store excess food as body fat.

Fat Loss during the Athletic Season (not preferred)

Fat loss during the athletic season should be undertaken at a much slower rate than in the off-season, if required. Do this by reducing total daily calories by only 2 calories per pound of lean body mass. This will result in a slower rate of fat loss but may avoid or minimize adverse effects on athletic performance that would result from a higher rate of fat loss. However, ideally athletes should lose body fat during the off-season and early preseason.

The Gender and Age Gap When Losing Fat

The above fat-loss approach is intended for healthy adult males and females, under doctor supervision. Men tend to lose fat and gain muscle more easily than women do because of their hormonal differences, particularly testosterone. Testosterone is higher in men, which gives men the ability to maintain a higher proportion of muscle mass and a higher metabolic rate than women can.

A woman's hormonal system resists changes in body composition as a protective mechanism to conserve energy stores while pregnant. Women therefore may tend to lose fat at a slower rate and find it hard to maintain body fat levels below 16 percent. As men and women age (get older), reduction of body fat stores may occur at a slower rate. This should not discourage anyone but should rather underscore the importance of establishing realistic, lifelong goals. These include following a balanced nutrition plan and keeping up with a daily exercise program that best suits the individual athlete's needs.

Why Most Fat-Loss Diets Fail

Athletes usually do not have a problem losing body fat when they stick to the targeted fat-loss approach discussed above. The primary problems they may have encountered in the past had to do with the quality of weight loss. Fat loss, muscle loss, and water-weight loss results from gimmick diet plans that are unbalanced in essential nutrients and too low in calories. By following the above approach, athletes should easily start to lose body fat and reach their realistic, new body composition goal.

Most of the population is interested in quick weight-loss gimmicks that are easy to use. Dieters want a magic pill or food that melts away fat. Although many of these diet programs can reduce weight, evaluations report that they have less than a 10 percent success rate in keeping the weight off. This is because these plans do not use realistic menus and do not advocate sensible exercise. They also result in loss of lean body mass, which means lowering metabolic rate, leading to *low calorie dieter's syndrome.* When you lose lean body mass, even if reducing body fat, the percent body fat may not change, or even increase if the amount of lean body mass lost is greater than the amount of body fat lost. Avoid weight-loss gimmicks that are not for athletes. Avoid fad weight loss too!

Important Rules for Making Performance Nutrition Work for an Athlete's Fat-Loss Program

Sound athletic nutrition is not always an easy job. But it is something every athlete should follow. Although it is not always practical to eat 100 percent properly, attempts to do so will make athletes better competitors. Listed below are some suggestions for good athletic eating habits, whether an athlete is trying to lose fat, gain muscle, or simply maintain body composition.

Rule One

Always eat at least five (5) meals a day. Two or three meals simply aren't often enough. If muscles don't get the calories they need, how are they going to keep going? By cannibalizing muscle tissue! Space meals accordingly, similar to when following a sports nutrition program. Meal spacing may be about every three to four hours but could vary depending on each person's daily schedule and rate of digestion.

Rule Two

Remember the 1-2-3 rule. In each of your five or more meals, approximately 1 part of the calories should come from fats, 2 parts from protein and 3 parts from carbohydrates.

Here's an example. Let's say an athlete eats 600 calories five times a day. That's 3,000 calories. If he or she is following the 1-2-3 rule, each meal is broken down like this:

100 calories from fat,

200 calories from protein, and

300 calories from carbs.

This is a general rule to follow. You can also use the worksheet and food charts to make a more specific dietary intake plan for specific individual needs. The important thing to remember is that when following this plan, when reducing calories, do not cut back on protein calories: cut back first on fat, simple carbohydrates, and then on complex carbohydrates. Keep protein intake the same as determined by daily activity. Note that Athlete-Type Nutrition Plan examples can also be used.

Rule Three

When you sit down to eat, ask yourself, "What am I going to be doing for the next three hours of my life?" Then, if you're taking a nap, eat less; if you're planning on a training session, eat more, and so forth. Remember, when overeating at a meal, the excess calories get stored as fat. If a meal is skipped, do not eat to make up for it: eat for what is required based on post-meal activity.

Rule Four

ZIGZAG caloric intake for reducing body fat mass or increasing lean body mass. Depending on the main body composition goals, this approach involves increasing or reducing caloric intake for four to five days, followed by normal caloric intake for two to three days. Refer to the respective sections of this unit for details. The basic idea to this approach is to avoid reducing basal metabolic rate that is common with reduced calorie diets that are sustained for many weeks or months. When a person stays on a negative caloric diet too long, his or her body's BMR will drop in response to it, causing low calorie dieter's syndrome. To avoid losing lean body mass when reducing body fat mass, and to avoid increasing body fat mass when increasing lean body mass, caloric intake should be zig-zagged.

Rule Five

The final rule of thumb for serious athletes is that no matter how hard they try:

- You can't always eat perfectly balanced meals;
- You can't always eat five or six times daily;
- There are many instances in which your body requires certain nutrients in greater amounts than what can be derived from diet alone; and
- With today's advanced nutritional and botanical sciences, we now know that there are many substances (both synthetic and those provided by nature) that aid in taking you far beyond the performance limits that are possible through diet alone.

Make use of dietary supplements to fill in essential nutrient gaps and, when required, under physician supervision, use additional specialty fat-loss aid supplements. The use of specialty fat-loss supplements will depend on the issues being experienced by the athlete, such as poor appetite control or a sluggish fat-burning metabolism.

Here are examples of some fat-loss aid supplements based on independent research and natural health products approved in Canada for weight reduction purposes. Also, note that meal replacement food products, technically not supplements, can often play a role in a fat-loss program.

Supplement Weight-Loss Aid Examples.

Includes clinically researched ingredients that are either approved as Natural Health Products in Canada, or Received Positive Weight-Loss Benefits reported in "Dietary Supplements for Weight Loss

Fact Sheet for Health Professionals," Office of Dietary Supplements, National Institutes of Health, and subject to multiple clinical research studies. Consult products for directions and dosages, under physician supervision.

African Wild Mango – *Irvingia gabonensis*	Glucomannan
Caffeine (alone and in combination with other ingredients, like green tea extract)	Green Coffee Bean Extract
L-carnitine	Green Tea and Green Tea Extract
Chitosan	5-HTP
Chromium (extra)	Pyruvate
Conjugated Linoleic Acid (CLA)	White Kidney Bean Extract

Note: Supplement weight loss aids may be effective along with a weight loss diet and exercise program, to increase rate of weight loss, in studies that compare ingredients to placebos. Studies are typically short term, a few to several weeks or months, under doctor and researcher supervision. Supplement weight loss aids typically have a wide range of effectiveness depending on each person's metabolism, diet, activity level, and genetics. In other words, the same supplement weight-loss aid ingredient that may be effective for one person, may not exhibit the same effectiveness for another person. This is not intended to be an exhaustive list of all the possible supplement weight loss aids, just examples of some of the ingredients with clinical research evidence, official approvals, and or recognition by authoritative bodies.

The Zigzag Method of Fat Loss

"I eat like a BIRD, and I still gain weight!"

"No matter WHAT I do, I get fatter and fatter!"

"All I have to do is SMELL food and I put on weight!"

Anyone who has been around the fitness world for any length of time has heard these complaints. Even athletes and bodybuilders preparing for competition often have trouble shedding those last couple of pounds of third-place-rendering, muscle-masking ugliness called adipose.

Scientists have long known that stringent dieting causes a corresponding drop in resting metabolic rate (called "basal" metabolic rate, or "BMR"), making it difficult—often impossible—to continue the fat-shedding process. Scientists at the University of Pennsylvania performed a 48-week research study, which explored this phenomenon. They arrived at some intriguing findings that you – elite athlete or couch potato – can benefit from. The study involved 18 women weighing an average of 216 pounds at the beginning of the research period. Half received a 1,200-calorie per day diet, and the other half received 16 weeks of a common meal replacement liquid followed by a conventional weight-reducing diet. All the women walked to increase their caloric burn.

While the BMRs of both groups fell after five weeks, it fell significantly more for those taking the meal replacement supplement (the more stringent of the two experimental treatments). Their BMRs quickly returned to a level considered normal for their new (lower) bodyweight. After the 48 weeks, the BMRs of both groups had dipped an average of 9 percent, and their percentages of body fat had dropped an average of 16–19 percent.

Now, what's interesting about this study's findings (other than the relatively predictable outcome that the crash dieters weren't any better off than the moderate dieters were after 48 weeks) is that scientists had previously assumed that any reduction in body weight triggered a permanent corresponding drop in BMR. A permanently lowered BMR would mean that a dieter would not burn calories as rapidly and might therefore regain the lost pounds or have real problems shedding more pounds.

Of course, the mechanism responsible for this highly undesirable turn of events is the loss in lean muscle. It's simple: bigger muscles burn more calories than little muscles. And if you are losing weight from both fat and muscle, your ability to continue losing fat—and keep it off—is literally sacrificed.

Scientists are finally beginning to garner some hard data supporting what experts of "Irondom" have known for a long, long time. That is, there's a way to lose fat and maintain a reasonably high BMR so your fat-loss process can continue smoothly. It's called the "zigzag" method of fat loss, and it works better than any fat-loss method there is. Why? It's permanent. Permanent, that is, if you continue to eat five or six smaller meals per day and exercise regularly. It also allows you to maintain (or improve) your lean muscle mass.

Refer to the following tables for examples. You'll notice that as you reduce your caloric intake and increase caloric burn, body fat percentage drops correspondingly. But so does your BMR. Then,

Ineffective Bodyfat Reduction Plan

200 lbs.	200 pounds & 30% bodyfat					
190 lbs.						
180 lbs.						
170 lbs.				170 pounds & 30% bodyfat		
160 lbs.						
150 lbs.						
140 lbs.	140 pounds lean bodyweight					
130 lbs.						
120 lbs.				119 pounds lean bodyweight		
110 lbs.						
100 lbs.						
Week	1	2	3	4	5	6

This individual actually lost 21 pounds of muscle and only nine pounds of fat! He'll yo-yo back up to 200 in no time (within one to two years, according to information compiled during the Congressional investigation into the fat-loss industry). However, in doing so, he will be 35% body fat instead of his original 30%. Why? He will never regain all of the lean tissue he lost as a result of his crash-dieting earlier. This same scenario happens over and over to men and women alike.

Effective Bodyfat Reduction Plan

200 lbs.	200 pounds & 30% bodyfat					
190 lbs.						
180 lbs.						
170 lbs.				170 pounds & 10% body fat		
160 lbs.				154 pounds lean bodyweight		
150 lbs.						
140 lbs.	140 pounds lean bodyweight					
130 lbs.						
120 lbs.						
110 lbs.						
100 lbs.						
Week	1	4	8	12	16	20

By following the five rules of performance nutrition, this client gained 14 pounds of quality muscle (and a greatly amplified metabolic rate and immune competence). An effective nutritional strategy allowed him to lose 44 pounds of body fat!

to force your BMR back to a normal level, begin eating normally again for a brief period.

What happens is that body fat level again begins to climb but not as high as it was at the beginning. Then you lower caloric intake again; down goes body fat. Eat normal again, and up the body fat goes -- again, not so high as it was before. This process continues until body fat percentage is at healthful levels.

By zigzagging your caloric intake like this, you ultimately allow periodic BMR adjustments to take place, bringing it back to a level corresponding to your new (lower) bodyweight. Then it's easy to begin losing fat again—and again. If you simply try going down, down, down in body fat, your BMR never has a chance to adjust, and your fat loss efforts become harder and harder until, in thorough frustration, you binge out and get fat again—forever. This also will help you get over or avoid the phenomenon of plateauing, when a person loses several pounds of fat, then stops losing. When most people hit a plateau, what do they do? They reduce caloric intake, which is wrong. You now know that this just adds to the problem, by further dropping BMR. Zigzag calories up, and BMR will be readjusted higher, to burn more calories.

An important key to the entire process is weight training. Without the weight training, your lost weight will be from lean tissue, NOT only fat! And don't try to do it too quickly! Even with weight training, starvation diets will cause too much muscle loss rather than sheer fat reduction. Walking is OK for those considered "chronically" fat. And for those who are only slightly overweight, other forms of aerobic exercise are excellent for maintaining great cardiovascular

fitness. But even for such people, weight training stands out as the single best method there is for ensuring that gradually lost weight will come from fat stores, and not hard-won muscle tissue. Why? Because aerobic training simply does not build muscle to the extent that weight training can. In fact, aerobic training alone will reduce your lean body mass, and drop your BMR. This means you need to exercise to burn more calories. On the other hand, if you gain 5 or 10 pounds of muscle, you are burning more calories all the time, even when you are sleeping.

Further, when you couple the zigzag method and weight training with moderate aerobic exercise and a careful diet and supplement program, you will be amazed at how easy it is to lose fat and how utterly enjoyable it is to keep it off forever. Your new lifestyle will ensure that!

Finally, for diehard athletes or fitness enthusiasts who insist on becoming fat between contests or during the winter months of inactivity, I have only a couple of things to say: 1) change your slovenly ways, or 2) if not, be prepared to suffer the indignation associated with being overweight, always "on a diet," and stuck in a rut wherein you never quite realize your true potential as an athlete.

Muscle Gain Approach

The muscle building/bodybuilding market continues to grow. Just walk into a health food store and you are faced with hundreds of muscle-building products. They range from powders to sophisticated kits. Gaining muscle is just as scientific as losing fat is and requires a specific training and nutrition program. When athletes want to build muscle mass, they can follow the nutrition and training guidelines given for bodybuilders as a starting point. This is an effective approach for increasing muscle mass and reducing body fat. As with fat loss, muscle building should be undertaken in the off-season. Preseason and in-season efforts should focus on strength training and maximizing athletic performance for the particular sport; noting that increase in muscle mass can occur as a side benefit.

Many books will mislead you into thinking that gaining muscle weight is a matter of just increasing caloric and protein intake. Not so. Athletes must primarily be following an effective weigh-training/resistance-training program that is designed for muscle building. That's right. Not all weight-training programs result in optimum muscle gains. In fact, most of the weight-training programs labeled "strength training" will build muscle but are more focused on building strength and power. These performance factors are important but can be worked on in the preseason after gaining desired muscle mass. In addition, the muscle-building and development goals of each athlete must be considered to best result in being compatible with overall athletic performance training program.

Set realistic muscle gain goals and focus on the long term. An athlete's ability to gain muscle will vary considerably and depends on your body type, gender, age, and current training status. Mesomorph men tend to be able to pack on muscle the fastest. Endurance athletes will initially find that due to their previous training, and training-induced muscle fiber content, they will gain muscle more slowly. Can an athlete gain 30 pounds of muscle in a year? This is possible, but do not be discouraged if the rate of muscle gain is slower based on each athlete.

Here are some tips for a muscle-gaining program.

- Add 2 calories per pound of body weight to the daily caloric intake for 4 to 5 days, and then reduce caloric intake to normal caloric body-weight maintenance levels for 2 to 3 days.
- If body fat levels are increasing too much, try for a week or longer the previously mentioned fat-loss approach, which can be cycled into the muscle gain program. This may slow down the increase in lean body mass, but some increase in lean body mass is usually possible with targeted fat loss. Then once body fat levels are reduced to the desired levels, return to the muscle-gaining program by adding 2 calories per pound of body weight, and so on.
- Some athletes may be able to add more than the 2 calories per pound of body weight to the daily caloric intake, which can be experimented with by closely monitoring changes in body composition to determine rate of lean body mass increase and rate of body fat mass increase.
- The added calories should be mostly protein and some complex carbohydrates (no added fat calories).
- Spread these added calories equally among at least five meals per day.
- Evaluate using a bodybuilding/strength athlete nutrition program model during

off-season, when compatible with overall sport specific program or with appropriate sport-specific modifications.

