# FUNCTIONAL EXERCISE AND REHABILITATION

## THE NEUROSCIENCE OF MOVEMENT, PAIN AND PERFORMANCE

JAMES CROSSLEY

ROUTLEDGE

# FUNCTIONAL EXERCISE AND REHABILITATION

Functional training develops the attributes and abilities required to perform tasks, skills and activities useful and relevant to daily life. *Functional Exercise and Rehabilitation* serves as an accessible and visual guide providing the essentials of therapeutic exercise and rehabilitation, including mobilization, stabilization and myofascial release.

This book begins by explaining functional training and the foundation of the STRIVE approach. Chapter 2 introduces functional anatomy and Chapter 3 explains the fundamentals of neuroscience. The final chapters discuss the STRIVE principles and apply them to exercise, program design and injury recovery. Each chapter includes key point boxes, illustrations and photos of exercises discussed.

Written by an exercise specialist and osteopath, this practical guide is presented in an easy-to-read style. *Functional Exercise and Rehabilitation* is essential reading for all health professionals, sports therapists and trainers involved in exercise prescription.

**James Crossley** is an osteopath with dual Master's qualifications in Sports Science (Loughborough University, UK) and Osteopathy (Unitec, NZ), and 15 years' experience in the health and fitness industry. He is also a published author in the field of strength and conditioning, and an experienced presenter on injury prevention and rehabilitation.

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# Functional Exercise and Rehabilitation

## The Neuroscience of Movement, Pain and Performance

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# INTRODUCTION

## STRIVE Movement: Functional Training and Rehabilitation

## #INTELLIGENT-MOTION

### Background

The human body is an amazing instrument. Whether we are watching sport, gymnastics or dance, it is astounding to see athletes explore the boundaries of human movement and physical performance. I have always enjoyed watching athletes like Daley Thompson, Lennox Lewis, Martin Johnson and Jessica Ennis-Hill, and as a youngster I tried to emulate my sporting heroes. Whilst enthusiastic, I was never a particularly talented sportsman, but I always worked hard and ever since playing with my father's plastic dumbbells at 13 years of age, I have always been interested in training and physical development.

I studied as a gym instructor and qualified as a personal trainer in 1998, continuing my education with a degree and then a Master's in Sports Science. I have worked as a personal trainer in large health clubs, small private studios and in clients' homes, and I have presented workshops, taught diplomas and written books. I went on to study musculoskeletal therapy, qualifying as an osteopath in New Zealand.

The more I learn, the more I realize I know very little. As scientific knowledge expands, so does the realization that we understand only a mere fraction of the science of human movement. Over time I felt convinced that much of the knowledge passed on to me from courses and classes was fundamentally flawed. As Arthur Kornberg states, 'half of what we know is wrong, the purpose of science is to determine which half'.

As a functional trainer, we must stay on top of emerging science and re-evaluate beliefs based on emerging science. As Steve Jobs (2005) suggests, 'don't be trapped by dogma, the results of other people's thinking'. There is much dogma in health and fitness.

I have always been baffled by the conventions of gym training. I question the benefit of resistance exercises like the bench press, leg extension and bicep curl. I question the benefit of exercising sat down, when most of what we do is stood up. I question the wisdom of training in a slow and controlled manner, in straight lines without the need for flexibility, stability and balance. Surely this type of training can't be the best way to improve strength, speed and flexibility?

Exercise machines cannot be the best way to make clients more gymnastic, make them more fluid and better able to move in work or sport. I was determined to question the dogma and discover the truth: What is the most effective way to 'train for function'?

Many of my ideas originate from a team of trainers and therapists at a studio called Original Movement. Original Movement was a 'Functional Training and Holistic Therapy Studio'. There were no resistance machines, no 'Leg-Press' or 'Smith Machine'. Original Movement encourages clients to move in lots of different directions and in lots of unusual ways, performing familiar everyday tasks, like running, jumping, pulling, pushing, twisting and turning, loading the body using body weight, gymnastics and calisthenics. 'Original Movement' was a revelation.

As I worked with this amazing team, I was also becoming aware of emerging neuroscience. New scientific tools like Magnetic Resonance Imaging (MRI) and Computer Tomography (CT) was enabling scientists to map the activity of electrical signals and movement of fluid within the brain. We can now investigate the activity of the brain as we think and move. These new tools have led to an explosion in our understanding of the brain and how it works.

We now know more about how the brain controls movement, pain and performance than ever before. Neuroscience is applied to patients suffering brain injury and has been instrumental in changing many therapists' approach to treating chronic pain syndromes like fibromyalgia and complex regional pain syndrome. Neuroscience has revolutionized modern medicine's approach to chronic musculoskeletal pain conditions like back pain, neck pain and headache.

Original Movement was entirely consistent with what I was reading about how the brain controls and coordinates movement, and how thoughts and feelings impact on performance. This book combines 20 years of experience of functional training with amazing insights into how the brain controls movement. I have tried to apply this knowledge to reconceptualize exercise design to better improve how clients move, feel and perform.

## USING THIS BOOK

To outline your journey through this book:

- We start with an 'Introduction to Function', explaining what *functional training* is and how it may be different from a more mainstream approach.
- We go on to introduce *neuroscience*, the workings of the '*functional mind*' and the foundation for the STRIVE approach.
- In Chapter 2, we introduce 'Functional Anatomy', a brief introduction to the workings of the physical body.
- In Chapter 3, we introduce the fundamentals of *neuroscience*, looking at the processes of *sensation*, *activation*, *coordination* and *learning*.
- In Chapter 4, we apply neuroscience and discuss the 5 key 'STRIVE Principles', making exercise:
    - Subconsciously controlled
    - Task-orientated
    - Reactive
    - Intelligently varied
    - Emotional
- STRIVE principles are then applied to 'Functional Exercise Design' and 'Functional Program Design' and we discuss *periodized programs*.
- And finally, in 'Functional Rehabilitation', we apply STRIVE principles to clients either recovering from pain or injury. We discuss:
    - The most common injuries and the process of soft tissue repair
    - How pain works and where it comes from
    - Pain management
    - STRIVE functional rehabilitation applied to the various regions of the body

To support this text, further information and resources have been provided on our website: www.strivemovement.com

At this site you will find further discussion of STRIVE principles applied to exercise, training and rehabilitation. We recommend you visit www.strivemovement.com for further resources, discussion, case studies and links to videos, all relevant to the topics discussed within this book. We hope you enjoy …

**Figure 0.1** Creator of STRIVE – James Crossley.

## REFERENCE

Jobs, S. (2005). Commencement address, 12 June. Available at: https://news.stanford.edu/news/2005/june15/jobs-061505.html.

# 1 INTRODUCTION TO FUNCTION

- Functional Training
- Conventional Training
  - Coordination, Integration and Synergy
- Authentic Functional Movement
- Introduction to STRIVE

The fitness industry is vast. People pay large sums to stay fit and healthy. Functional training is just one small branch of this flourishing community. But what exactly is functional training? Search the internet and you find a vast array of ideas, opinions and perspectives about what constitutes and characterizes functional training. You might have your own ideas about what a 'functional exercise' looks and feels like. But what makes one exercise more or less functional than another?

In this chapter, we introduce some fundamental concepts in *functional training*. We scrutinise the factors that underpin an individual's 'movement ability' – their ability to move with ease, efficiency and effectiveness – and we investigate how we might structure training to enhance movement.

We start by looking at what might be regarded as a conventional approach to training, including isolation exercise and fixed resistance machines. We go on to propose that this conventional approach may not be the most effective if our goal is to improve how clients feel, move and perform.

## FUNCTIONAL TRAINING

Everything has a *function*, a use or intended purpose. A knife is designed to cut, a broom is designed to sweep. Some objects appear more functional than others. If one bottle opener takes the top off a bottle better than another, it could be described as being more '*functional*'.

The function of a car is to transport us from A to B. There are lots of different makes and models of car. Some are more comfortable than others, some have better fuel economy, others boast superior performance – higher top speeds, faster acceleration, tighter cornering and so on. These are all components of a car's *functional performance*. What is the body's function? What is our intended use or purpose? What are we designed to do?

Like many creatures, we respire, digest, excrete and secrete. These homeostatic functions are essential for keeping us alive and are coordinated deep within the recesses of the brain. But what distinguishes the human race from other species is the wide diversity of ways in which we can move.

The human body is exquisitely designed to locomote from one place to another – to step, walk, run and jump. We are uniquely designed to handle and manipulate tools – to bend, lift, twist, shift, reach, push and pull; to hunt or fend off predators – our brain is programmed to punch, kick, throw and strike targets. We might consider these familiar movement patterns the body's functions. One perspective would be to say that 'functional training' should develop the body's unique ability to move and perform these familiar movement tasks.

Beyond these basic movements, we use the body to perform a vast array of other tasks, skills and activities. Many people have physical jobs, active hobbies or play sport. Our body has to be able to lay bricks, stack shelves, pull weeds out of the garden, chop hedgerows – all manner of weird and wonderful tasks. Some people like to stay fit playing sport, some climb, hike or swim to stay healthy. Maybe functional training should improve a person's ability to perform these daily tasks, activities and hobbies?

Some people take their sport more seriously, even getting 'paid to play'. Athletes can be paid vast sums based on how fast they can run, how high they can jump or how accurately they can throw. One of the most interesting applications of functional training is to enhance *sport performance*. How should we train for sport? How should instructors and coaches structure training to improve how athletes punch, kick, swing, throw or tackle?

Functional training develops the attributes and abilities required to perform tasks, skills and activities useful and relevant to daily life. Functional training is geared to develop the ease, accuracy and efficiency of movements that are:

- Useful
- Relevant
- Vital

Many clients arrive at training with some degree of pain, injury or dysfunction. Clients experience

## Definitions

**Functional task** – a movement or skill we rely on in normal daily life

**Functional training** – training designed to improve the ease, accuracy and efficiency of functional movement

**Functional performance** – an individual's ability to perform daily activities in life, either at work, sport or play

**Functional capacity** – an individual's ability to perform a specific task, e.g. throwing a ball or accelerating into a sprint

**Functional rehabilitation** – restoring the ease, accuracy and efficiency of movement to assist the recovery from pain or injury

**Sport performance** – developing function for sport or competition

traumatic events that cause pain and injury, hampering their ability to move in a way that potentially restricts performance. For many people, overcoming pain and injury or recovering function is a key goal.

Even if you haven't experienced injury, the older we get the more important it is to move freely, absent of aches and pains. Functional training is a fantastic tool to maintain or recover movement ability and recuperate from pain and injury. Chapter 7 of this book is dedicated to what we call *functional rehabilitation*.

There is great debate over the best way to train for function. What makes one exercise more functional than another? How should we train to improve movement, enhance sport performance or rehabilitate from pain and injury? I realized a long time ago that conventional resistance training may not be the answer.

## CONVENTIONAL TRAINING

Most modern gyms are filled with expensive exercise machines designed to burn calories and build muscle. The trend for machine exercise started in the 1980s with Nautilus and Gold's Gym. The average gym is filled full of men lifting huge weights, straining over dumbbells and barbells, and women burning calories on treadmills, cross-trainers and bikes. Apologies for the over-generalization, but modern training stems from a culture of 'body-building' and 'body-transformation'. It would be easy to assume training has always looked this way.

Historically, resistance training and other forms or exercise were less concerned about looks. Gymnastics and calisthenics were designed with a specific intent or purpose in mind. Many cultures trained for war, for example. The ancient Spartans, who valued bravery, endurance and self-denial above all else, developed martial skills like wrestling, boxing, running and riding. Building muscle and keeping in shape were a by-product rather than a goal of training.

Stress, anxiety and depression are rife in modern society. In eastern culture, exercise is used to maintain the mind as well as the body. To this day, ancient exercise forms like Yoga, Tai-Chi and Chi-Gong, integrate movement with controlled breathing and meditation to achieve mental, as well as physical well-being. Eastern forms of exercise like these are becoming increasingly popular in western culture to help maintain mental, spiritual and emotional balance. Unfortunately, despite research proving the benefit of exercise for mental health, anti-depressant medication still seems the treatment of choice within modern medicine.

Exercise is also hugely beneficial for cognitive function. This fact was well understood even in early civilisations. In ancient Athens, gymnasia were places of learning. Ancient gyms were filled with books, art and literature – very different from training spaces today. In contemporary culure, physical appearance seems to be held in higher esteem than mental health. Conventional gyms reflect a society obsessed with appearance.

Watch people train in conventional gyms and it can be difficult to discern exactly what it is they are training for. Fixed resistance exercise machines, like a 'Bench Press', 'Lat-Pull-Down', 'Leg-Press' or 'Leg-Curl' appear altogether peculiar, dissimilar to anything we do in normal life. As one instructor put it, 'take the machine away and exercise looks very odd indeed'. When did exercise become so abstract?

The nature of movement produced by resistance exercise is particularly distinct. Exercises are often performed sat down or lying, supported by benches and rests to ensure safety and stability. Movements tend to be slow and controlled with the protagonist pushing or pulling in one direction (i.e. *uni-linear motion*), usually forwards and backwards (i.e. *sagittal plane motion*). Each exercise tends to have a specific *form* and *technique*, considered vital for avoiding stress, strain and injury. Form and technique are taught ahead of time and generally require little coordination or skill. Exercises are highly *repetitive*. Each repetition looks much the same as the last, making exercise predictable, monotonous and dull. Motivation can be a problem, with many people dropping out due to lack of enthusiasm or injury.

**KEY POINT**

Conventional training is often:

- Uni-linear
- Contrived
- Predictable
- Repetitive

Aliens watching people lifting weights, running on treadmills or riding stationary bikes would have great difficulty understanding what is going on. Like hamsters in a wheel, conventional training does not seem to make much sense. So, why do we train this way?

Conventional exercises are designed to isolate and overload specific muscles. Loading of muscles isolated from their natural synergists is fantastic for creating rapid fatigue, which leads to lactic acid accumulation and microtrauma, and is ideal for triggering hypertrophic growth (the increase in the size of muscle fibers).

Conventional exercises are ideal for building muscle, but do they improve how the body feels, moves and performs? Are these exercises 'functional'? Will they improve strength, speed and power in a way that enhances a person's ability to walk, run, jump, twist, bend, push and pull? Let's start by looking at the research.

- Harris et al. (2000) reported that nine weeks of training with various squatting and pulling exercises produced approximately a 10% gain in squat strength, but this increase in strength was not associated with any change in 30m sprint performance.
- Wilson and Murphy (1996) demonstrated that to gain a 2.2% increase in sprint performance, a 21% improvement in squat strength was required.
- Experienced male sprinters who trained with various weight-training machines improved squat 1 Rep Max (1RM – the most an athlete can lift in a single maximal effort) by 12.4%, but corresponding improvements in acceleration and maximum speed were only 4.3% and 1.9%, respectively.
- Jump squats using a 4-kg bar over ten weeks of training improved performance by 16.8%, but this was associated with only a 1.1% change in 30m sprint time.
- Mutton et al. (1993) conclude that cycling training may even reduce running performance.
- Six weeks of core-stability training in recreational athletes has been shown to enhance measures of core stability without significant transfer to running economy or performance.

In their review, Carroll et al. (2001) concluded that physiological adaptations associated with resistance training can even have a negative impact on performance.

Although this is a small sample of articles, they are a fair reflection of the overall picture. The results seem unequivocal: conventional training has only a limited impact on *functional performance*. To find out why this is the case, we need to understand the concept of '*transfer*' and how it applies to functional exercise and program design.

## Transfer

*Transfer* is a key concept in functional training. Schmidt (1988) defined transfer as the 'transition of knowledge or capability gained in one task or setting to performance in another task or setting'. Most people are familiar with the concept of *transferable skills*. Hand-eye coordination, balance, strength, speed or agility are often considered *transferable* – intrinsic characteristics consistent across different situations and circumstances.

Whilst biomotor abilities like strength are considered transferable and consistent across situations, the research suggests skills and abilities are rarely transferable, or at least not by as much as we think. Physical attributes rarely transfer across different situations and circumstances. We assume strength applies across tasks and activities, that someone ostensibly 'strong' will carry that strength over and across into various different contexts and situations, but the research suggests this is not the case.

## TRANSFERABLE SKILLS

This was the job application of a fan who thought that his management skills in the 'Championship Manager' computer game would 'transfer' to management of a football club in the real world.

> I believe my record on Football Manager speaks for itself. In my latest file, I took Aston Villa into fifth position, only missing out on the Champions League by one point. Similarly, I have managed at the lower levels, with Southend United I was able to create club history with back-to-back promotions before cementing our place in the Championship. This is probably my greatest achievement on the 2013 edition.

This gentleman clearly overestimated transfer from one skill to another.

De Boer (1987) concluded that strength gained from training fails to transfer to other activities. Even other physical attributes like balance do not transfer from one context to another (Fleishman, 1958). Even skills that appear similar often fail to transfer. De Boer et al. (1987) found, for example, that 'off-ice skating' does not improve actual ice skating. The transfer of abilities from one activity to another is often far lower than we expect.

Transfer effects are notoriously difficult to predict. Whilst skiing and surfing look alike, olympic skiers are not automatically able to surf. Just in the same way that being able to play draughts may not transfer to chess, physical abilities do not always transfer between activities. Much like draughts and chess, there tend to be small but significant differences between similar tasks that undermines transfer effects. Small differences in how an activity is performed, the rules of the game, you might say, that reduce carryover.

The concept of transfer is fundamental to training. Sports coaches assume mid-week training will transfer to game day. Therapists believe rehabilitation exercises will reduce pain. Instructors assume gains in the gym will transfer to real life. Without transfer, training is somewhat pointless. To what extent do you believe your training will transfer into either your own or your client's daily life? To what extent will your training transfer to function?

Imagine a triathlete trying to improve cycling performance. If gains in fitness using an indoor bike do not transfer to outdoor cycling, indoor bikes are a waste of time. If a 50% increase in stationary cycling generates a 50% improvement in outdoor cycling, we can safely say that stationary cycling is 100% effective and is highly 'functional'.

Instructors assume strength, endurance and flexibility gains from conventional gym training transfer into real life. An instructor might prescribe a 'Leg-Press' to build leg strength for a runner, or a 'Lat-Pull-Down' to build arm strength for a climber, but research suggests that the transfer of training from these conventional exercises to function is poor. Unless programs are carefully designed transfer is typically low and, in some cases, training can even have a negative impact on performance. Functional trainers need to consider how to optimize transfer of training to function.

**THE TRANSFER EFFECTS OF ONE ACTIVITY TO ANOTHER CAN VARY AND CAN BE:**

- Positive – gains in one task are reflected by improved performance in another task
- Neutral – gains in one task fail to influence performance in another task
- Negative – gains in one task decrease performance in another task

## The Physiological Fallacy

Why is the transfer of conventional training so low? Conventional training is based on the premise that performance relies on physiological factors – that the size of muscles determines strength, for example; that lung volume measured using VO2 max predicts endurance, and so on. The problem is that physiology is not the only factor impacting performance.

Strength can vary irrespective of physiological markers. Novice weight lifters experience dramatic gains in performance in the first six to eight weeks of training, without any discernable change in muscle mass. Research suggests that as little as 2% of the strength gained in the initial stages of training can be explained by physiological factors like muscle mass. This rises to 65% in more experienced lifters, but muscle mass is far from the sole factor in determining strength gains with training. Only about 50% of the quadriceps' strength can be explained by the cross-sectional of muscle, for example (Rutherford and Jones, 1986). The force produced by muscles is only partly explained by their size. Muscle mass is one of a range of factors determining strength (Young et al., 1983; Jones and Rutherford, 1987).

Strength can vary from person to person and moment to moment. Performance can be influenced by a variety of factors, irrespective of muscle mass. Pain, injury and confidence, along with a multitude of various other factors, can impact performance. An athelete can be as strong as an ox one second and weak as a kitten the next, irrespective of the fact that their muscle mass has not changed one iota. What is the mechanism of effect for these changes and how do we explain rapid changes in performance independent of physiological factors?

The reality is that physical attributes, such as speed, power, endurance, flexibility, mobility or balance, are all contingent on a complex blend of characteristics, each of which can be grouped into one of the following categories:

- Structural
- Physiological
- Biomechanical
- Neurological
- Behavioral

### Structural

*Structure* is the physical make-up of the body – a person's height, the length of their bones, the shape of their joints, the orientation and insertion of muscle fibers. There are numerous structural factors to consider that impact function. We all have a distinctive structural make-up that predisposes us to be better adapted and suited to different activities. These structural factors are largely inherited from birth.

Whilst having a genetic predisposition, 'structure' is, to a certain degree, shaped and molded by an individual's experiences, their patterns of use, growth, injury and old age.

For example, bone is deposited and reabsorbsed under lines of mechanical stress, and so can change with time and stress. Boney adaptation occurs over long periods of time or with brute force or physical trauma. For a functional trainer looking to improve performance, structure is, for all intents and purposes, stable and unchanging. Structure is 'un-trainable'.

## Physiological

*Physiological factors* such as muscle mass, muscle fiber type, capillary density, mitochondrial density, heart size and lung function, all impact performance and are responsive to the appropriate training stimulus. Muscles hypertrophy, blood capillaries and mitochondria proliferate and lung tissue expands under stress. The nature of physiological adaptations depends upon the nature of the training stimulus. Irrespective of this, we know the speed of adaptation can be painfully slow.

Physiological factors like muscle mass and lung capacity are notoriously slow to adapt. Even under a well-structured training program, muscle can take weeks or months of hard work and dedication to build. The speed of physiological adaptation relies on a range of factors. Muscular hypertrophy can be particularly slow in the absence of a strong genetic predisposition. Adaptation requires suitable hormonal conditions, meaning adaptation can be negligible in females or males over a certain age. Adaptation also has to be supported by significant, and often expensive, nutitional supplementation.

Clients suffering congenital abnormalities, thyroid imbalance and hormonal deficiencies can all struggle. Even for the average adult, physiological adaptation can take a great deal of time and investment. For rapid results in terms of movement, pain or performance, *physiological adaptation* may not be the best place to focus.

## Biomechanical

Functional performance relies not only on strength, speed and power, but on how that strength and power are applied. The manner in which we walk, run, jump and throw all impact biomechanical factors like leverage, momentum and inertia, and these in turn influence the ease and efficiency of our movement.

Biomechanists analyze film footage and apply mathematical models to calculate the most efficient way to perform any task or skill. Biomechanics suggests that for any task there is a 'correct' *form* and *technique* that supports ease and efficiency. Deviation from the correct form and technique is regarded as an error, predisposing biomechanical stress, strain and injury.

Biomechanics can be applied by instructors and coaches to both enhance performance and reduce risk of injury. Biomechanical principles are frequently applied in the manufacture of training equipment and to exercise design, the goal being to design exercises that stress muscles without overloading joints, ligaments and tendons.

Whilst biomechanical models provide a useful insight into 'ideal' patterns of movement, they can be very difficult to apply in practice. Biomechancial models tend to be generated under ideal conditions, using elite athletes. In real life, conditions are rarely 'ideal'. The tasks and environments in which we move tend to be *complex* and *varied*, and the clients we work with are rarely biomechanically sound. Biomechanical models fail to appreciate that everyone is different, and so what works for one may not always work for another. In some cases, trying to force clients into biomechanically correct postures and positions, or correcting their natural form and technique, may end up causing more problems than it solves.

## Neurological

During movement, the brain activates hundreds of different muscles and integrates the actions of various systems of the body. Coordination and organization of movement play a huge role in determining athletic performance. Athletes perform better not because they have larger muscles, but because they process and interpet information faster and more effectively.

Elite athletes learnt to recruit musles, react and adapt to complex environments, and make better decisions in less time than the average person, in the context of their chosen activity or sport. Much of this book is dedicated to how athletes are able to move better than the rest of us, and to understand how the brain controls and coordinates movement, pain and performance.

It is clear that for any given task, an individual's functional performance can change from moment to moment. The speed of change cannot be explained by any adaptative process impacting either that person's structure or their physiological make-up. The only system that is able to adapt fast enough to explain instantaneous changes in performance is the nervous system. Only the nervous system has the ability to adapt fast enough to influence functional performance in such a short space of time. If a client suddenly regains mobility, experinces a sudden increase or descrease in strength, suddenly feels free from pain, or if muscles can suddenly stretch further, the only system that is able to explain this sudden change in performance is the client's nervous system.