- Then in the preseason, follow sport-specific strength-training program to maximize strength and power and athletic performance for the sport.
- Include some of the well-established muscle- and strength-building supplements such as creatine in addition to multivitamin/mineral supplements and other supplements as required.
- Eat a least five meals per day, increasing caloric intake strategically to result in increased lean body mass, not excess body fat.
- Have body composition measured at least weekly to determine where changes in body composition are occurring: body fat mass or lean body mass.
- Consume organic foods when possible.
- Eat fruits and nuts for energy boost.
- Eat more complex carbohydrates; whole grain rice, pasta, potatoes, whole grain breads, and beans.
- Eat whole foods instead of processed foods.
- Eat sport nutrition bars that are low fat, high carbohydrate and high protein.
- Because most people find it hard to eat all the required food, try eating low-fat, high-protein weight-gain drinks as a snack or as part of a meal.
- Remember not to overdo the protein at each meal; the body can only effectively digest and assimilate about 20 to 40 grams of protein per meal, but this may vary from person to person.
- Evaluate performing weight training in two shorter sessions per day to maximize anabolic hormones and optimize nutrient intake.
- Keep the dietary fat intake low.
- Eat high-quality, low-fat protein like egg whites, chicken, turkey, tuna, lean meats, low-fat dairy, and protein supplements.
- Consume the recommended healthy daily intake of fruits and vegetables.
- Do not overtrain. Overtraining—which is defined as "cumulative microtrauma"—actually stimulates the release of catabolic hormones, like cortisol, which break down muscle. Weight train at the appropriate level of fitness, beginner, intermediate, advanced, or elite. Give the body a chance to repair muscle and connective tissue with adequate rest and sleep each day and adequate intervals of rest from day to day based on resistance-training intensity and an individual's rate of recovery.
- Keep adequate body composition and training records and evaluate regularly
- Make adjustments to an athlete's caloric intake and nutrition program as determined by the progress in gaining lean body mass and changes in body fat mass and overall body weight.

Note that individuals with low body fat levels should be aware that they might have to increase their caloric intake levels higher than the average guidelines to avoid having too low body fat mass levels, which can be unhealthy or lead to disqualification in some sports.

Constructing a Custom Nutrition Plan for Fat Loss and Muscle Gain

If you find that the rate of fat loss or muscle gain is not occurring at the rate you want, you may have to get more specific with dietary intake than the general guidelines provide. First determine daily protein intake and then building carbohydrate intake on top of this. As most protein sources contain 10 to 50 percent of calories from fat, you want to keep added fat low during a fat-loss program, especially unhealthy saturated fats. When you ZIGZAG caloric intake, it is best to keep protein intake the same and cut back on fat, simple carbohydrates, and then complex carbohydrate intake if needed. The intake of protein is vital to maintaining and building lean body mass and adding a thermogenic effect to the diet. Note that when doing this, the percentages of protein:carbohydrate:fat will change from the starting values.

The following will provide an example for a more specific nutrition plan for reducing calories per day.

Example person will be male, 190 pounds, 22% body fat.

Lean Body Mass = 190 × .78 (78%) = 148.2 lbs.

From Units 14/15, add in daily range of caloric requirements for the different activity levels.

	BMR	130%	155%	165%	200%	230%
Calories	2073	2424	2892	3078	3731	4291

Determine Protein Intake from Unit 4: Using 148.2 pounds LBM and a need factor of .7, for sports participation or moderate training, 3 × per week, the protein requirement is: 105 grams per day. Protein intake can also be determined based on the sports-specific nutrition plans, using percentage of total daily calories needed. As with other nutrient intake approaches, fine-tuning will be required as the program progresses and as body composition and other data are collected and evaluated.

Thus, for a typical training day, this person would need 2,892 calories, containing 105 grams of protein. But remember you will be cutting back on calories for fat loss, by about 600 to 800 per day.

Divide protein intake by 5, to spread over 5 meals. That is:
105 grams/5 = 21 grams of protein per meal.

* Use the chart on the following page as a worksheet

Daily Food Intake Worksheet for Fat Loss or Weight Gain.				
Calories Per Meal Rest Day	Calories Per Meal Training Day Intake	Daily Protein Intake	Daily Carbohydrate Intake	Fat Intake
Meal 1	Meal 1			
Meal 2	Meal 2			
Meal 3	Meal 3			
Meal 4	Meal 4			
Meal 5	Meal 5			
Meal 6	Meal 6			
Meal 7	Meal 7			
Note: This approach is intended for the special conditions of losing body fat or building muscle mass, or both. For performance nutrition, follow sport-specific guidelines on caloric intake and protein, fat, and carbohydrate percentage intake.				

Daily Food Intake Goal Examples (estimates)

Listed below are food guidelines that range between 2,500 calories per day and 3,500 calories per day and that are designed for a lean reference individual of 175 pounds. The daily caloric intake can be adjusted by adding or subtracting about 1-2 servings from each food category, noting that suitable protein intake should be maintained, along with other essential nutrients. Spread out food intake over five to seven meals per day to match caloric demands following the meal. Following these food intake guidelines results in a 20% Protein, 60% Carbohydrate, 20% Fat diet. One of the performance nutrition plans can also be used as a guideline to be modified to best suit the individual athlete. Refer, too, to the Dietary Guidelines and DASH diet for additional examples and healthy eating considerations.

Choose whole foods, whole grains, and organic foods when possible.

Daily Food Intake Examples (estimates)

Listed below are food guidelines that range between 2,500 calories per day to 3,500 calories per day and are designed for a reference individual of 175 pounds, who is lean. If you are lighter or heavier, you can adjust the daily caloric intake by adding or subtracting about one serving from each food category. Spread out food intake over five to seven meals per day to match you caloric demands following the meal. Following these food intake guidelines result in a 20 percent protein, 60 percent carbohydrate, and 20 percent fat diet. You can also use one of the performance nutrition plans presented in Chapter 17.

Food Group	Suggested Servings Per Day	Serving Size
Fruits Citrus, melon, berries and other fruits	4 to 6 servings Fresh fruit preferred	1 whole fruit (like apple, banana. pear, orange); 1/2 grapefruit; 1/2 melon wedge; 3/4 cup of juice; 1/2 cup of berries; 1/2 cup cooked or canned fruit; 1/4 cup dried fruit
Vegetables Dark-green leafy vegetables and other non-starchy vegetables.	5 to 8 servings Include a diversity of vegetables each day	1/2 c cooked vegetables 1/2 c chopped raw vegetables 1 c leafy raw vegetables like lettuce or spinach
Complex Carbohydrates Bread, Cereal, Grains, Pasta, and starchy vegetables. (Whole grains)	11 to 14 servings Include several servings of whole grain products daily.	1 slice bread. 1/2 hamburger bun or English muffin. 1 small roll, biscuit or muffin. 4 crackers. 1/2 cup cooked cereal, rice or pasta. 1 ounce of breakfast cereal. Maintain intake of healthy complex carbohydrates, from whole grains, and low to medium glycemic index foods, limit high GI foods.
High Protein Foods Meat, poultry, fish, and other seafood. Also beans, protein and carbs.	3 to 4 servings Choose lean cuts of meat (trim the fat), skinless chicken and turkey or fish. Avoid over fatty meats.	Amounts per serving should range 5 to 7 ounces of cooked lean meat, poultry, or fish a day. Count 1 egg, 1/2 cup cooked beans, or 2 tablespoons of peanut butter as 1 ounce of meat.
Dairy Milk, cheese, and yogurt	2 to 3 servings per day. Choose low fat dairy products whenever possible to reduce fat intake	1 c milk, 8 oz yogurt, and 1 1/2 oz cheese.
Water/Fluids	Drink 8 to 12, 8-ounce glasses of water each day. Additional guidelines in Unit 6.	Plain filtered water, diluted fruit juices, and low-cal beverages.
Fats	Minimize consumption of dietary fats, saturated fats, and cholesterol.	Use food preparation methods that use little or no added fats or oils.
Sweets/Sugar	Minimize high ingestion of sugar and foods containing high sugar content.	Simple carbs from mostly fruits, and for special sports energetic purposes, sports nutrition preparations in moderation.
Alcohol	Avoid drinking alcoholic beverages. Or if you do drink, do so in moderation. Never do so before athletic events or during athletic season or other periods banned by sports governing bodies	Drinks containing 1 to 2 ounces of alcohol per day are considered to be moderate consumption. Low alcohol content beverages like beer and wine, with health benefits may be a top choice based on each individual.

Conclusion

Weight control: this refers to achieving and maintaining a healthy weight with healthy eating and physical activity

Weight control. Body composition management for athletes is an important factor for achieving and maintaining peak health and athletic performance. Weight-loss adjustments should ideally be targeted at adjusting body composition levels like body fat mass and lean body mass (principally skeletal muscle). Adjustments in body composition should be made off-season/early preseason when possible, especially for losing excess body fat mass, which requires creating a daily caloric deficient and can impair athletic performance for many types of athletes, but which will vary based on individual athlete and type of sport. Note that muscle mass can be increased concurrent with reduction of body fat mass. Gaining muscle mass (which is typically accompanied with the increase in other lean body mass, such as bone, connective tissues, and body water), depending on the sport, may include off-season, preseason, and athletic-season periods. Gaining muscle typically involves excess caloric consumption; therefore, athletic performance from calorie deficits is avoided. Whatever the weight-control or body composition management goals are for individual athletes, a top priority is an athlete's health and athletic performance goals.

Use of Dr. Hatfield's ZIGZAG method is proven approach to accomplish weight control and body composition management goals of healthy adult athletes, with applications for nonathletic adults, too. Physician and other applicable health professional supervision will determine an individual's state of health and the suitability of weight loss or weight gain approaches, including any health issues requiring special medical attention that are common in people with excess body fat.

Key Word

Weight control

Topics Covered In This Unit

UNIT 19

GLYCOGEN LOADING (SUPER COMPENSATION)

Unit Outline

I. **Introduction**

II. **Why "glycogen" loading (supercompensation) for athletes?**

III. **Glycogen-loading science**

IV. **Glycogen-loading (supercompensation) origins**

V. **Glycogen-loading (supercompensation) approaches overview**

  a. Traditional glycogen loading (carbohydrate loading approach)

  b. Modified glycogen-loading approaches

  c. International Olympic Committee 2000 glycogen-loading approach

  d. ASC glycogen-loading 2009 approach

  e. Military research study

VI. **Glycogen-loading considerations**

  a. For glycogen-depletion phase

  b. For glycogen-loading phase

VII. **Creatine with glycogen loading?**

VIII. **Conclusion**

Learning Objectives

After completing this unit, you will be able to:

- Define and describe terms related to glycogen loading;
- Discuss how glycogen loading works in the body;
- Understand the glycogen loading methods; and
- Determine which types of sports athletes can benefit from glycogen loading.

Introduction

Skeletal muscles use carbohydrates as a main source of energy during high-intensity exercise and competition to maintain high-level skeletal muscle contractions. Dietary carbohydrates can be used for energy production and can also be converted into glycogen and stored in muscles and the liver. When a person is at rest, the body burns carbohydrates and fats for energy production, the rates of which depend on level of fitness, training (aerobic or anaerobic athlete), and the composition of the diet. But as training intensity is increased, carbohydrates become the more dominant source of fuel for muscles. At very high training intensities, carbohydrates become utilized at even higher rates of energy production. This is true for endurance and strength sport activities.

Additionally, glycogen supply is usually much more limited than body fat stores are. It is therefore paramount to make sure an athlete's glycogen stores are at their maximum, replenished daily, and sparing glycogen loss with dynamic carbohydrate intake. One exception to this glycogen status would be during carbohydrate-loading approaches that first require glycogen depletion, followed by glycogen replenishment to achieve super-loaded glycogen stores.

As reviewed in Unit 3, glycogen is a type of polysaccharide branched molecule made of glucose, found in the cytosol/cytoplasm of cells. The amount of water stored in association with glycogen is estimated to be about 1 part glycogen to 3 to 4 parts water; for example, 1 ounce glycogen with 3 to 4 ounces water, or 1 gram of glycogen with 3 to 4 grams of water. Any athlete considering carbohydrate loading should experiment/practice with it during the months preceding the competition season to see how the body responds and during the off-season, too.

The athlete's body also uses fatty acids for energy production; this tends to fuel the body at a slower rate than carbohydrate does. Note that once glycogen stores run low or run out, fatty acids are used as a dominant source of energy, and physical and even mental performance is decreased. Exercise duration can be shortened, and exercise intensity level can be reduced under low and/or depleted glycogen levels in the muscles and liver.

Additionally, when glycogen is depleted, the body uses a higher amount of amino acids from muscle tissue for energy and to manufacture glucose, which the body thrives on, especially to fuel the brain and high-intensity muscle contractions, along with some of the body's other functions. The depleted body glycogen means increased muscle tissue catabolism, which is undesirable. Glycogen depletion can occur during long duration training and competition.

Thus, while long-distance endurance athletes have been regarded as utilizing glycogen loading, carbohydrate loading may be suitable for other types of athletes, in particular during long competitions and those grueling tournaments. Glycogen loading aside, as reviewed in the Carbohydrate Unit, maintaining adequate carbohydrate intake daily is vital for all athletes, including before, during, and after training.

Why "Glycogen" Loading (Supercompensation) for Athletes?

Traditionally, the terms carbohydrate loading and carbohydrate supercompensation have been used in the research and various publications regarding sports nutrition, including in previous editions of this course book. However, from conversations I have had with students and athletes, and from conducting seminars with health professionals over the years, when discussing the ultimate reason of carbohydrate loading (supercompensation)—muscle and liver glycogen loading (supercompensation)—I have found that this shift in focus seemed to better connect with the various audiences. Therefore, in this updated edition, "Glycogen Loading (supercompensation)" is utilized, a phrase that also appears in research studies.

The phrase also connotes dynamic aspects, ranging from the traditional method of lowering carbohydrate intake to attempt to completely deplete muscle glycogen and liver glycogen stores, followed by increasing and maintaining high carbohydrate intake to replenish body glycogen stores to a higher level compared with normal conditions; to the modified methods that are more "carbing up" approaches to make sure body glycogen levels are filled up, with a bonus if they are higher than normal. In other words, athletes load up on carbohydrates to load up their glycogen stores: glycogen loading (supercompensation). However, with all the different approaches that have evolved during the decades, the primary outcome of a glycogen loading program is to increase glycogen body stores to above normal levels. But some of the more recently developed, modified glycogen loading approaches may be also suited for all athletes looking to maximize glycogen stores, in addition to the conventional long-distance endurance athletes who were the basis of developing glycogen loading in the first place.

Glycogen Loading Science

From reviewing the glycogen loading science, some insights in to the underlying metabolic aspects can be found. For example, on a fundamental basis, during glycogen depletion, catabolism is involved during the breakdown of the glycogen molecule, and liberation of glucose for energy, which is further catabolized by the cells to produce energy. During glycogen loading, anabolism is involved for the synthesis of glycogen molecules from glucose. As with most biochemical reactions, enzymes are involved. A core enzyme occurring in the body involved in the biosynthesis of glycogen you will read about is called glycogen synthase. Researchers observed that from depleting glycogen stores via exercise and also low glycogen levels in the body, glycogen synthase activity can be stimulated to replenish glycogen supplies. Of course, adequate substrate, such as glucose, is required to take advantage of the increased glycogen synthase activity to rapidly restore glycogen. Other enzymes are involved in the biosynthesis of glycogen, but glycogen synthase is considered to be a rate-limiting enzyme, so boosting its activity is a vital part of achieving glycogen supercompensation potential, along with maintaining an adequate supply of glycogen molecule substrate. In addition, adequate hydration, as water is stored along with the glycogen molecules.

Glycogen Loading Origins

Decades ago, scientists discovered that when glycogen is depleted, fatigue sets in and reduces work, physical, and athletic performance. Additionally, it was determined that when glycogen stores are depleted, they can hold more glycogen when replenished properly, to achieve glycogen supercompensation. Scientist then used this knowledge to devise a method of packing greater-than-normal amounts of glycogen inside athletes' muscles and liver tissues. This allowed long-distance endurance athletes to be able to run for longer periods without "hitting the wall." When the wall is hit, and high energy-yielding glucose becomes low or absent, when the body must rely on mostly fatty acids and amino acids and various metabolic by products, the bioenergetics of muscle contractions become reduced, slowing down even slow-twitch muscle fiber output, in addition to increasing the feelings of physical and mental fatigue. Therefore, with body glycogen depletion, athletes experience lower energy muscle contraction output, becoming fatigued sooner during exercise, and can also experience mental/cognitive fatigue. This depleted condition can also leave athletes susceptible to injury and potential adverse health events.

As the story goes, it is reported to be during the 1960s, that Scandinavian researchers (Bergstrom and Hultman for example) were experimenting with the different influences of diet manipulation on glycogen stores and exercise duration. Through their experiments using normal mixed nutrient diets, carbohydrate-free diets, and carbohydrate-rich diets, they found some interesting effects on exercise capacity. Additionally, intervals of heavy work were performed in association with the different diets. What they discovered was that when individuals underwent heavy exercise along with diets low in daily carbohydrate content, their work capacity was shortened. Then when these individuals consumed carbohydrate-rich diets for a few days directly following the period after their glycogen stores had been depleted, these people's exercise capacity significantly increased.

What was also determined was that muscle glycogen content was much higher than that attained when just following a normal mixed-nutrient diet. The traditional approach to carbohydrate loading was thus born—referred to as the classical approach or method.