The nervous system is the most rapidly adapting system in the body. Unlike the physiological systems, the nervous system has boundless potential for adaptation and growth. If we want to trigger rapid changes in functional performance, trainers would be well advised to focus on developing a client's ability to organize movement, synergize muscle and integrate the various systems of the body, transforming performance without the time, effort and money required for physiological adaptation.

## Behavioral

Whether we are lifting a baby out of the car, throwing a cricket ball or climbing a tree, behavior is how we *react* in any given situation or circumstance – the 'movement strategies' we adopt and the decisions we make. Behavior governs how and when we move. Ask any sports coach, functional performance relies on sound decision-making and appropriate behavioral responses. The more appropriately people behave, the better they perform.

Changing behavior can be challenging. We know that education has little impact on behavior. Teaching a client correct form and technique will have little impact on how that client moves in the real world. Teaching, instruction and education rarely impact the decisions people make. This is because, to use an old adage, decisions are rarely made with the head, they are made with the heart.

Functional trainers need to understand how to influence behavioral reponses. The only way to do this is to understand how and why the brain makes decisions. 95% of decisions are not conscious but emerge from an instinctive and intuitive reaction to the situation and circumstance, and are primarily influenced by how we feel about those situations – our emotional response. We will see that performance in the real world relies on effective decision making and faster and more appropriate behavioral reactions. To improve behavioral responses, a trainer needs to change how a client feels about any given situation or circumstance – their emotional response to that situation.

Conventional training discounts the impact of behavior on movement. Conventional gyms are removed from the real world. Gyms are the only place where we lift dumbbells or curl barbells. Whilst cardiovascular machines like the cross-trainer and stationary bike work the heart and lungs, when does anyone ever 'cross-train for a bus'? In conventional gyms people do not learn how to react to any useful or relevant situation or circumstance.

Exercise machines designed to stress specific muscles and physiological systems are removed from the context in which those muscles or systems are designed to work. We can develop arm muscles, but what does the dumbbell curl really teach us about how to bend and lift a child out of a cot? The emphasis on physiological adaptation means conventional exercise is designed without any specific purpose in mind, and therefore fails to resemble any task or activity useful or relevant to daily life.

In sport, *generalized training* is referred to as '*strength and conditioning*'. It is not uncommon to see athletes working with strength and conditioning coaches, learning 'Olympic-lifts', like the squat, deadlift, clean and snatch. The assumption is that strength gains achieved within these exercises will transfer into athletic abilities like running, jumping, kicking and throwing. Rugby players lift weights and do chin-ups, footballers ride bikes and swimmers use exercise machines. Where is the sense in this approach?

Generalized training fails to account for the *biomechanical*, *neurological* and *behavioral* factors that underpin performance. To increase the *transfer* of training to function, trainers need to discard the '*physiological fallacy*' that performance relies on physiological factors, like the size of muscles or the capacity of lungs. In this book, we encourage trainers and coaches to engage with a training philosophy that assumes it is the brain that controls movement, pain and performance.

## Similarity and Specificity

To increase the transfer of training, where do we start? *Similarity* and *specificity* are key training principles that impact transfer. In 1901, Thorndike and Woodworth introduced the theory of 'identical elements', stating that the transfer of abilities is dependent on the extent by which those two activities contain 'identical elements'. The more *similar* two tasks are, the greater the transfer between them.

The principle of specificity states that, 'the adaptations we experience as a result of training are specific to the training stress we apply' (Fahey, 1998). Gains in strength, for example, are specific not only to the muscles we train, but also the lengths, angles and speeds at which we train them. Strength developed slowly is unlikely to transfer to faster speeds. Strength developed within an inner range of movement does not transfer when that same muscle works in a lengthened state, within its outer range. Leg strength developed sat down (e.g. using a Leg-Press) is unlikely to transfer to movements in which we stand up (e.g. running), and so on. The greater the dissimilarity between two tasks, the less the transfer.

Similarity and specificity explain why non-specific drills are largely ineffective (Schmidt, 1988) and why a generalized approach to training is highly inefficient. Functional exercise requires *coordinative similarity* – exercises need to reflect the nature of the tasks and activities we are training for.

Similarity and specificity are fundamental principles because most of the benefits of training are derived not from physiological, but from neurological and behavioral adaptation. Essentially, most of the gains in performance we see as a result of training arise due to improvements in '*task-specific coordination*' and behavioral adaptation.

## Coordination, Integration and Synergy

The Oxford Dictionary describes '*coordination*' as the act of arranging; putting things in order, or making things run smoothly. In training, coordination is the process of organizing movement to make it easy, accurate and efficient (Schurr, 1980). Performance within any task relies both on the ability to create force, and also on the ability to apply that force in a coordinated manner – the ability to organize movement, synergize muscle and integrate the various systems of the body.

Let's try to understand the importance of coordination by understanding how muscles work to create movement at a single joint. To create motion, one muscle contracts (the agonist) and the opposing muscle (the antagonist) needs to relax. If the opposing antagonistic muscle fails to relax, movement would not occur. Muscles would be working, but they would be resisting each other. To create movement the action and relaxation of muscle has to be coordinated. Just in the same way that rowers in a boat have to learn to pull together, muscles also have to learn to work synergistically. Musles working 'out-of-sync' resist motion and waste energy. A large part of strength training is to develop the ability of muscles to work in a coordinated manner within the context of a specific movement. As Frans Bosch (2015) states, strength training is 'coordination training against resistance'.

Think of the body like a symphony orchestra. Each muscle an instrument, each movement a melody. Playing sport is like composing a symphony. The quality of the music relies not on how loud each instrument plays, but how well each instrument harmonizes. In conventional training, we are obsessed with the size of muscles, analogous to playing each instrument as loadly as possible and expecting the music to sound better. Functional training emphasizes an idividual's ability to harmonize and synergize. Rather than the size of muscles, training focuses on an individual's ability to move with *ease*, *accuracy* and *efficiency*, creating *fluidity* and *flow*. Functional training is not muscle size or strength training but *coordination training*.

How is it that Tiger Woods can hit a golf ball over 400 yards, Jonathan Edwards can jump over 60 feet and Usain Bolt can run 100 meters in 9.6 seconds. These elite performers do not look like bodybuilders, they do not have huge physiological advantages, yet they can out-perform any other athletes. This is because functional performance is not about muscle mass. Elite atheletes learn to utilize biomechanical forces like momentum, leverage and inertia, making movement easy and efficient. These athletes master task-specific coordination, learning to coordinate movement and synergize muscle to achieve amazing feats.

For endurance athletes, like runners, swimmers and cyclists, ease and efficiency are fundamental – the ability to travel further with less effort. For endurance athletes, the goal is to contract muscles as little as possible. Unwarrented muscle contraction is only likely to hinder rather than help movement. Whilst conventional training is obsessed with working muscles harder, functional training focuses on the ease, accuracy and efficiency of movement. Functional training teaches clients to conserve energy and effort.

A few years ago I had a go at training Jiu-Jitsu, a martial art much like judo or Akido, in which the aim is to throw opponents to the ground and grapple on the floor, manipulating joints and limbs to the point where the opponent submits from pain. I was 'gym fit', but certainly not 'fighting fit'. When I first started grappling, I fatigued quickly. I did not know how to leverage my opponent, how to throw them off balance. Every attempt relied too much on brute force. I didn't know when to breathe, or when to rest and conserve energy. I was inefficient and, as a result, tired quickly. Each bout was a painful lesson in efficiency. Coaches encouraged me to relax, flow and breathe, and not to rely on brute force. Functional fitness was very different from gym fitness.

Each and every functional task has a unique physical and physiological profile. Every function stresses the body's ability to provide energy and remove waste in a unique way. Developing 'general fitness' is an inefficient and ineffective strategy because each and every task or activity requires a unique physiological output. Coaches call it being 'match-fit'. To learn to integrate each physiological system in a manner matched to the demands of an activity, training needs to be *task-specific*.

Whether throwing a javelin, kicking a ball, climbing, jumping, sprinting or lifting, functional performance relies not on the size of muscles or capacity of lungs, but on how we organize, synergize and integrate movement. Coordination is key. How do we develop coordination? The first strategy is to make exercise similar and specific to ‘function’ – to design exercises that ‘reflect’ the tasks, skills and activities we are training for or that we carry out on a daily basis.

**KEY POINT**

Functional performance relies upon coordination and our ability to:

**Organize movement –** creating biomechanically efficient and effective motion

**Integrate systems –** maintaining systemic support

**Synergize muscle –** helping muscles operating as teams

## AUTHENTIC FUNCTIONAL MOVEMENT

People move very differently in the real world compared to how they move in the average gym. While a friend or colleague is working, playing sport or taking part in their favorite hobby, take a second and watch how they move. Notice how everything someone does in the real world is complex and varied. Whether they are stacking shelves, gardening or playing games, movement is often awkward and unusual. Movement occurs in lots of different directions, at different speeds and angles, from an assortment of different postures and juxta-positions. In function, movement never occurs the same way twice.

Whilst conventional exercise is planned and premeditated, functional movements simply emerge from an *instinctive* and *intuitive* reaction to what is happening around us. There is little thought or consideration – people just spontaneously *react* to where they are and what they are doing, to the task they are performing and the tools, obstacles and targets with which they are interacting.

Whether working to earn money or scoring a goal, functional movement is always triggered by a clear goal and purpose. Whilst conventional exercise tends to be monotonous and dull, functional movement injects emotional content. Functional training should also trigger positive emotion.

**KEY POINTS**

Functional movement is:

- Complex
  - Three-dimensional
- Varied
- Unscripted
- Instinctive
- Reactive
- Emotional

**Figure 1.1** STRIVE Exercise.

Functional training should reflect natural movement. Exercise should reflect the tasks, skills and activities we perform on a daily basis. Movement should be complex and varied, and should encourage instinctive and intuitive reactions to external targets that drive movement in different directions, at different speeds, under awkward and interesting loads. Functional exercises should inject emotion by being social, fun, exhilarating or exciting.

### Function Is 'Complex and Open'

We can classify tasks or skills depending on whether they are '*simple*' or '*complex*' and '*open*' or '*closed*' (Knapp, 1967). *Simple* skills are less intricate and contain fewer interacting variables. They are generally more controlled and concise, with fewer moving parts. There are less confounding factors, such as variations in the environment, interaction with other people or confounding events. 'Simple' tasks are easier to plan and predict (Galligan, 2000).

To ensure safety and isolate muscles, gym exercises are often kept 'simple', with little variation in form and technique. Movements are slow and controlled with little interference from external factors. Now consider a group of children playing ball games. Consider all the different postures, positions and movements they perform, the complexity of movement, the different speeds and angles. Compared to gym exercise, functional movement is highly *complex*.

Tasks and skills can also be classified as '*open*' or '*closed*'. *Closed* skills have a relatively well-defined start and finishing point, generally lasting over a relatively short period of time. Throwing a dart at a board would be a relatively closed skill, for example. Gym exercise are also relatively closed, tightly defined by sets and reps, all with a clear start and end point.

In function, tasks, skills and activities tend to be more *open*. Mowing the lawn, playing a ball game, building a wall, these are all relatively open skills that have longer, less defined time scales. In open skills, movements and tasks blend in complex, less defineable ways.

It can be useful to think of tasks and skills as either being simple and closed (SC-skill) or complex and open (CO-skill). When we analyze the attributes required for SC-skills compared to CO-skills, we see they tend to be entirely different. An SC-skill, like throwing a dart at a board or taking a shot in snooker, relies on precision and strict form and technique to maintain consistent performance over multiple repetitions. Many SC-skills rely on basic physical attributes like strength, speed or endurance. In neuroscience, these physical attributes are called biomotor skills, and in STRIVE they are referred to as *performance parameters*.

**Performance parameters are generic physical attributes like:**

- Flexibility
- Mobility
- Strength
- Speed
- Power
- Endurance
- Balance
- Coordination

Cycling is an SC-skill. A track cyclist rides from point A to point B with the start and end points of performance clearly defined. Cycling performance relies on endurance to maintain pedal power over extended periods of time, and precise pedaling technique to maintain efficiency and prevent energy 'leaks'. Gym exercise is also simple and closed. Performance in conventional gym exercises relies on strict form and technique, strength and power. Each repetition is performed much the same as the last to support efficient and effective movement, maintain efficiency and avoid biomechanical stress.

**Performance in SC-skills involves:**

- Precision and accuracy
- Correct form and technique
- Basic performance parameters

In contrast, functional tasks tend to be complex and open. Whether we are clearing the garden, playing with the kids, tidying the house or playing sport, most functional tasks combine multiple interacting variables, ill-defined time frames and multifaceted layers of complexity. High performance in CO-skills relies on the ability to adapt and react to the changing demands of any situation or circumstance.

Because CO-skills can be tough to predict in terms of outcomes, effective behavioral responses can be equally challenging to predict. The success an individual has in any CO-skill relies on their ability to adapt their behavioral responses to match any situation quickly and efficiently.

In any functional task, skill or activity, effetive decision-making relies on a detailed knowledge of the task at hand. Task-specific knowledge is acquired only with time and experience. We can teach someone to kick a ball, (an SC-skill), but to *pass* a ball though a defence and set up a goal (a CO-skill) is a skill that takes time and experience to develop. More often than not this knowledge is non-transferable and cannot be taught in a classroom.

Identifying the factors that determine the level of success in CO-skills can be difficult. Even though basic biomotor skills like strength, speed or endurance are useful, functional performance relies on far more than simply these attributes. As a football coach picking a team for example, how would you evaluate each player? You might consider physical attributes like strength and speed, (i.e. performance parameters), ability to run with the ball or tackle (i.e. task-specific performance, or functional capacity), ability to pass or shoot (i.e. coordinative skill), or the ability to implement tactics and read the game (i.e. behavioral responses). Football players have to adapt and react to highly complex situations – the moving ball, uneven terrain, weather conditions, the actions of teammates and opponents, and specific tactics and strategies. Top players make appropriate behavioral responses for any given situation and circumstance. Complex, task-specific decision-making determines functional erformance.

**Performance in CO-skills involves:**

- The ability to adapt and react to specific circumstances
- The ability to select appropriate behavioral respponses

Functional performance in CO-skills relies on adapting to a countless number of different interacting variables and making appropriate behavioral responses in every situation and circumstance. Rather than focusing on form and technique, functional training needs to develop an individual's ability to adapt and react within the context of a specific task or skill. Improving functional performance in CO-skills relies on developing a client's task-specific knowledge. Functional training should enhance a client's knowledge of *useful* and *relevant* tasks and skills.

## Within-Task Training

The principles of similarity and specificity suggest a reduced role for generalized training. Taken to its natural conclusion, we might abandon 'training' altogether and 'just do what we do'. If you want to get fit for football, just play football, if you want to swim faster, just swim, and so on. Many modern coaches downplay the role of generalized training in favor of modified 'game-play'. To develop football fitness, a football coach might create small sided games, limiting space to encourage fast and frenetic movement, for example.

Fortunately for functional trainers, there is still an important role for physical training. Optimal training applies fundamental principles like *overload*, *progression* and *variation*. To be optimally effective, training needs to emphasize specific elements of performance in a systematic, planned and progressive manner.

In the same way that a football coach has to isolate specific skills pertaining to football, such as passing, shooting, tackling and so on, and has to design specific drills to emphasize and overload each one, a functional trainer has to design and prescribe drills to emphasize specific biomotor skills, like strength, speed and endurance. Ideally, physical training drills should reflect an individual's sport, or be developed in the context of tasks, skills and activities that the client relies upon in daily life. As Eyal Lederman (2010) states, 'for learning, practice should be similar and within the context of the task of performance'.

At the very least, training drills should 'look like function'. For example, exercises should encourage the client to develop coordination within tasks of daily living. We call this creating *coordinative similarity.* One of the most effective ways to achieve coordinative similarity is to prescribe '*within-task training*'.

Rather than a series of abstract exercises that target specific physiological systems, it may be more effective to incorporate useful and relevant functional tasks into training. For example, rugby players can develop power and strength by lifting each other's body weight as if tackling or jumping in a lineout. Weight vests, bands and parachutes can be used to overload sport-specific movements like sprinting or jumping, and could even incorporate sport-specific tasks, like kicking, throwing and tackling. Within-task training creates similarity and specificity by utilizing the specific tasks and skills used in performance. For regular clients, this means replacing the 'leg-extension' and 'bench-press' with lifting, stepping, pushing and pulling movements, whereas for a tennis player it might mean 'loading' a forehand, backhand and serve.

Creating exercise that 'looks like function' is simply not enough. Ensuring coordinative similarity is only the first step in creating exercise that *transfers* to function. Functional performance relies not just on the body but also on the mind, because behavior has such an impact on decision-making and is determined by how we feel about any given situation or circumstance.

Behavior can vary tremendously from one situation to another, and therefore, learning in one context does not necessarily transfer to other contexts. Most of us can read out loud, but it is far more challenging to perform to an audience or make a speech. The context in which skills take place can be all important. A functional trainer has to create exercise that not only looks like function, but also '*feels like function*'.

For learning to transfer to function, learning must occur in situations and circumstance that reflect the context in which learning is to be applied. Training has to reflect not just the mechanics of movement, but also the environment, situation and setting in which skills will be applied. In creating *contextual similarity*, clients learn to make correct decisions and react appropriately in similar situations and circumstances to those they will encounter within function.

Research suggests that learning is specific, not only to movement pattern but also to the context and environment in which that learning occurs. This means that gains in performance are specific to the tools, obstacles and targets with which we train. I can build strength by loading movement using a barbell, but strength will transfer poorly when lifting other more awkward and unusual objects, like a screaming toddler.

Training is specific to the context and environment in which we train. Training in a comfortable, relaxed, stress-free environment is not likely to improve performance in competitive situations or when pressure is more acute. Ask any footballer, is it worth practicing penalties? The psychological pressure can be difficult to reproduce in training.

To improve transfer, training should reflect the emotional and psychological stress and strains of real life, and replicate the social and psychological pressures relating to performance. Achieving *contextual* and *emotional similarity* can be a

## OLYMPIC TRAINING

Within-task training is not a new concept. Take the Olympics for example. Historically, Olympic events were designed to help warriors develop their military prowess. Events included throwing a javelin or discus, wrestling, fencing or equine skills. All these events have clear military significance. In Ancient Greece the 100-yard dash was performed in armor to reflect military application. The Greeks understood that training had to reflect function.

challenge. The psychological, social and emotional factors impacting performance are complex and can be difficult to replicate.

Warren (2006) states that training should reflect the demands of competition. For a footballer this might mean introducing football drills to increase speed, power and fitness. For the hockey player we might integrate hockey sticks, balls and goals into training. To recreate stress and psychological pressure, training should incorperate competitive games, goals and targets. Trainers can introduce rewards and penalties to increase pressure and recreate the stress of a game situation.

To transfer to function, training has to achieve coordinative, contextual and emotional similarity. Functional training develops task-specific coordination. The brain is the integration and coordination centre of the body, therefore, to improve coordination, we have to understand the functional mind.

## INTRODUCTION TO STRIVE

Historically, scientists have tried to understand the body by studying anatomy and physiology. For centuries anatomists have dissected bodies to fathom how each anatomical and physiological component works – the meat and bones of movement, if you will. Conventional exercise programs have applied anatomical and physiological principles to design training programs, working muscles to build strength and expanding the lungs to develop endurance.

The downside with cutting up dead bodies to determine how the body works is that whilst anatomists can visualize tissues and bones, they struggle to see how each component interacts and interrelates. Anatomists can strip away tissue to reveal biceps and speculate how the bicep flexes the arm, but they cannot see how muscles integrate and coordinate during movement as we reach, push and pull. Cadavers are lifeless, devoid of a functioning nervous system and lacking conscious thoughts, attitudes and beliefs. Up until 30 years ago scientists struggled to visualize the brain and how it controls and coorinates movement, pain and performance. What little was understood has been fathomed from studying patients with severe brain injuries and diseases.

- Injured soldiers experienced damage to certain areas of their brain but were able to survive. Researchers could link the injured area of the brain with the loss of function the soldier experienced.
- In 1848, a railway accident drove a metal bar through the frontal lobe of the railway worker, Phineas Gage. Although he survived, he experienced a distinct change in personality. The injury made him 'thoughtless, irresponsible, and fitful' (Macmillan, 2000), symptoms that scientists now commonly associate with frontal lobe injury.

As soon as they realized the brain lacks sensation, neurosurgeons started physically stimulating different regions of the cortex, the outer layer of the brain, in awake patients, asking for feedback on what sensations they experienced. Canadian neuroscientist Wilder Penfield (1891–1976) applied electric currents to the surface of the brain in patients he was surgically treating for epilepsy, recording their responses. After stimulating the physical brain, Penfield would then record a patient's sensations and movements. Slowly he was able to map the *sensor-motor cortex*, for which he received a Nobel Prize.

Only recently have advances in physics provided amazing new tools like Positron Emission Tomography (PET) and Magnetic Resonance Imaging (MRI). These tools have allowed scientists to study the inner workings of the brain in healthy adults, monitoring the flow of fluid and electrical activity in the brain of patients as they perform different functions.

Beyond the physical brain, neuroscientists now understand more than ever before about the inner working of the '*functional mind*'. This explosion in neuroscience is producing revolutionary new findings regarding how the brain controls, coordinates and regulates movement, pain and performance.

Previously, scientists thought that the adult brain developed much like the rest of the body, growing and developing throughout childhood until it becomes fully formed in maturity, remaining relatively stable and unchanging in adult life. We now know that the adult brain is constantly adapting and changing in response to thoughts, actions and experiences. *Neuroplasticity*, the brain's ability to transform, is the foundation for learning and the key to unlocking human potential.

Whenever we think or move, imaging of the brain reveals a virtual fireworks display of activity throughout multiple areas of the brain. In neuroscience, this explosion of activity is called a neurotag, and the neurological scaffolding within which it occurs is called the *neuromatrix*. The neuromatrix, or *functional mind*, supports a complex, integrated web of activity each time we think, act or move. The brain is the fastest adapting system of the body. Unlike the other physiological systems, the brain is unconstrained, with limitless potential to adapt and learn. Being able to 'program' the functional mind is the key to unlocking human potential.

In mainstream medicine, neuroscience is starting to be applied to patients with chronic pain and complex pain syndromes. Neuroscience is disseminating into musculoskeletal therapy to help practitioners treat pain and injury. We are seeing that managing a patient's thoughts, attitudes and beliefs is equally, if not more important, than treating their physical body.

In this text, we apply principles of neuroscience to design functional training programs, helping trainers design exercise to improve movement, reduce pain and enhance performance. Our goal is to reconceptualize functional exercise design, creating exercise that facilitates neuroplastic adaptation.

We have condensed neuroscience to create a package of STRIVE principles, which guide exercise design and take advantage of the neurological and behavioral factors that underpin performance.

## STRIVE Principles

- Subconscious Controlled
- Task-Orientated
- Reactive
- Intelligently Varied
- Emotional

As we progress through this text, we analyze neuroscience and each of these STRIVE principles. In the next chapter, we introduce functional anatomy, the 'meat and bones of movement', before taking a closer look at the neurology of movement. Finally, we apply STRIVE principles to functional exercise design and rehabilitation.

## BRINGING IT TOGETHER

- Functions are tasks, skills or activities that are relevant, useful or vital to daily life.
  - Functional training is designed to improve the ease, accuracy and efficiency of these functional movements, and develop the neurological and behavioral factors underpinning performance.
- Exercise should develop a client's:
  - Coordination
  - Adaptability
  - Behavioral decision-making
- Transfer of training to performance is difficult to achieve and relies on coordinative, contextual and emotional similarity.

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# 2 FUNCTIONAL ANATOMY

- Bones
- Joints
- Muscle
- Fascia – The Connective Tissue
- Skin
- Supporting Systems
- Functional Anatomy
- Functional Bone Motion

To understand movement, we start with *functional anatomy*, 'the meat and bones of movement'. Whilst much of this book is dedicated to the brain and how we can apply principles of neuroscience to exercise design, anatomy and physiology is still fundamental to understanding how the body works. Here we have provided a brief introduction to anatomy.