This research led to the practice of glycogen loading; however, one drawback of this traditional approach is that athletes will experience very low glycogen stores for two or three days, which may interfere with training and cause some undesirable side effects. As carbohydrate loading is commonly used before important **endurance sport** competitions, this depletion could ironically hinder an athlete's performance. Further research conducted in the 1980s by Sherman and Costill shows that similar glycogen loading results can be accomplished using a modified nutrition/exercise regimen. About six days prior to the important competition, the athlete will gradually taper down exercise. Researchers found that when athletes use this modified approach, extremely high levels of muscle glycogen, similar to those reached using the traditional approach, are attainable.

Endurance sport: a sport that requires the ability to perform for long periods at low intensities, such as marathon running and cross-country skiing.

The roster of glycogen-loading scientists continues to grow as, each year, research is conducted investigating glycogen loading dynamics and searching for alternative approaches, new insights, additional sport applications, gender differences, and so on. The following section will present examples of some of the glycogen-loading approaches.

Glycogen loading is popular with long-distance athletes such as triathletes, cross-country skiers, cyclists, and long-distance runners. Other athletes continue to experiment with carbohydrate loading.

Athletes find that carbohydrate loading is especially beneficial during tournaments that demand participation in several events or matches that only last for a short period. However, athletes who need to meet weight-class requirements may find it hard to use glycogen loading because of the high-calorie intake required and the gain in water weight in the days leading up to the day of competition during loading, as water is stored with glycogen in the body, hydrated glycogen.

Sport activities that traditionally are expected to benefit by glycogen loading are generally sports that are long in duration and continuous, like long-distance running, in which glycogen depletion body stores may occur: generally, continuous endurance athletic events lasting more than 90 minutes, but depending on the intensity of the exercise, and starting body glycogen stores, athletic events over 60 minutes may be of concern for the onset of reduced physical and/or mental athletic performance. Additional factors involved carbohydrate consumption during exercise or sports events. Note that athletes competing in daylong tournaments may also benefit from glycogen loading along with ingesting carbohydrate drinks during the tournament and a high-carbohydrate diet. And at certain times, all athletes who need to make sure their glycogen stores are at capacity may experience benefits following one of the more recently developed modified approaches and following a sports nutrition program that provides adequate carbohydrate intake—in addition to the other essential nutrients.

Regarding the non-traditional types of sports, Aaron Raman and coworkers (2014) found improved physical performance among athletes in a squash match. These researchers used a 48-hour “Carbohydrate Loading” program and a simulated squash match. The squash match simulation was designed to mimic a five-game match lasting approximately one hour. Improved physical performance was measured for the carbohydrate-loaded athletes (48-hour high-carbohydrate diet, 11.1 grams per kilogram of body weight), compared with the athletes on low-carbohydrate diets.

Glycogen-Loading (Supercompensation) Approaches Overview

Experts who supervise athletes using glycogen-loading programs, and the athletes themselves, will attest to the reality that mastering glycogen loading can be just as challenging as is mastering their other athletic training, nutrition, and performance skills. Similar to other sports nutrition examples, the methods are general and need to be fine-tuned for each athlete. Mastering glycogen loading may take years to perfect for each athlete. However, as with other sports nutrition approaches, the payoff (improved athletic performance) can be worth the athlete’s painstaking effort and his or her expert support team.

There are a few ways to glycogen load. It’s up to the heath professional team and coach working together to determine which approach is suitable for their athletes. Together with integrated training, glycogen loading makes it possible to significantly load up more glycogen than normal into muscle cells and other body tissues: supranormal glycogen tissue levels.

Glycogen supercompensation or loading methods can follow two phases:

- Glycogen depletion phase in which the amount of glycogen is depleted to some degree by dietary manipulation, moderate calorie restriction, or increased training duration that is sufficient to deplete muscle glycogen stores. Note that the muscles being used in the athletic event need to undergo the glycogen storage depletion exercises. In addition, it seems that based on ongoing recent research, the glycogen depletion phase may be shortened or even eliminated for some athletes and situations.
- Glycogen replenishment phase in which training intensity and duration are reduced (exercise taper) and dietary carbohydrate content is greatly increased. Concerns about the duration of the exercise taper associated with the different glycogen loading approaches can be an issue with some athletes and their coaches and need to be personalized to best meet an athlete's competition preparation goals, which can also include exercise taper days and rest day(s) leading up to the competition.

Traditional Glycogen-Loading (Carbohydrate Loading) Approach

The following presents an overview of the Traditional Glycogen-Loading Approach, also referred to as classic or original. Note from the start that although this Traditional Approach can be effective for most long-distance endurance athletes, there has been a trend by coaches and athletes to follow less grueling modified or alternative glycogen loading approaches—ones that are more pre-event schedule friendly and with fewer or no annoying potential side effects that may arise from the traditional approach.

- **Glycogen-Depletion Phase, typically three days, starting six to seven days prior to the athletic event day.** Diet is very low in carbohydrate content, as low as 100 grams per day, about 15 to 20 percent of total daily calorie range. The diet should be high protein and high lipid, in proportions that works best for the individual athlete. Right from the start, it is apparent how this traditional approach glycogen depletion diet gained a reputation for being "unpleasant." Exercise or training is kept at a high- to moderate-intensity level to further assist in completely depleting glycogen stores along with maintaining the very low carbohydrate diet. Note that side effects from the very low carbohydrates can limit or make exercise or training hazardous (refer to comment section for details.) Dietary protein and healthy lipids are increased to higher than normal levels to compensate for the calorie deficiency from reducing carbohydrate content. You still want to try to maintain adequate total daily calorie intake. Including oily fish is an example of increasing both healthy protein and lipid content. Increasing consumption of healthy nuts and nut butters can increase lipid content of the diet. Note that nut butters can be used as spreads and added to sauces. Choose soft nuts and avoid hard nuts that entail chewing, which may damage teeth and interrupt athletic training and performance to repair. Adequate hydration should be maintained.

- **Glycogen Loading Phase, typically three days in duration, starting directly after glycogen depletion phase.** High carbohydrate about 60 to 70 percent of total daily calories; 400 to 700 grams per day. Adequate protein and lipid content, in proportions that works best for the individual athlete. Taper exercise: exercise or training intensity and duration is reduced to a low level, with a day of rest (no training) typically occurring the day before the athletic event. Adequate hydration should be maintained.
- **Comments.** Potential unpleasant side effects during the depletion phase may include ketosis; irritability; fatigue; nausea; hunger; muscle soreness; dizziness; hypoglycemia; metabolic upset from the low carbohydrate higher lipid diet; weight loss, primarily associated with glycogen depletion and glycogen bound water; and the potential for injury during training due to some these side effects, such as dizziness causing falling. Potential unpleasant side effects during loading phase might include weight gain from glycogen storage and associated glycogen-bound water and perhaps temporary muscle stiffness. Good to know about, but considered obsolete by many sports performance experts.

Modified Glycogen-Loading Approaches

With the decades that passed since the development of the Traditional Approach, many sports scientists have conducted and continue to conduct research regarding modifying or alternative glycogen loading procedures. This is in attempt to overcome some of the scheduling and/or annoying side effect issues sometimes encountered with the Traditional Approach. The following overviews present a range of dynamic modified glycogen-loading possibilities, based on the numerous studies conducted after the original Traditional Approach research studies were conducted.

- **Glycogen Depletion Phase.** Either eliminate or modify the depletion phase approach, compared with the traditional approach. For example, afternoon or evening glycogen-depletion training session, followed by low-carbohydrate meal and evening snack; overnight fast during sleep. The next morning, start high-carbohydrate loading. Or if energy levels are adequate, perform another training session for further glycogen depletion, followed by starting the high-carbohydrate-loading diet. The low-carbohydrate diet approach can be varied. For example, following the traditional method's lead, very low-carbohydrate intake reduced to about 100 grams per day, while increasing healthy lipids and protein intake to maintain an athlete's specific daily caloric needs, noting that known side effects will occur. A low-carbohydrate range of about 30 percent to 50 percent of total daily calories is also associated with reducing glycogen levels. Note that when very low and low-carbohydrate diets are followed during the glycogen-depletion phase, three or four days of high-carbohydrate glycogen-loading diet should be followed for a higher level of body glycogen restoration. Adequate hydration should be maintained.
- **Glycogen-Loading Phase.** Although there is some indication that one or two days of high-carbohydrate diet glycogen loading may be sufficient to increase body glycogen levels, three to four days is likely more appropriate and may result in higher body glycogen levels. Keep in mind that for each athlete, you need to evaluate how much extra body glycogen storage above normal will benefit each one's competition athletic performance the most. Exercise taper (reducing exercise/training duration and intensity) should occur, leading typically to a day of rest prior to the day of competition as appropriate to each athlete and the duration allotted for the loading phase. High-carbohydrate diets may range from 60 to 70 percent carbohydrates of total daily calories. On a body weight basis, an example range is 8 to 12 grams of carbohydrate per kilogram per day. Maintain adequate protein and essential lipid intake. Adequate hydration should be maintained.
- **Comments.** When you determine a modified glycogen approach to follow, remember that long-distance endurance athletes will likely benefit most from some type of low-carbohydrate glycogen depletion followed by three to four days of high-carbohydrate glycogen-loading diet. Middle-distance endurance athletes who might benefit from glycogen loading could likely benefit from the less stringent high-carbohydrate glycogen loading diet approach for one to three days, without the glycogen depletion phase, or from simply trying the overnight glycogen depletion strategy.

This overview of modified approaches exemplifies the need for personalization by experienced health professionals to best suit an athlete's specialized performance nutrition needs. Fitness trainers and other health professionals who are new to glycogen loading and who want to become experts should team up with an existing glycogen-loading expert to develop some supervised hands-on experience. How many times per season an athlete may be able to handle this is also a consideration. Some of the research reports a few times per year for the extreme traditional approach, whereas others indicate higher frequency per season may be possible with a suitable modified glycogen-loading approach. One thing is certain: adult athletes who are new to glycogen loading should approach first using this performance-boosting nutrition approach in the preseason under health expert supervision, well before the competition season, to determine how their body responds to it and to establish which modified glycogen loading approach works best.

International Olympic Committee 2000 Glycogen Loading Approach

The IOC 2000 glycogen loading approach is worth mentioning, as it appears in the 2000 "Nutrition in Sport" publication by the IOC Medical Commission and International Federation of Sports Medicine and is relied on by many sports nutrition experts training Olympic athletes. The approach is located in Chapter 7 Optimization of Glycogen Stores, written by John L. Ivy. Following a detailed review of the numerous related scientific studies, some recommendations are made. Some crucial points of the recommendations for endurance athletes include:

- Hard training bout performed seven days prior to event;
- During the next three days, employ moderate-intensity and -duration training, a well-balanced mixed diet of 45 to 50 percent carbohydrate composition; and
- During the next three days, taper training. Increase carbohydrate content to 70 percent of total daily calories, which should promote glycogen loading/supercompensation, similar to the traditional/classic approach, with less stress and fatigue.
- Additional details can be found in the referenced chapter by J. L. Ivy.

ASC Glycogen Loading 2009 Approach

In 2009, the Australian Sports Commission published a modified glycogen/carbohydrate-loading approach that is much simplified. As the ASC and IOC work closely together, it is useful to be aware of the ACS's 2009 approach, details of which can be found on its website. Note that with this approach, there is no glycogen-depletion phase. It reports that leading up to the competition day, use one to four days of exercise taper, along with following a high-carbohydrate diet. The guidelines for a high-carbohydrate diet prescribe daily carbohydrate calculated on a body weight basis: 7 to 12 grams of carbohydrate per kilogram of body weight per day to elevate glycogen levels. Therefore, for example, daily carbohydrate for a 70-kilogram athlete would be 490 grams (about 1,600 kilocalories) to 840 grams (about 3,360 kilocalories).

Military Research Study

From a historical point of view, it is interesting to include information and a copy of research conducted by the military regarding glycogen loading. The research study report is titled "Manipulation of Muscle Glycogen Concentrations Using High and Low Carbohydrate Diets and Exercise Report No T32-87." The US Army Research Institute of Environmental Medicine, Natick, Massachusetts, conducted this research in August 1987. The research team sought to evaluate the effectiveness of the classical approach (somewhat) and to establish exercise and diet examples that could be used for military personnel and for future studies.

It is important to note that this research did not include physical performance effects of glycogen loading. It sought to establish a program to accomplish glycogen loading. This research report is worth reading and keeping as a resource for those interested in glycogen loading for a number of reasons. The complete diets for the depletion and loading phases are included, which could be used as starting point to customize for athletes. During glycogen depletion, average carbohydrate intake each day was about 118 grams (16.5% of total daily calories), protein 142 grams (19.9% of total daily calories), and fat 206 grams (64.8% of total daily calories). During glycogen loading phase, average carbohydrate intake each day was about 517 grams (63.7% of total daily calories), protein 115 grams (14.2% of total daily calories); and fat 86 grams (24% of total daily calories).

Here is the "somewhat" part of the story. The male subjects were not competitive endurance athletes. In addition, the discussion section of the research study explained that the depletion phase and loading phase were separated by some time, not directly one before the other. It was also noted that some research subjects did the loading phase part of the experiment first and then the depletion phase. It was interesting that the loading phase did result in a significant increase in glycogen store levels, which the researchers noted supports other research about achieving adequate muscle glycogen levels without previously depleted glycogen stores, but reducing physical activity along with employing a high-carbohydrate diet.

Glycogen Loading and Gender Differences

Though some differences have been reported in the various scientific studies regarding glycogen-loading effects for males and females, Jennifer Wismann and Darryn Willoughby noted in their 2006 review study titled "Gender Differences in Carbohydrate Metabolism and Carbohydrate Loading" that female athletes do have the capacity for glycogen supercompensation at levels comparable to males when fed comparable amounts of carbohydrates relative to lean body mass. This statement was based on the results of research conducted by Dr. James and coworkers, 2001. Both males and females were able to attain supranormal muscle glycogen levels. Here are some interesting points:

- The James study used endurance-trained female and male subjects.
- These subjects ingested 12 grams of carbohydrate per kilogram of lean body mass per day.
- This was in conjunction with the cessation of their daily physical training.
- A three-day exposure to this diet resulted in a marked rise in muscle glycogen levels.
- Comparing female and male athletes on a lean body mass basis did not show any differences.

Glycogen-Loading Considerations

The following includes some additional information or considerations for the glycogen-depletion and glycogen-loading phases.

For Glycogen-Depletion Phase

Extra niacin may help speed up glycogen depletion. For example, two days prior to glycogen depletion and on the first day of the program, taking extra amounts of niacin and or pyridoxine (1 to 2 mg per pound of lean body mass each day for example) may increase the rate of glycogen depletion by stimulating greater rate of release from glycogen body stores. In addition, use of protein supplements to achieve the higher dietary protein intake required during the low-carbohydrate diet phase may help increase the rate of glycogen depletion. Maintain adequate hydration.

For Glycogen-Loading Phase

Some extra vitamins and minerals may help increase the rate of glycogen loading. For example, taking extra amounts of chromium with each meal may be beneficial: 1 to 2 micrograms per pound of lean body mass each day, spread out in two or three divided dosages, is one example, but needs to be determined on an individual basis. Chromium is an essential mineral nutrient that is reported to enhance the action of insulin, a hormone involved in the metabolism and storage of carbohydrate (including glycogen), fat, and protein in the body.

Primary carbohydrate food sources should be healthy complex carbohydrates during both phases. Depending on each athlete's ability to digest that high-carbohydrate glycogen-loading diet, fiber content may have to be reduced. For a one-day method, higher amounts of faster digesting complex carbohydrates, short-chain **glucose polymers**, and simple carbohydrates may be beneficial.

Glucose polymer: a processed form of polysaccharides, or complex carbohydrates.

Use carbohydrate supplements that are low in fiber and fat and protein free and that consist mainly of glucose-polymers and maltodextrin in addition to glucose. In addition, sucrose may be useful as appropriate in the context of the total glycogen-loading program. High glycemic index carbohydrate supplement consumption may generally be focused during and post exercise/training.

Drink a complex-carbohydrate beverage before bedtime and upon waking; for example, 400 to 600 calories per serving, noting that more or less may be needed based on the individual athlete's requirements. Protein and micronutrients may also be present depending on each individual athlete's digestion receptiveness. Use of a mixed-carbohydrate and protein supplement drink post-exercise/training may help increase the rate of glycogen replenishment leading up to the post-exercise meal, but after the immediate intake of faster digesting water and carbohydrate beverage that should be ingested right after exercise.

Maintain adequate hydration all day.