Anatomy is the branch of biology concerned with the structure and function of organisms, in this case the human body. The word 'anatomy' is derived from the Greek term '*anatomia*', meaning 'to cut up or cut open'. Historically, anatomists have learnt about the body by dissecting cadavers – corpses dedicated to medical science. Anatomists work to seperate each individual tissue and organ to fathom what each part does, its function, and how it works.

Dissection clearly has several drawbacks. Dead bodies do not have a nervous system and they lack thoughts, feelings and emotions. This makes an anatomical analysis only one small part of the human puzzle. Despite this, *functional anatomy* is fundamental to understanding how the body works and how we control and coordinate movement. We start our functional training journey with an overview of the anatomical structures of the body – a brief insight into the structure and function of the:

- Bones
- Joints
- Muscles
- Fascia
- Skin

# BONES

Children have approximately 300 bones, many of which fuse by adulthood, leaving approximately 200 bones forming an adult's skeletal framework. There are 14 bones in the face, 27 in the hand. The smallest bone is the stirrup bone in the ear, measuring 1/10 of an inch. The longest bone is the femur or thigh bone, constituting roughly 1/4 of our height. Bones can be classified based on their shape:

Bones are designed to provide solid attachment sites for muscles and absorb the stress and strain of movement. If we look at a typical long bone (see Figure 2.1), it has a head at each end, called the *proximal* and *distal epiphysis*, which is connected by a long *diaphysis*. The *epiphysis* is made up of spongy bone and is coated in hyaline articular cartilage, designed to absorb shock and support the gliding movement of joints.

The long *diaphysis* has a compact outer layer made of hard mineralized bone and reinforced with tough collagen for strength. Beneath the compact bone, the *medullary cavity* is composed of *spongy bone* formed into thin columns called *trabecular*. *Trabecular bone* is deposited in lines of stress, creating a structure that is both light but strong. Between trabecular columns we find red

| Bone Type | Characteristics | Example |
|---|---|---|
| • Long | Long shaft with widened ends | Humerus, Femur |
| • Short | Cube shaped | Carpals and Tarsals |
| • Flat | Thin, designed to protect | Scapulae, Patella |
| • Irregular | Unique in shape and function | Vertebrae |

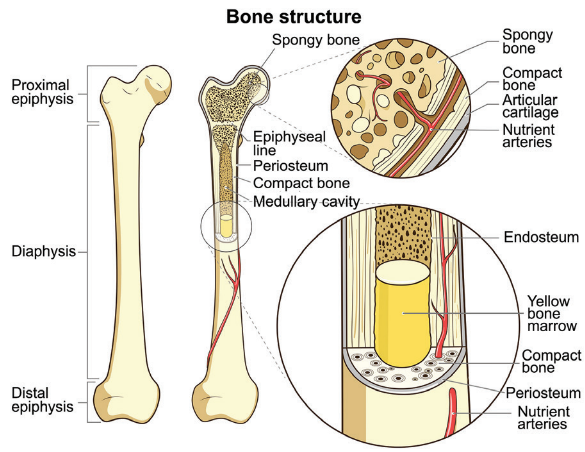


**Figure 2.1** Bone Structure.

*bone marrow*, the substance that produces *red* and *white blood cells*.

Trabecular bone is deposited along lines of load. When we expose bones to axial load (load along their length) we encourage bone deposition. This is particularly helpful for certain populations susceptible to osteoporotic stress, like post-menopausal females, the elderly or people who have taken steroids for long periods, which leads to bone de-mineralization. Functional exercise in the form of upright loaded movement is useful for these vulnerable groups because it stimulates mineralization along lines of stress and strain, keeping bones strong and healthy.

Bone has a *periosteal* outer skin that provides a firm attachment for ligaments and muscles. This skin is infiltrated with blood vessels that provide nourishment and support healing. The *periosteum* also contains nerves, making it susceptible to pain if irritated or damaged.

Maintaining the health and integrity of bones is extremely important. Bone is continually being broken down, reabsorbed, deposited and remodeled. *Osteocytes* lay down minerals to

### SHIN SPLINTS

*Pain on the inside of the shin is often caused by irritation of the periosteal skin of the medial tibia. This irritation is often caused by tightness of the deep calf muscles, usually caused by excessive running. This condition is called Periostitis and is known to most people as shin splints.*

maintain the strength and integrity of compact bone. Even as adults, bone is continually healing, repairing, growing and adapting along lines of stress and patterns of use.

*Use* in the form of activity and exercise stimulates bone repair. *Functional loading* creates healthy bone by organizing the absorbtion and deposition of bone. Exercising in 'resting postures', sat down, like on a stationary bike or inner and outer thigh machine, does not provide natural or normal loads along long bones, and therefore may not provide an effective stimulus for bone deposition. Whilst ingesting sufficient calcium is important for bone health, stimulating and organizing bone deposition along useful lines using *functional movement* is equally essential.

The skeleton is formed from various bones that act as a scaffold, giving the body form and shape. The skeleton can be divided into two parts, the *axial* or *central skeleton* and the *appendicular skeleton*. The axial skeleton is found on the midline of the body and includes the cranium, spinal column, ribcage and sternum. Its primary function is to protect major organs. The appendicular skeleton includes the limbs and the pelvic and shoulder girdle, and has the primary function of enabling movement and locomotion. Between each bone is a joint that allows motion to occur.

## JOINTS

The articulations between bones are called joints. There are between 250 and 300 joints in the human body depending on your definition. Joints are designed to support mobility whilst balancing the need for stability. There are different types of joints, *fibrous joints* (e.g. sutures of the skull) that allow virtually no movement, *cartilaginous joints* (e.g. intervertebral disc) that allow limited movement and *synovial joints* (e.g. elbow and knee) that are designed to allow considerable movement.

- Fibrous – bone ends united by collagen fibers
- Cartilaginous – joined by cartilage
- Synovial – not directly joined

Arthrology is the study of the structure and function of joints. Joints move in a complex and subtle manner to support an infinite number of different motions and functions. The subtle internal motion of joints is called *arthrokinematics*.

*Synovial joints* like the hip, shoulder or knee, are specifically adapted to move. Synovial joints tend to be either uniaxial, biaxial or multiaxial.

- Uniaxial – allowing rotation in one direction, such as the elbow
- Biaxial – allowing movement in two directions, such as the ankle and wrist
- Multiaxial – allowing movement in three directions. These tend to be called ball and socket joints and include the shoulder and the hip

Synovial joints are distinct in that they have a *joint cavity* – the space within the joint. They tend to have *articular cartilage*, a spongy, cartilage 'spacer' that supports smooth movement and reduces friction. Synovial joints also have an *articular capsule* that encloses the joint, filled with *synovial fluid* that lubricates, reduces friction and provides nutrition. Additional facial and cartilaginous structures provide *passive* support (i.e. non-contractile as with muscle). Passive supporting structures within a synovial joint include:

- The joint capsule
- Intra-capsular and extra-capsular ligaments
- Articular discs or menisci
- Articular lips and labrum

The *fascial system* is extremely important for maintaining the health and stability of joints. Cartilaginous and fascial structures provide stability, offer shock absorption and, under normal circumstances, facilitate motion of the joint. Soft tissue and cartilage are highly innervated with nerves providing *proprioceptive* feedback essential in coordinating local muscle activation to provide local stability. Healthy fascial structures are therefore essential for joint stabilization. Fascial dysfunction is a frequently overlooked cause of joint restriction and instability.

Joint capsules are frequently reinforced by strong *ligaments*. Ligaments attach from bone to bone, providing static stability and preventing excessive motion at a joint. Ligaments are comprised primarily of *collagen*, a substance with great tensile strength (i.e. resisting tension or pull). They are characterized by poor blood supply, which means they take a long time to heal compared to muscle. Ligaments are imbedded with a large number of sensory nerve endings, providing a rich source of sensory feedback regarding the position and motion of a joint.

The *synovial capsule* releases *synovial fluid* in response to movement. Varied, rhythmic compressive load stimulates the release of synovial fluid, flooding the joint with nutritious fluid. The rhythmic loading and unloading of the knee during walking, for example, stimulates the release of synovial fluid, providing nutrition and stimulating fibroblastic action, which maintains cartilage health. Functional movements like walking, climbing and crawling are all fantastic for joint health.

Squatting, bending, stepping and walking are fantastic movements to slow arthritic degenerative change of the hips, knees and ankles. Anyone worried about joint health should maintain good nutrition, stay hydrated, maintain a healthy weight and take regular 'functional' exercise.

Joint degeneration is a natural side effect of ageing. Whilst osteoarthritis (OA) is often talked about as a disease, OA can result from natural wear and tear, an inevitable part of life. It would be unusual if a 70-year-old man lacked osteoarthritic degeneration. Whilst wear and tear is 'normal', joint degeneration is accelerated when joints are loaded unevenly or excessively.

Excessive or uneven load, over-use and even under-use can all accelerate joint degeneration. Excess weight, repetitive patterns of loading from sport, for example, and a sedentary lifestyle can all irritate joints and should either be avoided, or at least mitigated by the addition of some balanced *functional movement*.

## MUSCLE

Muscles are the largest group of tissues in the body, accounting for almost half of the body's weight. Muscles are contractile tissue that convert energy into motion. There are three main types of muscle, *skeletal muscle*, known as *voluntary muscle* because we have conscious control over its action, *cardiac muscle* forming the wall of the heart, and *smooth muscle* that forms the walls of most vessels and organs. Both cardiac and smooth muscle are *involuntary*, working without conscious awareness.

Skeletal muscle is composed of many individual muscle fibers wrapped together in bundles. Connective tissue known as *fascia* covers each of these bundles. The outer layer that covers the whole muscle is called the *epimysium*. The epimysium runs into *tendon* of the muscle that attaches and transmits force to the bone. Muscles attach to bone proximally (*origin*) and distally (*insertion*).

- Origin – muscle attachment that is generally more proximal and moves the least
- Insertion – muscle attachment that is generally more distal and moves the most

Under the epimysium we see bundles of muscle fibers known as the fascicles, wrapped in fascia called the *perimysium*. Each muscle fiber is wrapped in a connective tissue called the *endomysium*. Each muscle fiber forms the building blocks of muscle called *myofibrils*.

The *myofibril* structure of *myosin* and *actin* allows contraction of muscle. Actin and myosin run parallel with each other. The thick myosin filaments have small heads called *cross bridges*. Folllowing electrical stimulus from a *motor neuron*, cross bridges interact with, bind to and pull against the thin actin filaments. This pulls the actin and myosin filaments together to produce movement, a process referred to as the *sliding filament theory*.

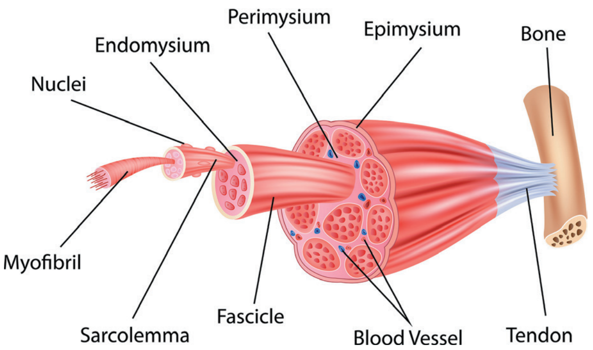


**Figure 2.2** Structure of Skeletal Muscle.

Muscles are formed into different shapes and orientations, specifically adapted for functional patterns of movement. For example, the Latissimus Dorsi is adapted for hanging and climbing, a genetic hangover from our origins as apes swinging through trees. The 'lats' have a twist near their insertion, making them particularly strong and stable. Hanging is a fantastic way of maintaining the flexibility and mobility of the shoulder joint. The Latissimus Dorsi is not designed to 'pull-down' and as such the lat-pull-down machine may not be a healthy way to develop shoulder strength. Repetitive pulling down could potentially contribute to stiffness and tension in the shoulder. Far better to hang, pull-up, swing and climb.

Skeletal muscle is composed of varies different types of fiber, each with different characteristics. Muscles are composed of a blend of either:

- Fast twitch fibers
  - Produce large amounts of force
  - Are quick to relax
  - Fatigue quickly
- Slow twitch fibers

- Produce low levels of force
- Relax slowly
- Are resistant to fatigue

Individuals with predominantly *slow twitch fibers* generally make better endurance athletes, long-distance runners for example. Individuals with muscles that contain a higher proportion of *fast twitch fibers* are generally suited to more explosive activities, such as sprinting, jumping or throwing. The extent to which training can alter the relative proportion of muscle fiber types is up for debate.

## FASCIA – THE CONNECTIVE TISSUE

The terms *connective tissue* and *fascia* are commonly interchangeable. *Fascia*, derived from the Latin for a '*band or bandage*', is a term anatomists use to describe the dense connective tissue that wraps around every other tissue or organ of the body. You will have seen fascia, it is the tough white substance attached to meat and bones you buy from the butcher. Anyone who has skinned a chicken breast or trimmed meat has felt fascial tissue.

Historically, anatomists have overlooked fascia, viewing it as unimportant compared with its more specialized neighbors. During dissection, fascia was typically stripped away to reveal underlying muscle and organ. More recently, fascia is being considered to have a role in supporting global stability and whole-body communication. Fascial function is rapidly being seen as pivotal in supporting function and in preventing musculoskeletal dysfunction (Benjamin, 2009).

The collagenous network that forms fascia, known as the 'extracellular matrix' (ECM), is a three-dimensional web of fibrous, gluey, soggy protein, formed from three major components: *elastin*, *collagen* and *ground substance*. *Collagen* is our most prevalent protein type within fascia, comprising about 15% of its dry weight.

Collagen fibers act like tough threads, providing tensile strength, supporting and binding tissues together. *Elastin* is a rubber-like substance designed to resist distension, absorb load and recoil after stretch. *Ground substance*, a lubricating gel composed of proteoglycans, hyaluronic acid and water contains various cells, including *fibroblasts* that synthesize collagen and maintain the extracellular matrix. Fibroblasts play a critical role in wound healing by maintaining the health of connective tissue cells.

### Fascial Strength

The term fascism derives from the Latin word fasces, which was a bundle of rods tied (bandaged) around an axe, which was an Ancient Roman symbol of authority. The symbolism of the fasces represented strength through unity because whereas a single rod is easily broken, a bundle is difficult to break.

Healthy fascia optimizes elastic recoil by maintaining a 'crimped' structure (Staubesand et al., 1997). *Crimps* act like a coiled spring, increasing the potential for elastic storage. As well as being crimped, fascia is arranged like a lattice structure, similar to a woman's stocking, allowing it to tension under stretch (Staubesand et al., 1997). The structure of fascia makes it perfectly adapted to absorb mechanical force, a useful quality in supporting functional movement.

Fascial tissue contains a rich supply of sensory nerves, having ten times more nerve endings than muscle (Schleip et al., 2012). Fascia is one of the richest sensory organs, acting as a body-wide sensory organ supporting functional myofascial integration and coordination (Langevin, 2006). Fascia is 'the listening tissue', providing a rich supply of sensory feedback, essential for coordinating movement.

Fascial tissue within joint capsules is particularly important for joint stability and health. The capsules of synovial joints are densely innervated with mechanoreceptors highly sensitive to stretch, compressive load and increased internal pressure (Tesarz et al., 2011). The capsule blends with other soft tissue structures like ligaments and muscles and provides sensory feedback during motion. The sensory information from the joint capsule is highly important for function not only of the joint, but also of the surrounding tissues and muscles.

Anatomists frequently regard fascia as having a passive role, merely absorbing and transmitting mechanical tension through its elastic elements. However, there is new evidence to suggest it has a more active role (Schleip et al., 2005). Emerging research suggests fascia is embedded with smooth muscle, called *myofibroblasts*, that influence musculoskeletal dynamics by exerting a clinically significant force (Schleip et al., 2005). Contractile cells within muscle appear to 'pre-tension' connective tissue prior to loading, creating 'tensegrity' for global stability.

Fascia passes seamlessly throughout the body, forming aponeuroses, retinacula, blending into tendons, ligaments, joint capsules and the periosteal tissue of bones, encapsulating and passing through muscle. Fascia is typically classified into three types:

- Deep – dense, fibrous connective tissue surrounds specialized tissues like muscle, bone, blood vessels and nerve tissue
- Superficial – a layer of fascia directly beneath and communicating with the skin
- Visceral – wraps and suspends organs within their cavities

Anatomists have identified clinically significant regions of fascia, such as the *plantar fascia* located on the plantar surface of the foot, the *clavipectoral fascia*, found around the base of the neck, and the *thoracolumbar fascia*, thought to play a key role in stability of the lumbar spine.

More recently, clinicians have theorized that myofascia is organized in continuous chains, supporting functional movement by absorbing, distributing and returning force during dynamic functional movement. *Anatomy Trains* by Myers (2011) is an example model of integrated fascial function. The notion of fascial chains suggests that, rather than stretching and strengthening muscles individually, we should consider *fascial chains*.

As well as working along extensive longitudinal chains, fascia also influences local tissue via *lateral attachments*. When muscles contract, the forces they produce interact with adjacent tissue via lateral fascial attachments, exerting as much as 30% of their pulling force onto adjacent tissue. Muscles do not simply pull from origin to insertion, they exert force multi-directionally throughout surrounding tissue. The model of muscles attaching to bones via tendons needs to be updated. The hamstring does not only pull to extend the hip, they also pull on local tissue, contributing to *tensegrity*.

Fascia not only runs in long chains but also forms a continuous, interconnected web designed to transfer mechanical force and generate global stability (Fuller, 1962). The fascial system could be considered as a collection of bags and balloons, encasing and encapsulating other specialized organs in a single closed system.

The various functions of the fascial system are broad reaching – contributing to stabilization, proprioception, sensation, organization and coordination. Exercise should reinforce fascial function. Conventional exercises like the Chest-Press or Lat-Pull-Down isolate individual muscles and overload pockets of fascia. Conventional exercises overlook the integrated nature of the fascial system and therefore could potentially disrupt movement in a way that may predispose pain and injury. Far better to load muscle and fascia using natural movements within a program of 'functional training'.

## SKIN

The importance of skin as a sensory tissue is starting to receive more attention. The skin protects the body from infection, prevents fluid loss, insulates and regulates temperature.

The role of skin as a sensory organ and a transmitter of mechanical forces is also becoming a key area for research and investigation, and I am sure in the not-too-distant future we will be discussing the skin as a key ‘integratory organ’.

## SUPPORTING SYSTEMS

Physiology is a distinct area of study concerned with chemical processes that support the production and utilization of energy. Physiology is a vast scientific field, encompassing digestion, endocrinology, cardiovascular function and respiration. The size of this topic makes it beyond the scope of this text.

Broadly speaking, the supporting systems are concerned with providing the energy to support movement, growth and repair. In this text we have discussed the form and function of the human body as it relates to movement, and we leave detailed analysis of physiological function for another day.

# FUNCTIONAL ANATOMY

Whilst conventional anatomy depicts the structure of the body, it fails to explain how each component interrelates and communicates. In *functional anatomy*, we theorize how each anatomical fragment connects as a whole.

Functional trainers (FT) need a common language to describe *where* bones are, *how* they are moving and *why* they are moving. Here are some of the more common terms used to describe *where* a body is in space. We generally refer to points in relation to a central midline or middle point.

| | |
|---|---|
| • Proximal | Nearer the trunk |
| • Distal | Further away from the trunk |
| • Superior | Above (also known as cephalic) |
| • Inferior | Below (also known as caudal) |
| • Anterior | Towards the front of the body (also known as ventral) |
| • Posterior | Towards the rear of the body |
| • Medial | Towards the midline of the body |
| • Lateral | Away from the midline of the body |
| • Superficial | Towards the surface of the body |
| • Deep | Being further from the surface of the body |
| • Internal | On the interior (inner) |
| • External | On the exterior (outer) |
| • Central | Toward the centre |
| • Peripheral | Further away from the center |
| • Ipsilateral | The same side |
| • Contralateral | Opposite side |
| • Muscle origin | Proximal muscle attachment |
| • Muscle insertion | Distal muscle attachment |
| • Supine position | Lying facing upwards |
| • Prone position | Lying facing downwards |
| • Recumbent | Lying down |
| • Palmar surface | The anterior surface |
| • Plantar surface | The inferior surface |

## Functional Bone Motion

A trainer needs to be able to describe how bones are moving. The study of gross bone motion is called *osteokinematics*. In most anatomical texts, the musculoskeletal system is thought of as a simple system of levers and pulleys. You have probably seen images of one bone moving on top of another, pulled by the action of a muscle.

Bones are usually described as moving in one of three different directions. Either flexing and extending (i.e. tilting forwards and back), adducting or abducting (i.e. tilting inwards or outwards) or internally and externally rotating (i.e. twisting inwards or outwards).

| | |
|---|---|
| • Flexion | Bending or decreasing the angle between body parts |
| • Extension | Straightening or increasing the angle between body parts |
| • Abduction | Movement away from the midline |
| • Adduction | Movement towards the midline |
| • Rotation | Turning around an axis or pivot point |
| • Internal rotation | Rotation towards the midline |
| • External rotation | Rotation away from the midline |
| • Circumduction | Circular movement combining flexion, extension, abduction and adduction |
| • Eversion | Moving sole of foot outwards |
| • Inversion | Moving sole of foot inwards |
| • Supination | Turning the palm to face anteriorly |
| • Pronation | Turning the palm to face posteriorly |

When bones flex or extend or abduct or adduct, they are essentially *tilting*. *Tilt*, or *angular rotation*, occurs around a fixed axis (see Figure 2.3). Imagine a pole standing on its end, unless it is perfectly balanced, it will tilt one way or another. We can tilt forwards and backwards, side-to-side, or in any given direction for that matter. The degree of tilt or angular rotation is described in degrees.

Bones tilt or rotate around an axis. The angle of the axis dictates the direction of tilt or the type of angular rotation. Tilt is classically described as occurring on one of three '*cardinal axes*':

- Sagittal axis aka anteroposterior axis (AP)
- Frontal axis aka coronal axis
- Transverse axis aka vertical axis

The *sagittal axis* runs like a rod going horizontally across our body. The *frontal axis* goes straight through our middle (from front to back) and the *transverse axis* passes straight through our body from our head down through to the floor, as if passing through our spine.

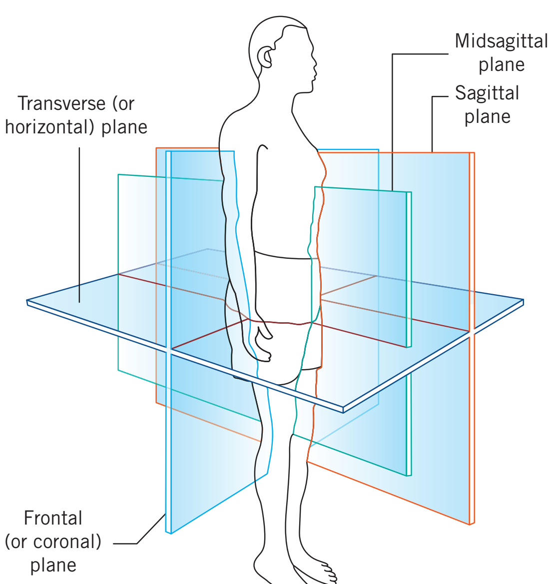


**Figure 2.3** Axes and Planes of Motion.

A body can also *translate*, which is to move from one place or another without angular rotation. We can tilt or translate in different directions or along different '*planes of motion*'. We can move forward and back along the sagittal plane, forwards and back, side-to-side in the frontal plane or twist in the transverse plane.

- Sagittal plane – allows motion forwards and back
- Frontal plane – allows motion left and right
- Transverse plane – allows twisting motion

When we consider motion of one body or bone on another, the conventional perspective suggests there are two main types of movement possible:

- Open chain movement – when the proximal segment is fixed and the distal segment moves (e.g. leg extension or bicep curl)
- Closed chain movement – when the distal segment is fixed and the proximal segment moves (e.g. press-up or pull-up)

Muscles work differently in either *open* or *closed chain* exercise. The pectoral muscles, for example, work very differently when performing a press-up (closed chain), compared to when we punch or throw (open chain).

Exercises can be classified on which plane of motion and axis of rotation they utilize, the motions occurring at each joint and whether the motion is open or closed chain. A bicep curl, for example, involves flexion at the elbow, occurring on a sagittal plane on a frontal axis running through the elbow joint, and is an example of an open chain exercise designed to stress the bicep muscles.