Including fructose as part of the daily beverages and food intake, in moderation, may provide certain glycogen-loading benefits. Fructose has a low glycemic index rating and is reported to replenish liver glycogen stores, noting that muscle glycogen has a higher affinity for glucose; however, glucose can also replenish liver glycogen stores. But do not overdo fructose intake, as it may cause gastrointestinal upset and, for some individuals, may contribute to fatty liver condition. Sucrose contains glucose and fructose, so this can be an option as a supply of fructose along with glucose, in moderation, for the days of glycogen loading. Examples of some fructose-containing fruits and fruit products are presented from the USDA Food Composition Database presented in the following table.

Creatine with Glycogen Loading?

Various studies have examined the effects of creatine loading along with high carbohydrate intake during the glycogen-loading phase. Although mixed results have been reported in the scientific literature, a study conducted by Paul Roberts and coworkers reported the results in 2016 in their research journal article titled "Creatine ingestion augments dietary carbohydrate mediated muscle glycogen supercompensation during the initial 24 hours of recovery following exhaustive exercise in humans." In this study, healthy male volunteers who were recreationally active, not highly trained, and had an average age of 26 years old participated. An exercise bout of cycling to exhaustion to help reduce body glycogen levels was undertaken. This was followed by a daily high-carbohydrate diet and 20 grams of creatine per day taken in divided dosages. Muscle biopsy sampling was used.

Some Examples of Fructose-Containing Fruit and Fruit Product Examples from Usda.Gov Food Composition Database			
Fruit or Fruit Product	**Weight(g)**	**Measure**	**Fructose(g)Per Measure**
Apples, raw, without skin	110	1.0 cup slices	6.63
Applesauce, canned, sweetened, without salt (includes USDA commodity)	246	1.0 cup	17.88
Blueberries, wild, canned, heavy syrup, drained	319	1.0 cup	28.77
Cherries, sweet, raw	138	1.0 cup, with pits, yields	7.41
Cranberry sauce, canned, sweetened	277	1.0 cup	27.01
Currants, red and white, raw	112	1.0 cup	3.95
Grapefruit, raw, pink and red, all areas	230	1.0 cup sections, with juice	4.07
Grapes,	6	1.0 grape	0.24
Kiwifruit, green, raw	180	1.0 cup, sliced	7.83
Lemon juice, raw	244	1.0 cup	2.68
Lime juice, raw	242	1.0 cup	1.48
Mangos, raw	165	1.0 cup pieces	7.72
Orange juice, chilled, includes from concentrate, with added calcium	249	1.0 cup	5.55
Orange juice, chilled, includes from concentrate, with added calcium and vitamin D	249	1.0 cup	5.55
Orange juice, frozen concentrate, unsweetened, undiluted	262	1.0 cup	19.78
Papaya, canned, heavy syrup, drained	39	1.0 piece	2.64
Papayas, raw	145	1.0 cup 1” pieces	5.41
Pears, canned, light syrup pack, solids and liquids	251	1.0 cup, halves	12.8
Pears, raw	140	1.0 cup, slices	8.99
Persimmons,	168	1.0 fruit (2-1/2”	9.34
Pomegranate juice, bottled	249	1.0 cup	15.86
Tamarind nectar, canned	251	1.0 cup	15.24
Tangerines, (mandarin oranges), raw	195	1.0 cup, sections	4.68

The results indicate that subjects engaged in creatine-loading along with high-carbohydrate diet experienced faster and higher muscle glycogen rates, starting on day one, and continuing during the six-day glycogen loading periods, compared with subjects following the same high-carbohydrate diet, but without creatine supplementation. However, note that exercise performance after glycogen loading was not examined. This approach might have some application with competitive athletes but needs to be confirmed with athletic performance outcome studies. Students interested in the details can locate the complete study using the citation in the reference section. You should be familiar with these emerging research developments, but also be aware of the study's limitations: It did not demonstrate an athletic performance improvement outcome with the subjects, nor did the research examine effects with highly trained competitive athletes.

Conclusion

Glycogen loading (supercompensation) is one of the sports nutrition practice breakthroughs that continues to be useful and that has gained popularity and acceptance in various sports and among experts. For best results, athletes should determine the glycogen-loading method that works best for them months before the actual events for which competition-phase glycogen loading will be used. "Carbing up" and following a sports nutrition program that is adequate in carbohydrate content all the time can benefit athletes by helping them maintain the highest levels of athletic performance as part of a complete sports nutrition program of food and dietary supplements.

Key Words

Endurance Sport

Glucose polymer

Topics Covered In This Unit

UNIT 20

SPECIAL CONCERNS OF ATHLETIC FEMALES

Unit Outline

I. **Introduction**

II. **Female athlete triad**

   a. Who is at risk?

   b. Menstrual irregularities, an early warning sign

   c. Measures that can be taken to prevent the female athlete triad

III. **Adequate calcium and vitamin D intake and reduction of osteoporosis**

   a. From 21 CFR

IV. **Adequate folic acid and reduction of neural tube birth defects**

   a. National Center on Birth Defects and Developmental Disabilities (NCBDDD)

   b. From 21 CFR

V. **Conclusion**

Learning Objectives

After completing this Unit, you will be able to:

- Define and describe terminology related to the Female Athlete Triad;
- Discuss the symptoms that characterize the Female Athlete Triad;
- Understand which nutrient-related diseases of concern to female athletes can be reduced from adequate dietary intake from food and dietary supplements.

Introduction

Over the decades, as female participation in sports has increased, some gender-specific health concerns have become apparent. Medical findings indicate that while in general female athletes require nutrition similar to that of male athletes on a pound-for-pound basis, female athletes are at higher risk for developing certain poor nutrition-related disorders that can have serious health consequences.

Female Athlete Triad

Among female athletes, a set of symptoms is sometimes encountered, which has become termed the “Female Athlete Triad” and can have devastating adverse health effects for individuals who fall victim to it. It is important to note that although this education course content is relevant for adults, this health concern can occur in young female athletes as well. Additionally, the triad can inflict females who are not competitive athletes, including but not limited to fitness exercising clients.

This ISSA course was one of the first to educate health professionals about this important female athlete health issue. Subsequently, other education organizations have joined in the effort and have since published position papers noted in the reference section, and there is even a website-based international resource referred to as The Female Athlete Triad Coalition (www.femaleathletetriad.org) that can be consulted for the most recent developments for people interested in this topic, including your clients.

Being aware of this syndrome is critical for all health professionals and for female athletes under their supervision. This also underscores the importance of athletes being under the strict supervision of their physician(s) and other health professionals to create and implement a training and nutrition program that can prevent the female athlete triad from occurring in the first place and to provide prompt attention if it does in fact develop.

The female athlete triad is a disorder that usually occurs with increased frequency among female athletes and is characterized by disordered eating and menstrual irregularities, which eventually lead to osteoporosis and other potential health problems. The female athlete triad symptoms primarily include:

- **Disordered Eating** (abnormal/dysfunctional eating behaviors resulting in inadequate caloric and nutrient intake, with or without eating disorders);
- **Amenorrhea** (loss of menstruation); and
- **Osteoporosis** (disease associated with loss of bone tissue, bone fragility, and increased risk to bone fracture).

[Note that terminology related to the Female athlete triad is evolving, and there may be differences encountered in publications from organization to organization.]

Early diagnosis of the symptoms is critical to prevent severe health risks from developing. It seems that the onset of menstrual cycle irregularities is among the first clinical warning signs. This is a common condition among female athletes, which historically has been thought to be a trivial occurrence due to commonly resolving itself after the competition season. Medical researchers now consider this condition more serious. In addition, weight loss and low percentage body fat are other physical symptoms often associated with the triad and generally precede menstrual cycle irregularities. Another consideration is that inadequate nutrition, menstrual cycle irregularities, and osteoporosis can be health problems individually, without the presence of the complete triad symptoms.

Who is at risk?

Poor nutrition combined with strenuous athletic training is thought to be the root cause of the triad. Inadequate nutrition practices create energy and essential nutrient deficiencies. This then typically leads to a poor state of health, which is typically associated with loss in body weight. Loss in body weight can include reduction of body fat mass, lean body mass, and water weight. This condition triggers menstrual cycle irregularities, which should be considered early warning signs of overtraining and inadequate nutrition. If the condition is allowed to persist without corrective treatment, osteoporosis can develop, which leads to increased risk of bone fractures; a variety of other health problems related to poor nutrition can be present as well.

It seems that female athletes who are at highest risk participate in sports in which nutrition deficiencies are common; in other words, distance sports and sports in which body weight or appearance are important. These sports include long-distance running, cycling, and swimming; gymnastics; diving; figure skating; triathlon; dancing; rowing; martial arts; and other sports in which weight control is involved

as demanded by the sport or because of body image concerns. But female athletes in any sport can be at risk.

Disordered eating may or may not include eating disorders, such as anorexia or other psychiatric eating disorders. Beware that eating disorders do occur among female athletes and are another serious problem to be aware of and can certainly be involved in causing the triad. However, disordered eating, without an eating disorder, is generally considered abnormal eating patterns and includes poor nutrition habits, inadequate energy intake, inadequate essential nutrient intake, eating unhealthy foods “junk foods”; unneeded or extreme dieting; and use of purging and laxatives for unhealthy weight control. This leads to an energy deficit, decreased metabolic rate, metabolic abnormalities, hormonal imbalances, and reduced structure and function of the body. Disordered eating, with or without eating disorders, combined with intense athletic training often lead to health problems, including the Female athlete triad.

Menstrual Irregularities, an Early Warning Sign.

Many factors can cause menstrual irregularities; however, the primary cause that characterizes the triad is triggered by poor nutrition practices and intensive athletic training, which depletes the body's nutrient balance, causes calorie intake deficiency, reduces body fat mass, and alters body function. Eventually ovarian function becomes impaired and can even lead to a decrease in the production of estrogen and other hormones along with various hormonal imbalances.

Although amenorrhea is observed in a small percentage of nonathletic females, it can occur in much higher frequency among athletic females. There are two types of amenorrhea observed in the Female athlete triad: primary and secondary. Primary amenorrhea is when there is an absence of menstruation by age 15 or 16 in females with developed secondary sex characteristics. It is crucial to prevent the triad from every occurring in teenage female athletes. Any type of menstrual irregularities in teenage females should be given serious attention and prompt medical treatment.

Secondary amenorrhea occurs when there is an absence of three or more consecutive menstrual periods after menarche, not caused by pregnancy. More than 35-day intervals between menstruation may also be considered menstrual irregularity. If menstrual irregularity occurs, prompt medical attention is warranted, as it is with younger female athletes. According to the Office on Women's Health, US Department of Health and Human Services, you should be aware too that athletic training and associated health issues are recognized as contributing to female infertility in some instances. Note that other medical causes of amenorrhea may be present, which a physician can properly diagnose and treat: Turner Syndrome and hypothalamic or pituitary problems are examples of some other amenorrhea causes.

I thought exercise helps prevent osteoporosis; can you elaborate on this point?

Osteoporosis is the term used to describe a condition in which there is decreased bone mass, causing a reduction in bone mineral density and a reduction of bone strength, thereby leading to increased risk of bone fracture. Osteoporosis has several causes and is primarily thought of as occurring in older females. In fact, a program of exercise and proper nutrition can prevent and treat osteoporosis. However, medical researchers have made a connection between secondary amenorrhea and osteoporosis in athletic females. This causes weakened bones and leads to increased risk of bone fractures. For example, female runners with amenorrhea were reported to have lower bone density than normally menstruating runners. Researchers believe that if this condition is allowed to develop, normal bone formation may not be able to be restored, and the triad's osteoporosis may not be completely irreversible. Males are also at risk of osteoporosis due to poor nutrition consisting of inadequate energy and inadequate essential nutrient intake, in particular, calcium and vitamin D.

Measures That Can Be Taken to Prevent the Female Athlete Triad

First and foremost, an adequate sports nutrition program must be strictly adhered to under physician supervision and along with other health professionals as appropriate—such as nutritionists and fitness trainers. Behavioral therapy may also be required for some individuals, in particular, those with eating disorders. This means eating the proper amounts of carbohydrates, protein, and fats, spread out over five to seven meals per day from healthy nutrient-rich foods providing other essential nutrients like vitamins and minerals. Maintaining adequate fluid intake is also vital.

As required, taking dietary supplements can be needed to ensure intake of the essential macronutrients and micronutrients, especially calcium, magnesium, vitamin D, folic acid, and iron. In fact, the Food and Drug Administration has approved a health claim for foods and supplements high in calcium (over 200 milligrams) and vitamin D as being able to help prevent osteoporosis. A reprint of the corresponding FDA regulation for health product companies to follow in included under the next heading. Moreover, some research studies also reported the use of high-calorie meal replacement products and weight-gainer-type supplement beverages to help add extra calories and essential nutrients to the diet, which are also convenient and typically easier to consume, helping people who are under eating due to lack of appetite or who may have poor food and meal choices. These products would be used in addition to other required recovery medical therapies.

Corrective treatment may also require reducing exercise and training volume and frequency, restoring lean body mass, and increasing body fat composition to a healthy level. Drug therapy may also be warranted, which is another reason for primary treatment by a physician along with other health professionals, such as nutritionists and fitness trainers. Experts, such as Thein-Nissenbaum in the journal article titled "Long-term consequences of the female athlete triad," concluded that multidisciplinary management is strongly recommended. However, be aware that Curry and coworkers (2015) in a survey-based study of physicians reported, "Our findings suggest that approximately one-third of the physicians surveyed have heard of the triad. Increased awareness through education to properly identify and manage the triad is essential for all physicians"; so it is important for non-physician health professions to confirm that a client's physician is knowledgeable about this condition. Approximately one half of physicians were comfortable treating or referring a patient with the triad. Regarding athlete awareness, in 2015, Folscher and coworkers reported based on their survey of ultra-marathon runner female athletes that only about 7.5 percent were aware of the triad, and about 44 percent were at high risk for the triad. Thus, confirm your athlete clients are aware of the triad along other female clients who exercise regularly and may also be at risk.

It is also a useful practice (habit) to keep a training journal that documents athletic life, including medical history, medical exams, health problems, medication, nutrition logs, dietary supplement intake, sleep patterns, menstrual periods, behavior patterns, and training logs. This simple daily task, which only takes minutes a day, will prove to be extremely beneficial and result in improved athletic performance and optimum health.

Adequate Calcium and Vitamin D intake and Reduction of Osteoporosis

The following paragraphs are from the FDA regulations related to calcium and vitamin D health claims. This helps illustrate a few things, such as the FDA's strict regulations for foods and dietary supplements, the FDA's involvement in approving ingredients and the claims to be used in nutrition products, and the significant science that exists to back claims. Note, however, that other very lengthy documentation not included herein that was published by the FDA in the Federal Register presented scientific information, which interested readers can view online at the Federal Register website. Moreover, the actual amounts of calcium, vitamin D, and other essential nutrients required for prevention and treatment programs will depend on individual needs and often may exceed the dietary reference intake amounts.

From 21 CFR:

Sec. 101.72 Health claims: calcium, vitamin D, and osteoporosis.

(a) Relationship between calcium, vitamin D, and osteoporosis. An inadequate intake of calcium or calcium and vitamin D contributes to low peak bone mass, which has been identified as one of many risk factors in the development of osteoporosis. Peak bone mass is the total quantity of bone present at maturity, and experts believe that it has the greatest bearing on whether a person will be at risk of developing osteoporosis and related bone fractures later in life. Another factor that influences total bone mass and susceptibility to osteoporosis is the rate of bone loss after skeletal maturity. Vitamin D is required for normal absorption of calcium and to prevent the occurrence of high serum parathyroid hormone (PTH) concentration, which stimulates mobilization of calcium from the skeleton and can lower bone mass. Calcium, along with vitamin D and several other nutrients, is required for normal bone mineralization. While vitamin D is required for optimal bone mineralization, it is more effective when calcium intake is adequate. An adequate intake of calcium and vitamin D is thought to exert a positive effect during adolescence and early adulthood in optimizing the amount of bone that is laid down. However, the upper limit of peak bone mass is genetically determined. The mechanism through which adequate intakes of calcium and vitamin D and optimal peak bone mass reduce the risk of osteoporosis is thought to be as follows. All persons lose bone with age. Hence, those with higher bone mass at maturity take longer to reach the critically reduced mass at which bones can fracture easily. The rate of bone loss after skeletal maturity also influences the amount of bone present at old age and can influence an individual's risk of developing osteoporosis. Maintenance of adequate intakes of calcium and vitamin D later in life is thought to be important in reducing the rate of bone loss particularly in the elderly and in women during the first decade following menopause, but a significant protective effect is also seen among men and younger women.