This is a highly simplified model of how the body works, so simple in fact that it becomes inaccurate and misleading. Conventional exercise programs tend to be designed based on these highly simplistic models, meaning conventional training is often far removed from how the body moves in real life.

## FUNCTIONAL BONE MOTION

The model of one bone moving over a second, static bone is hugely oversimplified. Is there a static bone as the foot moves over uneven ground? Is swimming open or closed chain? Is there ever a situation, other than in the gym, where the motion of one joint is isolated from that of another?

In reality, when bones move at a joint, they tend to do so simultaneously. There is very rarely a staic segment. When we consider that two bones move together, the various different ways bones can articulate becomes far more complex. If we consider two bones moving at the same time, rather than two different types of movement (open and closed), there are now five different types of bone motion existing at a joint:

1. Distal moving on static proximal
2. Proximal moving on a static distal
3. Distal and proximal moving in opposite directions
4. Distal and proximal moving in the same direction but the proximal is moving faster
5. Distal and proximal moving in the same direction but the distal is moving faster

Imagine all the different ways our bicep has to work, with different bones generating different types of motion. To perform just one type of bicep curl neglects all these different bone motions. The hip works not in one direction, but in all three planes of motion, and interacts with the pelvis and spine as they move in different directions. Imagine all the different exercises we would have to design to cover each one of these different types of movement.

In reality, as we move long chains of bones move together, their action blending and interacting. When we consider how each bone motion impacts the next, things get really confusing. No wonder textbooks reduce motion to simple open and closed chains.

Another key fact to consider is that joint surfaces are not entirely congruent. In other words, articulating bones rarely fit together perfectly. If one bone were to tilt on a fixed axis passing through the joint, as depicted in most texts, the incongruenty of each articulating surface would mean that as they move, joints would literally rip themselves apart. To maintain congruency, bone motion has to be accompanied by an *intrinsic joint motion*, a subtle spin, roll and slide of bones to maintain congruity of joints. The study of the intrinsic motion of joints is known as *arthrokinematics* and is an essential component of *osteokinematic* bone motion.

Arthrokinematics proposes that as we move, bones have to subtly 'spin, roll and glide' to maintain joint integrity (see Figure 2.4). Without arthrokinematic motion, joints would dislocate as we bend and flex:

- Tilt – rotation on an axis at the end of a body (e.g. a drawbridge)
- Spin – rotation on a fixed axis passing through a body (e.g. a car wheel spinning having lost traction)
- Roll – a combination of spin and glide (e.g. a wheel rolling on the road)
- Glide – translation of a body from one point to another (e.g. a wheel skidding to stop)

When bones *roll*, one bone literally rolls over another, much like the wheel of a car rolling over a road as we drive. A *glide* occurs when one bone *translates* over another, like a car wheel skidding on an icy surface. A spin occurs when a bone twists on its axis, one on

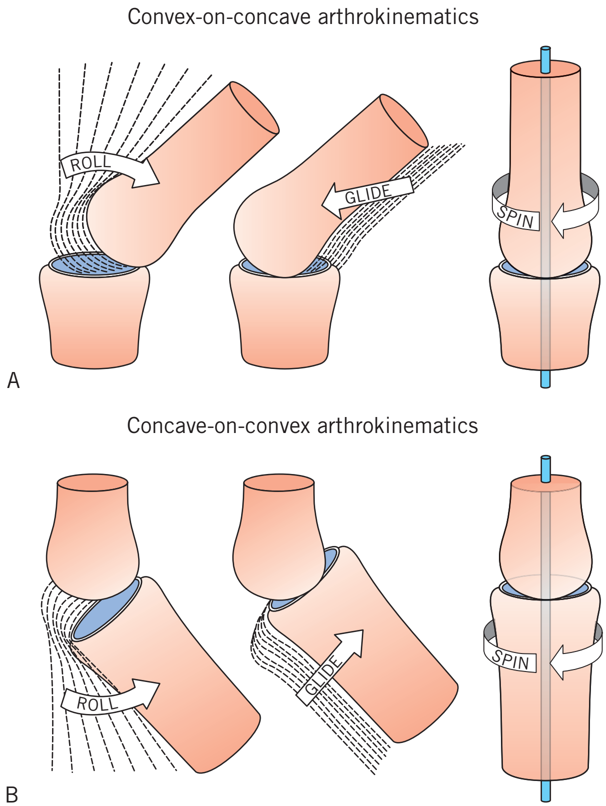


**Figure 2.4** Tilt, Spin, Roll and Glide.

top of the other, like a wheel that has lost traction on an icy road. A loss of arthrokinematic motion can be a reason why joints become dysfunctional, rigid and stiff. Restoring arthrokinematics motion is one way musculoskeletal therapists help to restore motion at a joint.

The notion of open and closed chain motion is far too simplistic to be of any real use. Bones move simultaneously, in lots of different directions and lots of complex and varied ways. Not only do bones move in chains, in complex directions, they also all move at different speeds and at different times. One bone could be moving faster than another, and the question of speed and timing is another layer of complexity often neglected in conventional gym training.

Not only does one bone move over another, but bones work in long 'kinetic chains', with many bones interacting in complex three-dimensional chains. To create a program reflecting the many different ways in which the gluteal muscles have to work to create lumbo-pelvic stability is almost un-imagineable.

In function, we have to think in terms of complex kinetic chains ('kinesis' indicates movement), in which the moton of one joint is dependent on other bones and joints. This concept is referred to as *regional interdependence*. Bones move in complex and integrated ways, in many different directions and at many different speeds. The challenge for an FT is to design exercise that reflects the complex nature of functional movement.

## BRINGING IT TOGETHER

Bones, muscles and fascia interrelate during movement. For an FT to prescribe effective functional training, they should appreciate the various anatomical structures of the body and how they move, including:

- Osteokinematics – bone motion
- Arthrokinematics – joint motion
- Kinetic chain function – interconnectivity of motion

In the following chapters, we discuss how the human nervous system controls the aforementioned anatomy to produce '*meaningful*' movement.

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# 3 FUNCTIONAL NEUROLOGY

What is the best way to develop functional movements like stepping, bending, lifting, twisting, pushing or pulling? How should athletes train to run faster, jump further and climb higher? A conventional approach focuses on the physiological factors underpinning performance – factors like muscle mass, lung capacity and capillarization. The problem is that physiology is slow to adapt. It takes time to grow muscle or expand lungs.

An alternative approach is to emphasize the *biomechanical*, *neurological* and/or *behavioral* factors that underpin performance. The nervous system is capable of astounding growth and instant adaption. The brain is the centre of coordination and controls and regulates movement, pain and performance.

In performing any functional task or skill, the brain has to *sense* the environment and *activate* muscle in a coordinated manner. Understanding how the nervous system coordinates movement may be the key to transforming *functional performance*.

In this section we investigate how the brain controls and coordinates movement, evaluating the key stages of motor control, including:

- Sensation
- Activation
- Adaptation
- Learning

We start with the anatomy of the brain and nervous system.

# NEUROANATOMY

- Neurons, Nerves and Synapses
- The Nervous System
- The Brain Stem, Limbic System and Neocortex
- The Spinal Cord
- The Peripheral Nervous System

Whilst most instructors and coaches have a good understanding of anatomy and physiology, far less is understood about the brain and the associated nervous system. This is shortsighted because it is the brain that controls movement, pain and performance. In this first section looking at the nervous system, we uncover the basic elements of nerve tissue – the building blocks of the brain – and how they combine to create a nervous system.

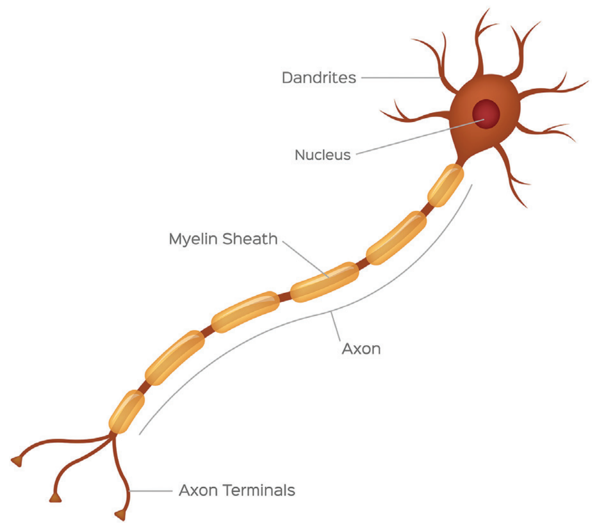


**Figure 3.1** The Neuron.

## Neurons, Nerves and Synapses

The basic building block of the nervous system is the *neuron* (see Figure 3.1). Neurons are specialized cells designed to transmit electrochemical impulses along thin fibers known as *axons*. The electrical signals that pass through neurons form the basis of cell-to-cell communication.

Neurons communicate with each other via synapses. It is estimated that there are approximately 100 trillion synapses within the human brain, all forming lines of communication between neural cells. Electric signals pass from neuron to neuron in a process called synaptic transmission. When an electrical signal reaches a synapse, it triggers the release of various chemical mediators, known as neurotransmitters. These neurotransmitters pass into the synaptic cleft, where they act upon and influence their neighboring neurons.

There are more than 60 types of neurotransmitter, including dopamine, serotonin, acetylcholine and histamine. Each neurotransmitter has a different effect. Some neurotransmitters activate neurons, making them more excitable, others inhibit, calming neighboring neurons down. Neurotransmitters affect the body in all manner of ways, influencing how we feel, how our body moves, how we sleep and even how much force muscles produce.

The action of neurons is altered at various points throughout the nervous system, a process referred to as *neuromodulation*. Modulation can either excite (increase) or inhibit (decrease) levels of transmission between neurons. Both stable changes in neuronal activity and the formation of new neurons, known as neurogenesis, are considered the foundations for learning and memory.

Neurons clump together to form nerves. Nerves can be either sensory, motor or interconnecting. Sensory nerves, also known as afferent nerves, relay signals from the peripheral tissues and organs to the central nervous system (CNS). Afferent nerves provide the CNS with information regarding our environment. Motor, or efferent nerves, transmit signals from the CNS to the tissues and organs. These signals 'activate' or alter the function of peripheral tissues and organs. Motor signals sent from the CNS innervate muscles, making them contract, for example. Interneurons are so called because they communicate between or connect spinal and motor neurons, influencing and modulating neuronal function on yet another level. Nerves congregate in various areas of the body, the entirety of which we call the nervous system.

## The Nervous System

The *nervous system* can be divided into two physical parts, the *central nervous system (CNS)* and the *peripheral nervous system (PNS)*. The CNS, consisting of the *brain* and the *spinal cord*, is the processing center of the body. The CNS receives, processes and interprets vast quantities of information provided by sensory systems and uses this afferent feedback to coordinate the efferent motor signals that drive muscular contractions and stimulate the secretion of various chemical hormones from *endocrine glands*.

The brain is the most complex organ in the human body – a massive biological computer coordinating all the various functions of the body, including how we move and the various physiological functions like digestion, respiration and excretion. The brain is the center for intelligence, consciousness and emotion. Here are a few brain facts:

- The human brain is the largest brain of all vertebrates relative to body size
- It weighs about 3.3 lbs (1.5 kilograms)
- The cerebrum makes up 85% of the brain's weight
- It contains about 86 billion nerve cells (neurons) – the 'gray matter'
- It contains billions of nerve fibers (axons and dendrites) – the 'white matter'
- These neurons are connected by trillions of connections, or synapses
- Whilst the brain comprises only 2% of the body's total weight, it uses at least 20% of the body's oxygen and energy supplies

## The Brain Stem, Limbic System and Neocortex

The brain has evolved into three functional units, each with a different primary role (see Figure 3.2). These are:

- The brain stem
- The limbic system
- The neocortex

The *brain stem* or '*hindbrain*' was the first part of the brain to develop from an evolutionary perspective. The brain stem coordinates basic survival functions, like breathing, excretion and blood flow, and is often referred to as the 'reptilian brain'.