(b) Significance of calcium or calcium and vitamin D. Adequate calcium intake, or adequate calcium and vitamin D intake, is not the only recognized risk factor in the development of osteoporosis, which is a multifactorial bone disease. Maintenance of adequate calcium and vitamin D intakes throughout life is necessary to achieve optimal peak bone mass and to reduce the risk of osteoporosis in later life. However, vitamin D is most effective in this regard when calcium intake is adequate. Increasing intake of calcium has been shown to have beneficial effects on bone health independent of dietary vitamin D.

(c) Requirements. (1) All requirements set forth in 101.14 shall be met.

(2) Specific requirements --(i) Nature of the claim. A health claim associating calcium or, when appropriate, calcium and vitamin D with a reduced risk of osteoporosis may be made on the label or labeling of a food described in paragraphs (c)(2)(ii) and (d)(1) of this section, provided that:

(A) The claim makes clear the importance of adequate calcium intake, or when appropriate, adequate calcium and vitamin D intake, throughout life, in a healthful diet, are essential to reduce osteoporosis risk. The claim does not imply that adequate calcium intake, or when appropriate, adequate calcium and vitamin D intake, is the only recognized risk factor for the development of osteoporosis;

(B) The claim does not attribute any degree of reduction in risk of osteoporosis to maintaining an adequate dietary calcium intake, or when appropriate, an adequate dietary calcium and vitamin D intake, throughout life.

(ii) Nature of the food. (A) The food shall meet or exceed the requirements for a "high" level of calcium as defined in 101.54(b);

(B) The calcium content of the product shall be assimilable;

(C) Dietary supplements shall meet the United States Pharmacopeia (USP) standards for disintegration and dissolution applicable to their component calcium salts, except that dietary supplements for which no USP standards exist shall exhibit appropriate assimilability under the conditions of use stated on the product label;

(D) A food or total daily recommended supplement intake shall not contain more phosphorus than calcium on a weight per weight basis.

(d) Optional information. (1) The claim may include the term “vitamin D” if the food meets or exceeds the requirements for a “high” level of vitamin D as defined in 101.54(b);

(2) The claim may include information from paragraphs (a) and (b) of this section.

(3) The claim may make reference to physical activity.

(4) The claim may include information on the number of people in the United States, including the number of people in certain subpopulations in the United States, who have osteoporosis or low bone density. The sources of this information must be identified, and it must be current information from the National Center for Health Statistics, the National Institutes of Health, or the National Osteoporosis Foundation.

(5) The claim may state that the role of adequate calcium intake, or when appropriate, the role of adequate calcium and vitamin D intake, throughout life is linked to reduced risk of osteoporosis through the mechanism of optimizing peak bone mass during adolescence and early adulthood. The phrase “build and maintain good bone health” may be used to convey the concept of optimizing peak bone mass. The claim may also state that adequate intake of calcium, or when appropriate, adequate intake of calcium and vitamin D, is linked to reduced risk of osteoporosis through the mechanism of slowing the rate of bone loss for persons with a family history of the disease, post-menopausal women, and elderly men and women.

(e) Model health claims. The following model health claims may be used in food labeling to describe the relationship between calcium and osteoporosis:

Adequate calcium throughout life, as part of a well-balanced diet, may reduce the risk of osteoporosis.

Adequate calcium as part of a healthful diet, along with physical activity, may reduce the risk of osteoporosis in later life.

(f) Model additional health claims for calcium and vitamin D. The following model health claims may be used in food labeling to describe the relationship between calcium, vitamin D, and osteoporosis:

Adequate calcium and vitamin D throughout life, as part of a well-balanced diet, may reduce the risk of osteoporosis.

Adequate calcium and vitamin D as part of a healthful diet, along with physical activity, may reduce the risk of osteoporosis in later life.

[73 FR 56486, Sept. 29, 2008]

Adequate Folic Acid Intake and Reduction of Neural Tube Birth Defects

While we are on the topic of special concerns of the female athlete, it seems appropriate for this unit to include nutrition-related birth defects referred to as neural tube defects—even though this is a concern for the general reproductive-age female general population along with athletic females.

Note that medically supervised folic acid supplementation or higher dosage prescription folic acid supplements may be effective in reducing the risk in some females; however, due to the potential multiple causes of these birth defects, there is a significant but less than 100 percent reduction rate. Moreover, as reported in the journal article "Epidemiology of Neural Tube Defects" (Frey 2003), in some high-risk females, the reduction from taking folic acid may not occur.

National Center on Birth Defects and Developmental Disabilities (NCBDDD)

The Centers for Disease Control and Prevention NCBDDD reports that worldwide, more than 300,000 babies are born with neural tube defects each year, serious birth defects of the brain (anencephaly) and spine (spina bifida). Neural tube defects are a significant cause of infant death and lifelong disability, and most are preventable. Research has shown that taking 400 micrograms daily of folic acid, a B vitamin, before and during early pregnancy, reduces the risk of neural tube defects (but higher dosages may be required based on individual requirements). NCBDDD has a global initiative to significantly reduce infant death and lifelong disability resulting from neural tube defects that occur worldwide each year. The initiative aims to increase folic acid intake among women of reproductive age through fortification and other means. Folic acid dietary supplements can be a viable and effective means to helping to reduce certain neural tube birth defects. The scientific evidence is so compelling that it supported the FDA's approving a health claim for conventional foods and dietary supplements.

The following is health claim regulatory information reprinted as yet another example of how the FDA does regulate dietary supplements in addition to conventional foods and other health products, and the important findings about folate and reduction of neural tube defects in infants that all females of reproductive age should be aware of.

From 21 CFR

Sec. 101.79 Health claims: Folate and neural tube defects.

(a) Relationship between folate and neural tube defects — (1) Definition. Neural tube defects are serious birth defects of the brain or spinal cord that can result in infant mortality or serious disability. The birth defects anencephaly and spina bifida are the most common forms of neural tube defects and account for about 90 percent of these defects. These defects result from failure of closure of the covering of the brain or spinal cord during early embryonic development. Because the neural tube forms and closes during early pregnancy, the defect may occur before a woman realizes that she is pregnant.

(2) Relationship. The available data show that diets adequate in folate may reduce the risk of neural tube defects. The strongest evidence for this relationship comes from an intervention study by the Medical Research Council of the United Kingdom that showed that women at risk of recurrence of a neural tube defect pregnancy who consumed a supplement containing 4 milligrams (mg) (4,000 micrograms (mcg)) folic acid daily before conception and continuing into early pregnancy had a reduced risk of having a child with a neural tube defect. (Products containing this level of folic acid are drugs). In addition, based on its review of a Hungarian intervention trial that reported periconceptional use of a multivitamin and multimineral preparation containing 800 mcg (0.8 mg) of folic acid, and its review of the observational studies that reported periconceptional use of multivitamins containing 0 to 1,000 mcg of folic acid, the Food and Drug Administration concluded that most of these studies had results consistent with the conclusion that folate, at levels attainable in usual diets, may reduce the risk of neural tube defects.

(b) Significance of folate --(1) Public health concern. Neural tube defects occur in approximately 0.6 of 1,000 live births in the United States (i.e., approximately 6 of 10,000 live births; about 2,500 cases among 4 million live births annually). Neural tube defects are believed to be caused by many factors. The single greatest risk factor for a neural tube defect-affected pregnancy is a personal or family history of a pregnancy affected with a such a defect. However, about 90 percent of infants with a neural tube defect are born to women who do not have a family history of these defects. The available evidence shows that diets adequate in folate may reduce the risk of neural tube defects but not of other birth defects.

(2) Populations at risk. Prevalence rates for neural tube defects have been reported to vary with a wide range of factors including genetics, geography, socioeconomic status, maternal birth cohort, month of conception, race, nutrition, and maternal health, including maternal age and reproductive history. Women with a close

relative (i.e., sibling, niece, nephew) with a neural tube defect, those with insulin-dependent diabetes mellitus, and women with seizure disorders who are being treated with valproic acid or carbamazepine are at significantly increased risk compared with women without these characteristics. Rates for neural tube defects vary within the United States, with lower rates observed on the west coast than on the east coast.

(3) Those who may benefit. Based on a synthesis of information from several studies, including those that used multivitamins containing folic acid at a daily dose level of 400 mcg (0.4 mg), the Public Health Service has inferred that folate alone at levels of 400 mcg (0.4 mg) per day may reduce the risk of neural tube defects. The protective effect found in studies of lower dose folate measured by the reduction in neural tube defect incidence, ranges from none to substantial; a reasonable estimate of the expected reduction in the United States is 50 percent. It is expected that consumption of adequate folate will avert some, but not all, neural tube defects. The underlying causes of neural tube defects are not known. Thus, it is not known what proportion of neural tube defects will be averted by adequate folate consumption. From the available evidence, the Public Health Service estimates that there is the potential for averting 50 percent of cases that now occur (i.e., about 1,250 cases annually). However, until further research is done, no firm estimate of this proportion will be available.

(c) Requirements. The label or labeling of food may contain a folate/neural tube defect health claim provided that:

(1) General requirements. The health claim for a food meets all of the general requirements of 101.14 for health claims, except that a food may qualify to bear the health claim if it meets the definition of the term "good source."

(2) Specific requirements --(i) Nature of the claim --(A) Relationship. A health claim that women who are capable of becoming pregnant and who consume adequate amounts of folate daily during their childbearing years may reduce their risk of having a pregnancy affected by spina bifida or other neural tube defects may be made on the label or labeling of food provided that:

(B) Specifying the nutrient. In specifying the nutrient, the claim shall use the terms "folate," "folic acid," "folacin," "folate, a B vitamin," "folic acid, a B vitamin," or "folacin, a B vitamin."

(C) Specifying the condition. In specifying the health-related condition, the claim shall identify the birth defects as "neural tube defects," "birth defects spina bifida or anencephaly," "birth defects of the brain or spinal cord anencephaly or spina bifida," "spina bifida and anencephaly, birth defects of the brain or spinal cord," "birth defects of the brain or spinal cord"; or "brain or spinal cord birth defects."

(D) Multifactorial nature. The claim shall not imply that folate intake is the only recognized risk factor for neural tube defects.

(E) Reduction in risk. The claim shall not attribute any specific degree of reduction in risk of neural tube defects from maintaining an adequate folate intake throughout the childbearing years. The claim shall state that some women may reduce their risk of a neural tube defect pregnancy by maintaining adequate intakes of folate during their childbearing years. Optional statements about population-based estimates of risk reduction may be made in accordance with paragraph (c)(3)(vi) of this section.

(F) Safe upper limit of daily intake. Claims on foods that contain more than 100 percent of the Daily Value (DV) (400 mcg) when labeled for use by adults and children 4 or more years of age, or 800 mcg when labeled for use by pregnant or lactating women) shall identify the safe upper limit of daily intake with respect to the DV. The safe upper limit of daily intake value of 1,000 mcg (1 mg) may be included in parentheses.

(G) The claim shall state that folate needs to be consumed as part of a healthful diet.

(ii) Nature of the food --(A) Requirements. The food shall meet or exceed the requirements for a "good source" of folate as defined in 101.54;

(B) Dietary supplements. Dietary supplements shall meet the United States Pharmacopeia (USP) standards for disintegration and dissolution, except that if there are no applicable USP standards, the folate in the dietary supplement shall be shown to be bioavailable under the conditions of use stated on the product label.

(iii) Limitation. The claim shall not be made on foods that contain more than 100 percent of the RDI for vitamin A as retinol or preformed vitamin A or vitamin D per serving or per unit.

(iv) Nutrition labeling. The nutrition label shall include information about the amount of folate in the food. This information shall be declared after the declaration for iron if only the levels of vitamin A, vitamin C, calcium, and iron are provided, or in accordance with 101.9 (c)(8) and (c)(9) if other optional vitamins or minerals are declared.

(3) Optional information --(i) Risk factors. The claim may specifically identify risk factors for neural tube defects. Where such information is provided, it may consist of statements from 101.79(b)(1) or (b)(2) (e.g., Women at increased risk include those with a personal history of a neural tube defect-affected pregnancy, those with a close relative (i.e., sibling, niece, nephew) with a neural tube defect; those

with insulin-dependent diabetes mellitus; those with seizure disorders who are being treated with valproic acid or carbamazepine) or from other parts of this paragraph (c)(3)(i).

(ii) Relationship between folate and neural tube defects. The claim may include statements from paragraphs (a) and (b) of this section that summarize the relationship between folate and neural tube defects and the significance of the relationship except for information specifically prohibited from the claim.

(iii) Personal history of a neural tube defect-affected pregnancy. The claim may state that women with a history of a neural tube defect pregnancy should consult their physicians or health care providers before becoming pregnant. If such a statement is provided, the claim shall also state that all women should consult a health care provider when planning a pregnancy.

(iv) Daily value. The claim may identify 100 percent of the DV (100% DV; 400 mcg) for folate as the target intake goal.

(v) Prevalence. The claim may provide estimates, expressed on an annual basis, of the number of neural tube defect-affected births among live births in the United States. Current estimates are provided in 101.79(b)(1), and are approximately 6 of 10,000 live births annually (i.e., about 2,500 cases among 4 million live births annually). Data provided in 101.79(b)(1) shall be used, unless more current estimates from the U.S. Public Health Service are available, in which case the latter may be cited.

(vi) Reduction in risk. An estimate of the reduction in the number of neural tube defect-affected births that might occur in the United States if all women consumed adequate folate throughout their childbearing years may be included in the claim. Information contained in paragraph (b)(3) of this section may be used. If such an estimate (i.e., 50 percent) is provided, the estimate shall be accompanied by additional information that states that the estimate is population-based and that it does not reflect risk reduction that may be experienced by individual women.

(vii) Diets adequate in folate. The claim may identify diets adequate in folate by using phrases such as "Sources of folate include fruits, vegetables, whole grain products, fortified cereals, and dietary supplements." or "Adequate amounts of folate can be obtained from diets rich in fruits, dark green leafy vegetables, legumes, whole grain products, fortified cereals, or dietary supplements." or "Adequate amounts of folate can be obtained from diets rich in fruits, including citrus fruits and juices, vegetables, including dark green leafy vegetables, legumes, whole grain products, including breads, rice, and pasta, fortified cereals, or a dietary supplement."

(d) Model health claims. The following are examples of model health claims that may be used in food labeling to describe the relationship between folate and neural tube defects:

(1) Examples 1 and 2. Model health claims appropriate for foods containing 100 percent or less of the DV for folate per serving or per unit (general population). The examples contain only the required elements:

(i) Healthful diets with adequate folate may reduce a woman's risk of having a child with a brain or spinal cord birth defect.

(ii) Adequate folate in healthful diets may reduce a woman's risk of having a child with a brain or spinal cord birth defect.

(2) Example 3. Model health claim appropriate for foods containing 100 percent or less of the DV for folate per serving or per unit. The example contains all required elements plus optional information: Women who consume healthful diets with adequate folate throughout their childbearing years may reduce their risk of having a child with a birth defect of the brain or spinal cord. Sources of folate include fruits, vegetables, whole grain products, fortified cereals, and dietary supplements.

(3) Example 4. Model health claim appropriate for foods intended for use by the general population and containing more than 100 percent of the DV of folate per serving or per unit: Women who consume healthful diets with adequate folate may reduce their risk of having a child with birth defects of the brain or spinal cord. Folate intake should not exceed 250% of the DV (1,000 mcg).

[61 FR 8779, Mar. 5, 1996; 61 FR 48529, Sept. 13, 1996, as amended at 65 FR 58918, Oct. 3, 2000]

Conclusion

Awareness about the female athlete triad for fitness trainers and other health professionals involved with athletes, coaches, parents, and the athletes themselves is of paramount importance for the prevention, and if the triad occurs, for the early detection and prompt physician-supervised medical treatment.

Key Words

Disordered eating

Amenorrhea

Osteoporosis

Topics Covered In This Unit

UNIT 21

PUTTING IT ALL TOGETHER:
ATHLETIC PERFORMANCE IMPROVEMENT APPROACH

Unit Outline

I. **Introduction**

II. **Legal aspects and limitations**

III. **Nutritional practices and coaching**

IV. **Dietary supplements**

V. **Training program considerations**
   a. Warming up and cooling down
   b. Flexibility training
   c. Strength training
   d. Periodization approach for skill training & conditioning

VI. **Psychological techniques**
   a. Meditation
   b. Visualization
   c. Anchoring and future pacing

VII. **Medical support team**

VIII. **Therapeutic modalities**

IX. **Avoid banned substances & methods**
   a. WADA (World Anti-Doping Agency)
   b. Prohibited list overview

X. **The next step for students**

XI. **Conclusion**

Learning Objectives

After completing this unit, you will be able to:

- Define and discuss key terms;
- Discuss athletic performance improvement factors;
- Understand periodized training program; and
- Discuss issues related to banned substances and methods.

Introduction

Whether an athlete's goal is to win the Olympics or just improve his or her level of fitness for health reasons, athletes need to address several factors in their personal performance-improvement programs to succeed. Primary among those factors are nutritional practices, dietary supplements, warming up and cooling down, strength training, skill training, flexibility training, psychological techniques, medical support, therapeutic modalities, periodization, and anti-doping.

ISSA-certified fitness trainers will benefit from their diversified experience and training. The approach to program development taught in their CFT course work, contained in the course book *Fitness: The Complete Guide*, is useful for addressing sports nutrition applications for athletic clients, too, as part of the entire athletic training and nutrition programs.

Here is a summary of the stages of Program Development, Drawing-in Phase:

- Stage One: Establish Yourself as a Professional.
- Stage Two: Data Collection.
- Stage Three: Guided Discovery.
- Stage Four: Feel the Water Before Jumping In.
- Stage Five: Establish an Integrated Fitness Lifestyle.

Utilize this ISSA Program Development approach when working with athlete clients, including with the athlete's health professional, coaching, teammates, and parent support team. All athletes should be under the supervision of their physicians and/or team physicians as appropriate.

Legal Aspects and Limitations

Each student/health professional must verify the legal requirements of working with healthy adult athletes related to the nutrition programs for health and athletic performance. The limitations of the information presented in this book include its being for education purposes and reference guidelines only. Suitability of any guidelines needs to be confirmed on an individual athlete's basis. Working with the athlete's physician and other health professionals as required. Personalization and suitability are crucial factors for athletic performance benefits of nutrition and training programs.

Nutritional Practices and Coaching

As this course has stressed from its very first pages, athletes do not eat solely to stay alive and healthy: they also eat to excel at their sports. Athletes' diets are designed to assist in achieving specific sport performance and training goals. Several special nutritional techniques also help in areas such as endurance and force output, the improvement of which further enhances training and competition efforts. Day to day, and even within the same day, there can be differences in nutrition intake that must be recognized and satisfied.

To put together the nutritional component of an athlete's performance-improvement program, begin with the dietary guidelines presented in the sport-specific plan as a starting guideline to personalize and determine suitability when working with healthy adult athletes. If there is a need to lose fat, build muscle, or carbohydrate load to improve performance, see the appropriate units for guidelines, noting this education information is for healthy adult athletes only.

Use Daily Nutrition Logs and other appropriate forms and planning tools to your liking. Keep a record of everything healthy adult athlete clients consume. This will let you stay on top of caloric and macronutrient intakes and helps fine-tune the diet. Do so in conjunction with the athlete's physician and other appropriate health professionals.

Examples of some common nutrition inadequacies with athletes during the season may in particular include:

- **Too low daily caloric intake.** This can be resolved by determining the athlete's daily caloric requirements, providing eating plan examples to attain the required daily caloric intake goals. Check body weight, body composition, and other anthropometric measurements to determine whether daily caloric intake is maintaining body weight and the desired body composition, such as lean body mass and body fat mass.
- **Too low daily protein intake.** Generally, all other nutrition factors being equal, loss of lean body mass can indicate too low protein intake.
- **Too low daily carbohydrate intake.** If daily carbohydrate is too low, along with total daily caloric intake being too low, weight loss can occur. If daily carbohydrate intake is too low, a decrease in athletic performance is commonly observed.
- **Too high fat intake.** Excessive dietary fat intake is a common occurrence with many athletes, which, for example, can lead to excessive body fat and displacement of protein and carbohydrates, reduce high-energy athletic performance, and promote inflammation in the body.
- **Hydration too low.** Measuring body weight several times a day, including before and after training and events, will provide insight as to whether water intake is not adequately replenishing water loss. Note: one approach for determining a well-hydrated body weight to serve as a baseline to compare with is after a period of two or three days of rest, with adequate hydration. Look for daily trends and for trends over several days. Body composition measurements will reveal additional details regarding changes in body fat mass and lean body mass (which water is part of).
- **Too low daily intake of essential vitamins and minerals.** Review of athlete's food diary will detect trend in all foods types and possible inadequacies, adequacies, and excess of micronutrients and macronutrients. A basic multivitamin/mineral supplement is routinely required as part of an athlete's nutrition program in addition to any other supplements that may be required for essential nutrients that cannot be provided from foods alone—on a consistent basis. Ideally, medical testing of nutrient levels will yield high-quality information to determine more exact nutrient deficiency, adequacy, or excess issues.

An up-to-date eating diary will help keep an athlete on the right track and provide a good update on the athlete's nutrition practices and areas to work on when required. Getting an athlete into the habit of keeping an eating diary will inherently help the athlete stick to the physician-authorized food and supplement programs.

Working with the athlete client's physician and other health professionals is vital to confirm the athlete's requirements, to confirm ongoing medical monitoring, and to be aware of any special nutritional needs. The athlete's nutrition and training coach can provide valuable support with winning results. Although surveys have reported there is a significant need for nutritional coaching, some teams do a better job than others do, and these better nutrition guidance teams will typically have nutrition reference guides published. For the fitness trainer involved with an athlete's nutrition coaching, it is beneficial to obtain copies these team nutrition guidelines when working with athletes. Note, however, it is common for team nutrition guides to have some areas in which they may be deficient in certain nutrition areas, typically protein and ergogenic supplements, and over relying on the various simple carbohydrate drinks and gels. Some team nutrition guides are also too high in total fat intake. There is also a major concern regarding the legal use of substances and methods. A following section of this unit will review the basics of this area.

Dietary Supplements

At a minimum, multivitamin/mineral supplements are part of an athlete's diet, and surveys on the supplement use by athletes reveal that multivitamin/mineral supplements have the highest frequency of use among athletes. Protein supplements are typically second highest frequency of us. Aside from supplementing the diet with macronutrients and micronutrients, athletes use a variety of dietary supplements for a number of purposes. There is also the wide selection of carbohydrate sports nutrition food and supplements ranging from carbohydrate/electrolyte drinks to simple carbohydrate syrups. The supplements' purposes include the following:

- To improve general health and fitness
- To build muscle mass
- To lose fat
- To improve anaerobic energy
- To improve aerobic energy
- To reduce fatigue
- To improve stamina
- To reduce pain and inflammation related to exercise
- To improve tissue repair
- To improve recovery
- To improve mental focus and arousal
- To improve strength
- To improve the immune system
- To improve sleep
- To maintain adequate essential nutrient intake

Each of these purposes is, in fact, included among most athletes' training goals at some point in their careers. It is therefore logical to conclude that athletes train, eat, and use supplements to enhance their planned progression toward their training and competition goals. Indeed, eating a proper diet and taking supplements are seen as part and parcel of a scientifically planned athlete performance nutrition and training program. A training program that did not include proper and personalized use of supplements could in fact be considered inadequate. As with other factors of a sports nutrition program, use of supplements will involve fine-tuning, seasonal change, and some evaluation for customization—even when using well-established and researched proven-to-work supplements, all under physician supervision, and when checking the use's legal status with the team's governing body.

Training Program Considerations

The following items will review elements and factors that are part of an athlete's performance improvement training program in addition to sports nutrition program development.

Warming Up and Cooling Down

Warming up generally consists of doing some calisthenics and stretching, followed by some training or undertaking a sport event or fitness activity. The main purposes of warming up are to raise the body temperature, increase circulation, and limber up the muscles and connective tissues. Depending on the sport and athlete, warm-up periods can be several minutes to more than 20 minutes. In addition to static slow stretching, athletes can include dynamic active stretching, too. Cooling down consists simply of reducing the intensity physical activity gradually as opposed to simply stopping it. The purpose is to ease breathing and heart rate back to their resting levels. This generally takes several minutes. In some sports, skill training can be combined with the warm-up and cool-down periods.

Flexibility Training

The first rule of flexibility is not to overstretch. When joints are stretched beyond their normal range of motion, they may become too loose and may actually become prone to injury. Do not compare athletes' flexibility to anyone else's. Everyone is different, and trying to be as flexible as someone else is can lead to overstretching.

If a particular joint or muscle group is inflexible, it may indicate that injury has occurred or that adhesions have formed. Proper medical attention may therefore be necessary. Inflexibility of a particular joint or muscle group may also be due to a muscle imbalance, which usually takes years to develop. Medical attention plus strength training may be required, and it can take months or even years to correct the problem.

Simply stretching as part of a warm-up before and after exercising may not be enough. A proper diet, strength training, skill training, and therapeutic modalities are all necessary factors that can contribute to ideal flexibility.

Some sports and fitness activities require more flexibility training than others do. Martial arts and ballet, for example, require a daily program of stretching. Powerlifting, discus throwing, and marathon running require less. Work closely with athlete clients to determine whether their flexibility is adequate for their sport activity and for general health and fitness.

Athletes should also consult an experienced sports massage therapist to determine whether there are problem muscles that are in spasm and need to be released. Note that if the muscle tissues are in a contracted and stiff state, and flexibility exercises are undertaken to improve range of motion, the connective tissues can become overstretched and lead to tearing or rupturing. An experienced sports massage therapist can usually identify the stiff muscles and work to release them, which can take a few to several or more sessions. Treatment by a sports medical physician and physical therapist may also be required. Athletes should make complete use of all the medical support team members they have access to.

Strength Training

Strength, simply defined, is applied force. When athletes lift a barbell, throw a ball, or even run, they are applying force, or using strength. Different actions use different kinds of strength. For example, some actions use aerobic strength, whereas others use anaerobic strength.

When most of us think of strength, we think of anaerobic strength-maximum or near-maximum force output that does not require the use of oxygen. But on the energy continuum, this is just one type of strength. The muscles also exert force during aerobic activities. Aerobic-strength training focuses on performing more muscle contractions with less force output. Furthermore, there are linear and nonlinear forms of strength. Linear-strength movements are movements performed repetitively without interruption, such as running strides. Nonlinear-strength movements come in bursts, such as the explosive plays of football and the jumping, starting, and dodging movements of basketball and soccer.

Another component of strength is power. The textbook definition of power is "force times distance divided by time," or "strength plus speed." Sprinters require massive amounts of speed-strength, which demands huge amounts of power output per contraction. Even long-distance runners, whose primary goal is the maintenance of speed, require some strength, which demands at least a modicum of power output per muscle contraction. Any muscle that contracts and relaxes exhibits strength, and every muscle contraction displays some combination of strength, power, speed, and endurance.

To condition the muscles to exert optimum strength and thereby enhance performance, a number of strength-training devices have been developed and are available in gyms or for home use. The best known are free weights. Also popular are the variety of systems that apply resistance to the muscles, such as hydraulic devices, pressurized-air devices, elastic devices, springs, and the host of machines that apply heavy external resistance. Most of these devices can be grouped into four major categories of strength-training technologies:

1. **Constant-resistance devices.** These are resistance-training devices in which the amount of weight (resistance) remains the same. Examples are dumbbells, barbells, and some pulley systems.
2. **Variable-resistance devices.** These are resistance-training devices in which the amount of weight (resistance) is increased or decreased during the exercise movement. Examples are the Nautilus and Cybex exercise machines.
3. **Accommodating-resistance devices.** These variable-resistance devices have been modified to allow maximum force to be exerted during the range of motion of the exercise movement, but they keep the speed of motion fixed. Examples are the Com II and Com III exercise machines.
4. **Static-resistance devices.** These are resistance-training devices that are immovable or fixed and designed to be pushed or pulled. They cause the muscles to contract without using motion. They can be used to focus strength development at a particular point in the range of motion. Examples are any of the exercise machines that can be locked into one position.

Another form of strength training includes any exercise in which the body alone is the source of resistance—for example, running, swimming, calisthenics, and aerobic dance. These exercises are called light resistance training. Another category of strength training utilizes machines that apply light external resistance, such as the stationary cycle, rowing machine, and stair-climbing machine.

With all these different training technologies and devices available, it is vital that athletes follow a program that is appropriate for the strength requirements of their specific sport and a nutrition program to meet the sports specific and health requirements. Following an incorrect strength-training program can actually have a negative effect on athletic performance. For example, if an athlete is a middle-distance or endurance athlete or fitness exerciser, he or she should not just go into a gym and start lifting weights like a bodybuilder or power lifter. Sure, the athlete will gain strength and, in the beginning, perhaps see some improvement in performance, but as anaerobic strength is developed, overall performance will begin to suffer. This does not mean that these types of athletes should not lift weights at all. Rather, they should train in a way that is appropriate for the sport-specific energetic goals.

Periodization Approach for Skill Training & Conditioning

Skill training and physical conditioning for sports are of paramount importance for peak athletic performance and typically fall in the coach's domain. Fitness trainers and other sports health professionals usually follow the coach's lead and established training programs.

However, there are also instances in which fitness trainers are expert coaches. That said, the common goal of the athlete's support is to work cooperatively to achieve what is in the best interest of the athletes and their individual and team goals.

Periodization is a quite sophisticated training concept used by professional and world-class athletes, which can also be used by other levels of athletes. With periodization, the year is divided into phases called macrocycles, with specific training goals set for each period of training. Four macrocycles are usually used, with each one lasting one to four months. Often, the macrocycles are further divided into mesocycles, which are several weeks long, and microcycles, which are several days long. The athlete's specific sport, skill level, and personal goals will determine how the year should be divided. Along with macrocycle training programs, macrocycle nutrition programs will be developed.

In general, a periodized training program includes the following:

Macrocycle I. Developmental phase, four months long. The training focus of this macrocycle should be on developing skills, defining physical performance parameters, adjusting body composition, and improving weaknesses and strengths. The training intensity should be moderate. Good health and performance nutrition goals should be established and followed. Use of special ergogenic sports nutrition foods and supplements can be evaluated during this period.

Macrocycle II. Preparation phase, three months long. This macrocycle immediately precedes the competitive season. The training focus should be on making final adjustments to body composition (preferably early in the macrocycle) and honing skills. The training intensity should go from moderate too high, over the course of the macrocycle. As the training program ramps up, so should the nutrition program, including use of special sports nutrition foods and supplements to confirm they are compatible and have no side effects.

Macrocycle III. Competition phase, four months long. The attention to training and good nutrition pays off during this macrocycle. The training focus should be on improving skills and physical performance factors that were found to be lacking after the first few competitions. The training intensity can reach extremely high levels throughout the macrocycle, with appropriate low- and moderate-intensity days for recovery. The sports nutrition program needs to be adhered to strictly, athletes must be monitored closely by their team of health professionals, and adjustments must be made to the nutrition program (fine-tuning) as required to maintain peak athlete performance.

Macrocycle IV. Recovery phase, one-month long. The goal of this macrocycle is to maintain fitness and flexibility. The training focus should be on healing injuries using professionally supervised therapeutic and nutrition programs. The training intensity should be low. During this macrocycle, plans for the following year's macrocycle should be made with input from the coach, trainer, fitness trainer, team physician, and other involved health professionals. Food and supplement nutrition programs should continue to be monitored to maintain the athlete's desired body composition and health and to address any special nutrition needs as determined by an athlete' physician.

Note that if athletes choose to let up on their nutrition program during this macrocycle, in addition to gaining excess body fat, this can cause undesirable metabolic changes that can take several weeks or longer to reacclimate their bodies to when the athletes return to the preferred athletic performance improvement nutrition program. Thus, while it is typical for some athletes to want to slack off and pig out, champions follow their healthy athletic performance nutrition programs all year long, year to year to year.

If a season runs longer or shorter than the typical four months used in this example, adjust schedule by modifying macrocycles I and IV. Do not change macrocycle II, which should always be three months long for the best results. A year-round training program will help athletes make steady progress toward their ultimate performance goals. The top athletes in the world train year-round to be their best.

Psychological Techniques

Self-hypnosis, mental imagery, meditation, visualization, and a number of other "mind strategies" can help you improve your strength and performance in competition and training. They can help athletes develop a mental edge and a winning mind-set.

Until recently, society generally overlooked the powers of the human mind. Other cultures place limitations on individuals and restrict their mental potential. The human mind has the capacity to store trillions of bits of information, more than the most powerful computers have. In fact, according to one progressive educational authority, the human brain has a greater storage capacity than the US National Archives have. Sadly, however, most people use only a small percentage of the mind's capacity.

For athletes, the mind is a powerful piece of "sports equipment," command central! Knowing how to maximize and control internal forces can offer athletes a big advantage in sports and life. Most athletes practice some kind of mental technique, even if it is just "psyching themselves up" before a competition. Among the more popular techniques practiced by athletes are meditation, visualization, anchoring, and future pacing.

Meditation

Meditation has been practiced since the beginning of recorded history. In its most fundamental sense, meditation is a technique in which you elevate your state of mind above the conscious to the unconscious. In other words, you clear your mind of all conscious thoughts and enter an altered state of consciousness, a state of relaxation and mental imagery.

In some approaches, practitioners examine the anatomical divisions of the brain and ascribe the power to meditate to the right hemisphere. In the contemporary model of the brain, the mind's logical functions (such as speaking, writing, calculating, and worrying) take place in the left hemisphere, whereas the more creative, visually orientated operations take place in the right hemisphere. Although this simple model of the human brain is constantly being updated and revised, of practical interest to us here is that even modern science recognizes the function and power of the creative right hemisphere. Put it in more practical terms, sometimes people tend to function from the left hemisphere, preoccupied with jealousy, insecurity, anger, and other negative thoughts that adversely affect their overall state of health and well-being. This type of thinking also distracts from athletic

performance focus. By meditating, athletes can open up and develop the powerful creative mind and use techniques such as visualization to help improve athletic performance and health. Other benefits of meditation include helping to relieve and manage stress.

Athletes and fitness trainers who are interested in trying meditation should seek the guidance of a trained professional.

Here are some general meditation guidelines:

- Plan to meditate at a time of day when you can relax and when you are not under the influence of a stimulant such as alcohol, a medication, or a recent meal.
- Find a quiet place away from distractions. Turn off the phone and create a comfortable, relaxing environment.
- Turn down the lights and sit in a comfortable position. If you wish, meditate in the dark while lying down.
- To meditate, first clear your thoughts. If you have trouble, try repeating the same word to yourself or focusing, with your eyes closed, on a bright object that you picture in your mind. Even beginners will find themselves slipping in and out of the meditative state. Your goal is the state between consciousness and unconsciousness, the point where the conscious and unconscious meet.
- Work up to meditation sessions lasting 30 minutes or longer if needed.

Whatever the exact physiological condition isthat your body enters into during meditation, one thing is certain: when you are done meditating, you will feel relaxed, refreshed, and renewed. And each time you meditate, the benefits will accrue. You will eventually find your general state of mind to be more controlled and less stressful. Meditation, therefore, is an important stepping-stone on the path to total empowerment. When you learn to control your thoughts and emotions, you will be on your way to mastering your sport and defeating your opponents. You will be on your way to success in life.

Visualization

Visualization is the technique of using mental imagery to picture your accomplishing a stated purpose. It is something like daydreaming, but more intense. Athletes can practice it as part of a meditation session, including helping them reach the meditative state.

Before beginning a visualization session, you must state your purpose. For example, your purpose may be to master a certain move or to prepare yourself mentally for a competition. Once you have stated your purpose, you must set your stage—that is, you must establish your setting and point of view before you bring on the "players." Then, begin the visualization, running a picture of yourself accomplishing your purpose over and over again in your mind. Visualize everything—all the sights, sounds, smells, and feelings. If you are preparing for a contest, visualize the specific moves you will use to defeat your opponent. Visualize everything you anticipate happening.

Visualization can be a powerful tool. Practice it regularly, for about 30 or more minutes per session. Increase sessions to once a day during the week before a tournament.

Anchoring and Future Pacing

Anchoring and future pacing are mental techniques related to meditation and visualization. Most people have experienced the sensation of having a memory triggered by a sight, sound, smell, or another stimulus. Perhaps a song on the radio makes you remember when you were a child playing with your best friend, or a sunset brings back memories of a romantic moment. Anchoring is a method in which you deliberately associate a stimulus with a particular experience. Your anchor can be a single stimulus, such as an internal verbalization, visualization, feeling, or smell, or it can be a combination of stimuli.

For an athlete, anchoring can be especially useful for tournaments and away games. When athletes practice in their regular environment, they can make a mental note of what it feels like to perform in home surroundings. When athletes win a competition, they can lock into memory the song that is playing as they accept the trophy, for example. Then, when they are in an unfamiliar environment, they can use the anchor to recreate these feelings and memories, helping them feel at home and reducing the intimidation of being in a strange place. This way, it is possible to recall the sights, smells, and sounds of being in a place that feels most comfortable and perhaps helping them perform at their best.

When you compete in a foreign environment, get to the location as early as possible. Find a quiet corner, meditate for a while, and visualize defeating the opponent. Then work out for a while, calling up an anchor to help feel as comfortable as possible. With practice as an athlete becomes comfortable with using anchoring as a technique, athletes will develop a routine that works best for their individual personalities.

Future pacing is similar to anchoring but focuses on future events, such as defeating an upcoming opponent. To future pace, visualize your anticipated performance and relate it to an anchoring stimulus. When the competition finally begins, use the anchor to stimulate yourself to play as well as you visualized. The goal is to do in reality what you picture yourself doing in your mind.

Medical Support Team

Medical support is a critical performance factor, and all athletes should be under the close supervision of their physicians and other required health professionals. Only qualified sports medicine specialists are allowed to prescribe such support. Sports medicine is a highly diversified and complex field, and fitness trainers should make an effort to know about the sports medicine experts in their area, the ones who may be involved with the athletes you are involved with. Preventive medicine is also an important factor. Athletes should keep copies of their medical records so they can share them with their team of health professionals.

Therapeutic Modalities

Whirlpools, electrical muscle stimulation, massage, ultrasound, light technologies, and a host of other therapeutic modalities can have an extremely positive effect on an athlete's training efforts, both directly (improve performance) and indirectly (how quickly an athlete can recover from training and events). Athletes should use all the medical and therapeutic options they have, effectively, safely, and promptly. Team athletic trainers, physicians, and coaches can be consulted to determine what medical support is available from the school and where gaps may exist for which additional sports medical expertise may be required.

There is nothing macho about letting injuries go unattended. When persistent pain is present, in addition to damage and injury from training and sports participation, pain can be a symptom of serious diseases, such as cancer, which does inflict some athletes. It is much smarter to address an injury when it occurs than to suffer the consequences when it heals incorrectly. Better yet, athletes should be proactive and make preferred therapeutic modalities a part of their preventive programs. Taking time during training for injury prevention might seem bothersome, but doing so will pay off in the long term in terms by promoting better athletic performance, prolonging an athlete's career, and fostering a healthier post-athletic career.

Avoiding Banned Substances & Methods

Avoiding the major tragedy of an athlete being disqualified because of banned substance use or methods is more than ever an important function of fitness trainers and others involved with training and supervising athletes. Awareness is a crucial factor, in that athletes must understand this topic, including confirmation that athletes you are involved with demonstrate proof of checking with their coaches and sports governing organizations. Proof can be in the form of showing the fitness trainer and other health professionals a printout of the sports organizations' rules and regulations regarding banned substances and methods. In addition, a fitness trainer's knowing about these topics provides valuable information for talking with athlete clients about this vital topic and knowing what to look for.

Today more than ever athletes are challenged with the temptation of using banned substances and practices. The Internet fosters even greater ability to purchase banned illegal drugs. But another consideration regarding illegal substances that are available is that they might contain other substances or drugs—some which can be hazardous to an athlete's health. Note that these illegal drugs commonly contain no drug. For some sports, readily available substances such as caffeine and alcohol are banned; as such, athletes in these sports can more easily violate the rules, which can lead to disqualification.

In addition to the specific sports governing organizations that have direct authority over the athletes, they can present information from one of the international organizations, such as WADA.

WADA (World Anti-Doping Agency)

The World Anti-Doping Agency (WADA) is an international independent agency, and its primary activities include scientific research, education, development of anti-doping capacities, and monitoring of the World Anti-Doping Code (Code) – the document harmonizing anti-doping policies in all sports and all countries. WADA is active in many areas related to anti-doping, including publishing the "prohibited list." The prohibited list is available for download from WADA's website:

https://www.wada-ama.org/en/what-we-do/prohibited-list

Prohibited List Overview

The prohibited list is updated regularly, so fitness trainers working with athletes should visit the WADA website a few times a year to determine whether they have the most current versions. The following table will summarize the main content headings included on the prohibited list. Some of the limitations apply for in and out of competition or in competition, which the official list will specify. Note that an APP for mobile devices is also available.

Prohibited Substances Categories	Examples
S0. Non-Approved Substances	Generally related to substances not addressed by any of the other sections of the list and those substances with no current approval for human therapeutic use, such as drugs.
S1. Anabolic Agents	Anabolic androgenic steroids, such as bolasterone, clostebol, nandrolone, testosterone, etc. And other substances with a similar chemical structure or similar biological effects(s).
S2. Peptide Hormones, Growth Factors, Related Substances, and Mimetics,	Erythropoietin-receptor agonists; hypoxia-inducible factor stabilizers; chorionic gonadotrophin and luteinizing hormone; corticotrophin and their releasing factors; growth hormone; insulin-like growth factor-1, etc.
S3. Beta-2-Agonists	All beta-2-agonists, with some exceptions noted.
S4. Hormone and Metabolic Modulators	Aromatase inhibitors; Selective estrogen receptor modulators; other anti-estrogenic substances; etc.
S5. Diuretics and Masking Agents	Desmopressin, acetazolamide, thiazides, etc.
S6. Stimulants	Non-specified stimulants such as adrafinil, cocaine, phentermine, etc.; specified stimulants such as, cathine, ephedrine, octopamine, selegiline, sibutramine, strychnine, etc.
S7. Narcotics	Buprenorphine, diamorphine (heroin), morphine, oxycodone, etc.
S8. Cannabinoids	Cannabis, hashish, cannabimimetics, etc.
S9. Glucocorticoids	All glucocorticoids.

Prohibited Methods	Examples
M1. Manipulation of Blood and Blood Components	Administration of red blood cell products; artificially enhancing the uptake, transport or delivery of oxygen; etc.
M2. Chemical and Physical Manipulation	Tapering to alter the integrity and validity of samples collected during doping control; intravenous infusions and/or injections; etc.
M3. Gene Doping	Transfer of polymers of nucleic acids; use of normal or genetically modified cells.

Substances Prohibited in a Particular Sport	Examples
P1. Alcohol	Air sports, archery, automobile, etc. Determined by analysis of breath and/or blood.
P2. Beta-Blockers	Beta-blockers are prohibited in competition only in certain sports and are also prohibited out of competition where indicated. Archery, automobile, golf, shooting, skiing, etc. Acebutolol, bunolol, esmolol, nadolol, pindolol, etc.

The Next Step for Students

Upon completion and certification, fitness trainers and other health professionals with athlete clients can continue to build on the foundational information from this course through continuing education. ISSA provides a variety of continuing education courses and will be expanding CE courses related to the variety of specialty sports nutrition topics and new research discoveries along with updates to the foundational sports nutrition information.

Conclusion

It is apparent to the student taking this course that there are a multiple opportunities to become part of an athlete's training and nutrition program team. Because many athletes are part of understaffed teams with limited resources for the time-intensive year-round attention athletes require, fitness trainers can be a dynamic specialized resource for such athletes. Although the legal ability to develop and prescribe nutrition programs for athletes may be restricted based on state or local law requirements, typically licensed health professionals, knowing about scientific evidence-based sports nutrition is knowledge worth having. For some athletes, doing only one thing wrong that is corrected or doing something new that is ergogenic to their athletic performance can mean the difference between winning and losing.

Appendix Table of Contents

APPENDIX

REFERENCES AND GLOSSARY OF KEY WORDS

REFERENCE SECTION

This reference section contains examples of scientific references and technical reports in support of the information provided in this course book. Note that not all of references are included due to space limitations as the authors have gathered and reviewed thousands of studies during the decades of their work. Some of the following references are cited in the course materials, while other referecnces included represent the general body of related scientific knowledge.

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Glossary of Key Words

A

Acetylcholine—a neurotransmitter that is critical for optimum nervous system functioning.

Adipose tissue—fat tissue in the body.

Aerobic—With oxygen.

Alpha-linolenic acid (ALA)—an n-3 fatty acid that is essential in the diet because it cannot be synthesized by humans. Primary sources include soybean oil, canola oil, walnuts, and flaxseed.

Amenorrhea—loss of menstruation.

Ammonia—A toxic metabolic waste product.

Anabolism—the biochemical process in which different molecules combine to form larger, more complex molecules.

Anaerobic—Without oxygen.

Anemia—a condition in which the oxygen-carrying capacity of the blood is reduced. It is the most common symptom of iron deficiency.

Anti-catabolic—describing a substance that prevents catabolism.

Antioxidant—a nutrient that has been found to seek out and neutralize free radicals in the body and to stimulate the body to recover more quickly from free-radical damage.

Assimilation—conversion of food into living tissue.

B

Bile—a substance secreted by the liver that is essential for the digestion and absorption of fats.

Bioavailability—the ability of an ingested nutrient to cross from the digestive tract into the bloodstream and then from the bloodstream into the cells in which it will be utilized.

Blood plasma—the liquid part of the blood; the substance in the blood that carries the red blood cells.

Blood Pressure—the pressure of the blood against the walls of the arteries.

Blood-brain barrier—a semipermeable membrane that keeps the blood that is circulating in the brain away from the tissue fluids surrounding the brain cells.

Body mass index (BMI)—BMI is a measure of body weight relative to height. The BMI tool uses a formula that produces a score often used to determine if a person is underweight, at a normal weight, overweight, or obese. For adults, a BMI of 18.5 to 24.9 is considered healthy (or "normal"). A person with a BMI of 25 to 29.9 is considered overweight, and a person with a BMI of 30 or more is considered obese.

C

Calorie—a unit of measurement used to express the energy value of food. Carbohydrates, fats, protein, and alcohol in the foods and drinks we eat provide food energy or "calories." Carbohydrates and proteins provide 4 calories per gram, fat has 9 calories per gram, and alcohol has 7 calories per gram.

Cannibalization—the breakdown of muscle tissue by the body for the purpose of obtaining amino acids for other metabolic purposes and may also include other body tissues.

Capillary—a tiny blood vessel through which nutrients and waste products travel between the bloodstream and the body's cells.

Carbohydrate drink—a sports beverage designed to provide energy substrate and to replenish the glycogen (energy) stores.

Carbon dioxide—a metabolic waste product.

Catabolism—the chemical reactions that break down complex biomolecules into simpler ones for energy production.

Cell membrane—the outer boundary of a cell. Also called the plasma membrane.

Cellular uptake—absorption by the cells.

Coenzyme—an enzyme cofactor.

Cofactor—a substance that must be present for another substance to be able to perform a certain function.

Collagen—a simple protein that is the chief component of connective tissue.

Complete protein—a protein that contains the essential amino acids in amounts that are sufficient for the maintenance of normal growth rate and body weight.

Connective tissue—tissue that either supports other tissue or joins tissue to tissue, muscle to bone, or bone to bone. It includes cartilage, bone, tendons, ligaments, reticular tissue, areolar tissue, adipose tissue, blood, bone marrow, and lymph.

Creatine (also, phosphocreatine)—a compound produced in the body, stored in the muscle fibers, and broken down by enzymes to quickly replenish the adenosine-triphosphate stores. Also a supplement ingredient.

Creatinine—a waste product of creatine metabolism.

D

Deoxyribonucleic acid (DNA)—the substance in the cell nucleus that contains the cell's genetic blueprint and determines the type of life form into which the cell will develop.

Di-peptide—two amino acids linked together.

Dietary Reference Intakes (DRIs)—DRIs are dietary reference values for the intake of nutrients and food components by Americans and Canadians.

Dietary sodium—also called "salt," sodium helps your nerves and muscles work properly. Table salt is composed of sodium and chloride. Your kidneys control how much sodium is in your blood, releasing it when needed and flushing out any excess. Too much sodium building up in the blood may raise blood pressure. High blood pressure is linked to serious health problems.

Digestive enzyme—an enzyme that acts as catalysts for the breakdown of food components.

Disaccharide—a simple carbohydrate composed of two sugar molecules.

Disordered Eating—abnormal/dysfunctional eating behaviors resulting in inadequate caloric and nutrient intake, with or without eating disorders.

Diuretic—a substance that increases urination.

E

Eating pattern (also called "dietary pattern")—the combination of foods and beverages that constitutes an individual's complete dietary intake over time. This may be a description of a customary way of eating or a description of a combination of foods recommended for consumption. Specific examples include USDA Food Patterns and the Dietary Approaches to Stop Hypertension (DASH) Eating Plan. (See USDA Food Patterns and DASH Eating Plan.)

Electrolyte Balance—the ratio of chloride, potassium, sodium, and the other electrolytes in the body.

Emulsifier—a substance that, during digestion, helps disperse fats in water mediums.

Endurance sport—a sport that requires the ability to perform for long periods at low intensities, such as marathon running and cross-country skiing.

Energy Drink—a beverage that contains caffeine as an ingredient, along with other ingredients, such as taurine, herbal supplements, vitamins, and added sugars or other carbohydrates. It is usually marketed as a product that can improve perceived energy, stamina, athletic performance, or concentration.

Energy Expenditure—The amount of energy that you use measured in calories. You use calories to breathe, send blood through your blood vessels, digest food, maintain posture, and be physically active.

Enrichment—the addition of specific nutrients (i.e., iron, thiamin, riboflavin, and niacin) to refined grain products to replace losses of the nutrients that occur during processing. Enrichment of refined grains is not mandatory; however, those that are labeled as enriched (e.g., enriched flour) must meet the standard of identity for enrichment set by the FDA. When cereal grains are labeled enriched, it is mandatory that they be fortified with folic acid. (The addition of specific nutrients to whole-grain products is referred to as fortification; see Fortification.)

Enteric coating—a coating on tablets that delays digestion of the tablets until they pass from the stomach into the intestines.

Ergogenic Aids—a catchall term that describes anything that can be used to enhance athletic performance. Ergogenic aids can be dietary or non-dietary and include dietary supplements, special training techniques, and mental strategies.

Essential Nutrient—a nutrient that the body cannot produce itself or that it cannot produce in sufficient amounts to maintain good health.

Euhydration—a term used to indicate a state of adequate hydration.

Extracellular—outside the cell.

F

Fat—a major source of energy in the diet, fat helps the body absorb fat-soluble vitamins, such as vitamins A, D, E, and K. Some kinds of fats, especially saturated fats and trans fatty acids, may raise blood cholesterol and increase the risk for heart disease. Other fats, such as unsaturated fats, do not raise blood cholesterol. Fats that are in foods are combinations of monounsaturated, polyunsaturated, and saturated fatty acids.

Food Groups—a method of grouping similar foods for descriptive and guidance purposes. Food groups in the USDA Food Patterns are defined as vegetables, fruits, grains, dairy, and protein foods. Some of these groups are divided into subgroups, such as dark-green vegetables or whole grains, which may have intake goals or limits. Foods are grouped within food groups based on their similarity in nutritional composition and other dietary benefits. For assignment to food groups, mixed dishes are disaggregated into their major component parts.

Food pattern modeling—(Pg. 79) the process of developing and adjusting daily intake amounts from food categories or groups to meet specific criteria, such as meeting nutrient intake goals, limiting nutrients or other food components, or varying proportions or amounts of specific food categories or groups. This methodology includes using current food consumption data to determine the mix and proportions of foods to include in each group, using current food composition data to select a nutrient-dense representative for each food, calculating nutrient profiles for each food group using these nutrient-dense representative foods, and modeling various combinations of foods and amounts to meet specific criteria.

Fortification—as defined by the US Food and Drug Administration (FDA), the deliberate addition of one or more essential nutrients to a food, whether or not it is normally contained in the food. Fortification may be used to prevent or correct a demonstrated deficiency in the population or specific population groups; restore naturally occurring nutrients lost during processing, storage, or handling; or to add a nutrient to a food at the level found in a comparable traditional food. When cereal grains are labeled as enriched, it is mandatory that they be fortified with folic acid.

Free-form amino acids—amino acids that are in their free state, or single.

G

Gluconeogenesis—the metabolic process in which glucose is synthesized from noncarbohydrate sources.

Glucose polymer—a processed form of polysaccharides, or complex carbohydrates.

Glucose—a simple carbohydrate that is a monosaccharide. Also called dextrose or grape sugar.

Glycogen Depletion—the draining of the body's glycogen stores.

Glycogen depletion—the draining of the body's glycogen stores.

Glycogen replenishment—the refilling of the body's glycogen stores.

Glycogen sparing—the saving of glycogen by the body for other functions.

Glycogen-bound water—the water that is stored in the muscles along with glycogen.

Glycogen—a complex carbohydrate that occurs only in animals; the form in which glucose is stored in the body.

Glycogenolysis—the metabolic process in which glycogen is broken down.

Glycolysis—the metabolic process in which glucose is converted to lactic acid.

H

Heart rate—the rate at which the heart pumps the blood through the body.

Hemoglobin—the oxygen carrier in red blood cells.

Hemolytic anemia—a condition in which the hemoglobin becomes separated from the red blood cells.

Hemorrhage—bleed excessively.

High blood pressure—your blood pressure rises and falls throughout the day. An optimal blood pressure is less than 120/80 mmHg. When blood pressure stays high; greater than or equal to 140/90 mmHg—you have high blood pressure, also called hypertension. With high blood pressure, the heart works harder, your arteries take a beating, and your chances of a stroke, heart attack, and kidney problems are greater. Uncontrolled high blood pressure may lead to blindness, heart attacks, heart failure, kidney disease, and stroke. Prehypertension is blood pressure between 120 and 139 for the top number, or between 80 and 89 for the bottom number.

High-density lipoprotein (HDL)—HDL is a compound made up of fat and protein that carries cholesterol in the blood to the liver, where it is broken down and excreted. Commonly called "good" cholesterol, high levels of HDL cholesterol are linked to a lower risk of heart disease. Men should aim for an HDL of 40 mg/DL or higher. Women should aim for an HDL of 50 mg/DL or higher.

High-intensity sweeteners—ingredients commonly used as sugar substitutes or sugar alternatives to sweeten and enhance the flavor of foods and beverages. People may choose these sweeteners in place of sugar for a number of reasons, including that they contribute few or no calories to the diet. Because high-intensity sweeteners are many times sweeter than table sugar (sucrose), smaller amounts of high-intensity sweeteners are needed to achieve the same level of sweetness as sugar in food and beverages. (Other terms commonly used to refer to sugar substitutes or alternatives include non-caloric, low-calorie, no-calorie, and artificial sweeteners, which may have different definitions and applications. A high-intensity sweetener may or may not be non-caloric, low-calorie, no-calorie, or artificial.)

Homeostasis—the tendency of the body to maintain an internal equilibrium.

Hormone—one of the numerous substances produced by the endocrine glands that regulate bodily functions.

Hyaluronic acid—a polysaccharide molecule which is one of the chief components of connective tissue, forming a gelatinous matrix that surrounds cells.

Hydrochloric acid—a stomach secretion that functions in protein metabolism, helps keep the stomach relatively bacteria-free, and assists in the maintenance of a low pH balance in the stomach.

Hydrogenation—a chemical process that turns liquid fats (oils) into solid fats, hydrogenation creates a fat called trans fatty acid (also known as "trans fat"). Trans fats are found in frostings, shortening, some margarines, and some commercial baked foods, like cakes, cookies, muffins, and pastries. Eating trans fats may raise heart disease risk. Federal dietary guidelines [found at http://www.health.gov/dietaryguidelines/External Link Disclaimer] recommend keeping trans fat intakes as low as possible.

Hydrolyzed protein—a protein that has already been broken down, usually by enzymes, and is a mixture of free-form, di-peptide, and tri-peptide amino acids.

Hydrostatic weighing—a method for determining body composition that involves weighing the body underwater.

Hyperhydration—excess body water.

Hypoglycemia—low blood sugar.

Hypohydration—occurs when water intake does not meet the body's hydration requirements

I

Incomplete protein—a protein that is usually deficient in one or more of the essential amino acids.

Insulin—a hormone made by the pancreas, insulin helps move glucose (sugar) from the blood to muscles and other tissues. Insulin controls blood sugar levels.

International unit (IU)—a measure of potency based on an accepted international standard. It is usually used with beta-carotene and vitamins A, D, and E. Because this unit is a measure of potency, not weight or volume, the number of milligrams in an IU varies, depending on the substance being measured.

Intracellular—inside the cell.

Ionic form—in the form of ions, which are atoms or groups of atoms that have either a positive or a negative charge from having lost or gained one or more electrons.

L

Lean body mass—all of a body's tissues apart from the body fat—the bones, muscles, organs, blood, and water. Also called fat-free mass.

Limiting nutrient—a nutrient that has the ability, through its absence or presence, to restrict the utilization of other nutrients or the functioning of the body.

Linoleic acid (LA)—one of the n-6 fatty acids, is essential in the diet because it cannot be synthesized by humans. Primary sources are nuts and liquid vegetable oils, including soybean oil, corn oil, and safflower oil. Also called omega-6 fatty acids.

Lipoprotein—a compound made up of fat and protein that carries fats and fat-like substances, such as cholesterol, in the blood.

Lipotropic—a substance that prevents fatty buildup in the liver and helps the body metabolize fat more efficiently.

Low-density lipoprotein (LDL)—LDL is a compound made up of fat and protein that carries cholesterol in the blood from the liver to other parts of the body. High levels of LDL cholesterol, commonly called "bad" cholesterol, cause a buildup of cholesterol in the arteries and increase the risk of heart disease. An LDL level of less than 100 mg/dL is considered optimal, 100 to

129 mg/dL is considered near or above optimal, 130 to 159 mg/dL is considered borderline high, 160 to 189 mg/dL is considered high, and 190 mg/dL or greater is considered very high.

M

Macronutrient Modulation—the practice of varying the ratio of the macronutrients in the diet to meet specific metabolic needs to enhance performance. Also called macronutrient manipulation.

Macronutrient—a macronutrient is any nutrient that the body uses in relatively large amounts. Macronutrients include carbohydrates, fat, and proteins. Macronutrients are different from micronutrients, such as vitamins and minerals, which the body needs in smaller amounts.

Malabsorption—incorrect absorption.

Metabolic pathway—a sequence of metabolic reactions.

Metabolic Rate—the body's total daily caloric expenditure.

Metabolic water—the water that is produced in the body as a result of energy production.

Metalloenzyme—a mineral-containing enzyme.

Micronutrients—nutrients present in the diet and body in small amounts

N

Nutrient Dense—a characteristic of foods and beverages that provide vitamins, minerals, and other substances that contribute to adequate nutrient intakes or may have positive health effects, with little or no solid fats and added sugars, refined starches, and sodium. Ideally, these foods and beverages also are in forms that retain naturally occurring components, such as dietary fiber. All vegetables, fruits, whole grains, seafood, eggs, beans and peas, unsalted nuts and seeds, fat-free and low-fat dairy products, and lean meats and poultry—when prepared with little or no added solid fats, sugars, refined starches, and sodium—are nutrient-dense foods. These foods contribute to meeting food group recommendations within calorie and sodium limits. The term "nutrient dense" indicates the nutrients and other beneficial substances in a food have not been "diluted" by the addition of calories from added solid fats, sugars, or refined starches or by the solid fats naturally present in the food.

Nutrition—the process of the body using food to sustain life.

O

Oils—lipids that are liquid at room temperature, oils come from many different plants and from seafood. Some common oils include canola, corn, olive, peanut, safflower, soybean, and sunflower oils. A number of foods are naturally high in oils, such as avocados, olives, nuts, and some fish.

Osteoporosis—disease associated with loss of bone tissue, bone fragility, and increased risk to bone fracture.

Oxidative pathways—the systems that supply energy for low-intensity, high-duration activities lasting more than approximately three or four minutes, such as marathon running and aerobic dance. They include oxidative glycolysis and beta oxidation.

P

Polypeptide—four or more amino acids linked together.

Polysaccharide—a complex carbohydrate.

Polyunsaturated fatty acids (PUFAs)—fatty acids that have two or more double bonds and are usually liquid at room temperature. Primary sources are vegetable oils and some nuts and seeds. PUFAs provide essential fats such as n-3 and n-6 fatty acids.

Precursor—an intermediate substance in the body's production of another substance.

Protein—one of the nutrients that provides calories to the body. Protein is an essential nutrient that helps build many parts of the body, including blood, bone, muscle, and skin. Protein provides 4 calories per gram and is found in foods like beans, dairy products, eggs, fish, meat, nuts, poultry, and tofu. Proteins are composed of amino acids, nine of which are indispensable (essential), meaning they cannot be synthesized by humans and therefore must be obtained from the diet. The quality of dietary protein is determined by its amino acid profile relative to human requirements as determined by the body's requirements for growth, maintenance, and repair. Protein quality is determined by two factors—digestibility and amino acid composition.

R

Ribonucleic acid (RNA)—the substance that carries the coded genetic information from the deoxyribonucleic acid (DNA), in the cell nucleus, to the ribosomes, where the instructions are translated into the form of protein molecules.

S

Saturated fatty acids—fatty acids that have no double bonds. Fats high in saturated fatty acids are usually solid at room temperature. Major sources include animal products such as meats and dairy products, and tropical oils such as coconut or palm oils.

Seafood—marine animals that live in the sea and in freshwater lakes and rivers. Seafood includes fish (e.g., salmon, tuna, trout, and tilapia) and shellfish (e.g., shrimp, crab, and oysters).

Skinfold calipers—the specialized calipers used to measure the thickness of skinfolds.

Skinfold measurement—a method for determining body composition that involves measuring the thickness of selected folds of skin using special calipers.

Solid fats—fats that are usually not liquid at room temperature. Solid fats are found in animal foods, except for seafood, and can be made from vegetable oils through hydrogenation. Some tropical oil plants, such as coconut and palm, are considered as solid fats due to their fatty acid composition. The fat component of milk and cream (butter) is solid at room temperature. Solid fats contain more saturated fats and/or trans fats than liquid oils (e.g., soybean, canola, and corn oils), with lower amounts of monounsaturated or polyunsaturated fatty acids. Common fats considered to be solid fats include—butter, beef fat (tallow), chicken fat, pork fat (lard), shortening, coconut oil, palm oil and palm kernel oil. Foods high in solid fats include—full-fat (regular) cheeses, creams, whole milk, ice cream, marbled cuts of meats, regular ground beef, bacon, sausages, poultry skin, and many baked goods made with solid fats (such as cookies, crackers, doughnuts, pastries, and croissants).

Starch—a complex carbohydrate that occurs only in plants.

T

Thermogenesis—the process by which the body generates heat, or energy, by increasing the metabolic rate above normal.

Thermogenic Response—the rise in the metabolic rate. Also known as the thermogenic effect or specific dynamic action (sda).

Trans fatty acids—a type of fat produced when liquid fats (oils) are turned into solid fats through a chemical process called hydrogenation. Eating a large amount of trans fatty acid, or "trans fats," also raises blood cholesterol and risk of heart disease.

Transamination reaction—the process in which an amino group is transferred from an amino acid to a molecule, usually to produce another amino acid.

Transmethylation—the metabolic process in which an amino acid donates a methyl group to another compound.

Tri-peptide—three amino acids linked together.

Triglycerides—a type of fat in your blood, triglycerides can contribute to the hardening and narrowing of your arteries if levels are too high. This puts you at risk of having a heart attack or stroke. Triglycerides are measured along with cholesterol as part of a blood test. Normal triglyceride levels are below 150 mg/dL. Levels above 200 mg/dL are high.

Triiodothyronine—a thyroid hormone that affects almost every physiological process in the body, including growth and development, metabolism, body temperature, and heart rate

U

Unsaturated fat—unsaturated fats are liquid at room temperature. Vegetable oils are a major source of unsaturated fat in the diet. Unsaturated fats include polyunsaturated fats and monounsaturated fats. Other foods, such as avocados, fatty fish like salmon and tuna, most nuts, and olives are good sources of unsaturated fat.

Urea cycle—the metabolic process in which ammonia is converted to the waste product urea, which is then excreted from the body.

Uric acid—toxic metabolic waste product.

USDA Food Patterns—a set of eating patterns that exemplify healthy eating, which all include recommended intakes for the five food groups (vegetables, fruits, grains, dairy, and protein foods) and for subgroups within the vegetables, grains, and protein foods groups. They also recommend an allowance for intake of oils. Patterns are provided at 12 calorie levels from 1,000 to 3,200 calories to meet varied calorie needs. The Healthy U.S.-Style Pattern is the base USDA Food Pattern. See—Healthy U.S.-Style Eating Pattern, Healthy Mediterranean-Style Eating Pattern, and Healthy Vegetarian Eating Pattern.

V

Vascularization—the creation of new blood vessels in the tissues.

Vitamin toxicity—vitamin poisoning.

$\dot{V}O_2$ max—the maximum rate at which oxygen can be consumed.

W

Weight control—this refers to achieving and maintaining a healthy weight with healthy eating and physical activity

Whole food—food that is in its natural, complete state; unprocessed food.

Whole fruits—(Pg. 79) all fresh, frozen, canned, and dried fruit but not fruit juice.

Whole grains—grains and grain products made from the entire grain seed, usually called the kernel, which consists of the bran, germ, and endosperm. If the kernel has been cracked, crushed, or flaked, it must retain the same relative proportions of bran, germ, and endosperm as the original grain to be called whole grain. Many but not all whole grains are also sources of dietary fiber.

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