Within the brain stem is the *cerebellum*, a name originating from the Latin word for 'little brain'. The cerebellum is a walnut-shaped structure that receives information from specialized sensors, called *proprioceptors*, located within skeletal

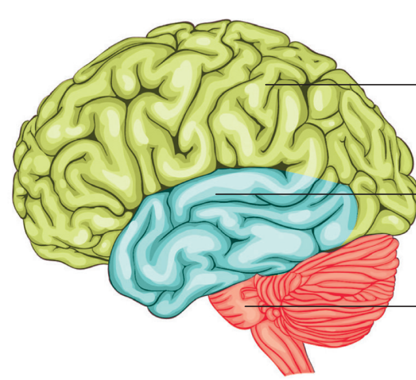


**Figure 3.2** The Brain.

muscles and joints. The cerebellum uses proprioceptive information to determine how we are moving and the forces acting upon tissue. Proprioceptive feedback is used to help the cerebrellum coordinate posture and direct certain reflexive movements. The cerebellum helps coordinate fine, voluntary motor skills, like those used to hit a tennis ball, ride a bicycle or write a sentence. Damage to the cerebeullum undermines this fine motor control, making movement jerky and uncontrolled.

The *limbic system*, including structures like the hippocampus, amygdala and hypothalamus, is the 'emotional centre' of the brain. The limbic system influences behavior by affecting emotion, motivation and learning. In doing so, the limbic system provides the impetus for goal-directed movement, how we act in any given situation and circumstance. '*Emotional intelligence*' is the term used to describe an individual's ability to moderate emotional responses and control limbic reactions in order to make reasonable and rational decisions.

The *cerebrum is* the outer layer of the brain, accounting for more than four fifths of the brain's total weight. The cerebrum has an internal mass of *white matter* and a thin outer covering of *gray matter*, called the *cerebral cortex*. The main difference between human and animal brains is the size of the cerebral cortex.

Humans have more neurons per unit volume than any other animal. The only way to create enough space for these neurons is for the outer layer of cortex to fold in upon itself (Lewis, 2016). As neural tissue grows and expands, the number of folds increase. The more intelligent the animal, the more folds we see. Animals like monkeys and dolphins have more corticol folds compared with the brains of mice, which are predominantly smooth, for example.

The cerebral cortex is the 'center of reason', the area responsible for intellect, memory and personality, and other activities associated with thinking and feeling. The cortex is split into four pairs of lobes, each lobe is associated with a specific function.

Historically, the function of each area of the brain was discovered by either investigating patients with significant brain injury or by stimulating the brain tissue of conscious patients whilst asking them to relay their experience. Whilst these techniques allowed scientists to 'map' the basic function of the anatomincal areas of the brain, it did little to tell us how the brain functions as an integrated unit.

The frontal lobe is one part of the brain worth noting. The frontal lobe is associated with higher-level functions, such as self-control, planning, logic and abstract thought – 'the things that make us particularly human' (Lewis, 2016). Humans have the largest frontal lobes of any animal.

## The Spinal Cord

The *spinal cord* is a tubular bundle of nerve tissue, approximately 40 to 50 cm long, that extends from the base of the brain down the vertebral column. The spinal cord acts like an information highway, connecting the brain to the peripheral tissues via spinal nerves. Messages travel from the brain, down the spinal cord and reach the muscles via motor nerves. At the same time, sensory information is sent from the periphery, up the spinal cord back to the brain.

The spinal cord has various functions, including helping control blood pressure, heart rate and body temperature. The spinal cord acts as the primary reflex center, coordinating incoming and outgoing information from tissues and generating movements through a range of simple spinal reflexes. Reflexes can be extremely useful, especially in making rapid adjustments, which is important for safety and for protecting us from harm.

## The Peripheral Nervous System

The *peripheral nervous system* (PNS) includes nerve tissue (nerves and ganglia) located outside the brain and the spinal cord. The PNS can be divided into two main branches, the *autonomic nervous system* (ANS) and the *somatic nervous system* (SNS).

The SNS controls voluntary movement by conducting impulses to and from skeletal muscle, creating patterns of muscle activation. The SNS has an afferent division made up of sensory nerves that send information from the periphery to the CNS, and an efferent division composed of motor nerves that send messages from the CNS to effect peripheral tissues, primarily to drive muscles to contract and create movement.

It is often assumed that sensory and motor signals travel in different nerves. In actual fact, most nerves combine both functions, carrying both motor and sensory signals. One fact of note is that far more information passes through sensory nerves compared to motor nerves. There is a rough 80% to 20% split of sensory afferent information passing back to the brain, compared to motor efferent signals passing from the brain to drive muscles. In other words, there is far more traffic travelling into the brain than passing out.

## The Autonomic Nervous System

The CNS both controls movement via somatic nerves and influences body function via the slow acting ANS. The ANS controls *involuntary* movement, such as the action of cardiac muscle and smooth muscle found within the walls of organs and viscera. The ANS also controls the function of the various endocrine glands that affect metabolism and energy utilization.

The ANS is further subdivided into the sympathetic and parasympathetic branches. The sympathetic nervous system (SNS) is the branch of the ANS concerned with excitation and is designed to mobilize energy to fuel work, especially in the case of emergency. The SNS, also referred to as the 'freeze, flight and fight system' dominates in times of elevated stress. The parasympathetic nervous system (PNS) is activated at times of rest, when repair and recovery is a priority, hence its nickname, the 'rest and digest system'.

The brain and associated nervous system work to control and coordinate the action of skeletal muscle and maintain vital physiological functions, like breathing, respiration, digestion and excretion. In any moment, the nervous system works to both keep us alive by maintaining homeostasis, the body's state of internal balance, as well as coordinating the action of hundreds of different muscles, working to drive the motion of various bones and joints.

The vast majority of coordination ocurrs beneath conscious awareness. The quality of neuromuscular coordination determines performance. How efficiently and effectively the body organizes movement, synergizes muscles and integrates the various systems of the body determines how fast we move or how much force we produce. A greater understanding of the nervous system is fundamental for effective 'functional program design'.

## Bringing It Together

Following this chapter, you should understand:

- The neuron
- The central nervous system, including:
  - The brain, cerebrum, brain stem and limbic system
  - The spinal cord
- The peripheral nervous system

In the next section, we take a more in-depth look at the 'function' of the nervous system. Specifically, how the brain senses our world, interprets sensory information and then acts upon that information to create skilled movement.

# SENSORY PERCEPTION

- Sensors
- Multisensory Integration
- Internal Body Maps
- Sensory Overload
- Perception
- Perceptual Filters
- Sensory Expertise

Functional performance relies on the ability to organize movement, synergize muscle and integrate the various systems of the body. Efficient and effective coordination relies on accurate sensory feedback. The brain needs a clear and concise image of where we and what we are doing.

To create accurate sensory images, the brain collects and collates vast sums of sensory information. The challenge the brain faces is the sheer quantity of sensory information it receives. Vast sums of sensory feedback in the form of electrical signals bombard the brain. These electrical signals have to be processed and interpreted to construct an accurate representation of the world in which we interact.

To act in a timely manner, the brain takes shortcuts, filtering and compressing sensory data and filling in the gaps using experience and expectation. Shortcuts leave the brain susceptible to error, leading to a whole host of problems, including errors in perception and poor coordination.

Understanding sensory perception can provide useful clues as to how we can improve the functional performance in clients. In this section, we take a deeper look into *sensory perception* and the perceptual errors that occur when we try and perceive the world around us.

## Sensors

The brain gathers information from receptors embedded within tissues and organs throughout the body. These receptors send a stream of sensory information and can be classified into one of four categories:

- Chemoreceptors – detecting chemical changes (e.g. change in acidity)
- Photoreceptors – detecting changes in light
- Mechanoreceptors – detecting changes in mechanical load and tensile stress
- Thermoreceptors – detecting changes in temperature

As well as receiving information from sensory receptors embedded within unspecialized tissues like skin and fascia, the brain also receives valuable intelligence from specialized sensory organs. The eyes, ears, nose and vestibular apparatus all contain specialized receptors that supply the brain with essential information. Aristotle identified five main human senses:

- Touch – somatic sensation from mechanoreceptors in the skin
- Taste – gustatory sensation from receptors in the nose
- Smell – olfactory sensation located from receptors in the nose
- Sight – visual sensation from photoreceptors in the eyes
- Hearing – auditory sensation from receptors in the ears

We do not have the time to unpick the intricacies of how each specialized sensory organ works within this text. It is enough to appreciate that each *sense* contributes to an individual's overall sense of 'self' within their environment.

To move with accuracy and precision, the brain needs reliable information on our body's position in space, our position in relation to other objects within our envieronment and how we are moving within that space – what neuroscience refers to as '*position sense*' and '*motion sense*'.

In 1826, neurologist Charles Bell questioned the assumption that the only role of muscles was to generate force for movement. Bell concluded that muscles also contain receptors that contribute to position and motion sense. Bell was correct and we now know that muscles are rich in sensory cells that detect changes in mechanical forces acting on muscles.

In 1887, neurologist Henry Charlton Bastian proposed the term '*kinesthesia*' to describe the sense of position and motion of limbs. In 1906, neurophysiologist Charles Scott Sherrington coined the term *proprioception* to describe the sensory information derived from mechanoreceptors, known as *proprioceptors*, embedded within soft tissue that detect the deformation of skin, muscles, tendons, fascia, joint capsules and ligaments during movement (Grigg, 1994).

Proprioception is the body's 'sixth sense' (Wade, 2003). Proprioceptors provide the brain with huge quantities of sensory feedback regarding the length, tension, load and effort passing through the body in any moment. The brain interprets proprioceptive feedback to establish the position of the limbs, both in relation to each other (e.g. our foot in relation to our hip) and in relation to the environment (e.g. our foot in relation to the rocks on the ground). Proprioception provides a whole range of inner senses, including:

- Position sense aka proprioception
- Movement sense aka kinesthesia
- Balance sense aka equilibrium

Proprioception provides a sense of our place in the world, essential for accurate and effective functional movement. There are people who contract viral infections that damage proprioceptive nerve pathways, causing them to lose position sense. These people rely on their vision to navigate the world. If at any point vision is taken away, say if the lights cut out for example, they often fall in a heap on the floor. Without vision, these individuals are robbed of the ability to produce successful voluntary movement. The ability to interpret proprioceptive information lies at the heart of how effective an individual is at producing coordinated movement.

Exercise and training can develop the brain's position and motion sense, leading to an overall improved coordination. An improved ability to coordinate is reflected in the ability to maintain balance and in the ability to create greater levels of strength, speed and power. To improve performance, ask how do we improve coordination, or how do we develop position and motion sense? Is it to sit and push and pull guided resistance machines, or do you think it might be better to stand and move dynamically through space?

## GTOs and Spindles

Scientists have identified two chief proprioceptors embedded within muscle, the *muscle spindles* and *Golgi tendon organs* (GTOs). In the 1960s and 1970s, scientists identified muscle spindles running along the length of muscle fibers. Muscle spindles provide the brain with sensory information regarding stretch and the rate of stretch of muscle. They also give information regarding the stress and strain passing through muscles as they 'deform' under load.

When spindles detect a rapid change in muscle length, due to excessive stretch, they trigger a spinal reflex, generating a muscular contraction. This is known as the *stretch reflex*. A popular illustration of the stretch reflex is the 'knee-jerk'. When a GP taps the underside of the knee, muscle spindles detect rapid stratch caused by the blow to the patellar tendon stretch, activating the quadricep and making the foot leap into the air.

Another example of the stretch reflex is when you are nodding-off in the passenger seat of a car. As you fall asleep, the head tips forwards and the weight of the head stretches the posterior neck muscles, triggering a stretch reflex, causing the head to jump up and waking you up.

In movement, stretch reflexes have many important functions. It is common knowledge that stretch reflexes protect the body from excessive stretch, but they also contribute to more subtle control and coordination of movement. Minor disturbances in posture and position trigger countless, imperceptible stretch reflexes, each one acting to contract muscles to help smooth movement, support posture and maintain stability.

Stretch reflexes may be one of the most important safety mechansism we have. We might question, to what extent can functional training 'sharpen' stretch reflexes, improving the ability to create smooth, fluid and stable motion?

*Golgi tendon organs* (GTOs) are located at the ends of muscle fibers, at the origin and insertion. The GTO is a *tension receptor*, designed to sense the degree of force generated by muscle. Sensory information from GTOs acts like a pressure gauge, providing feedback on the stress (i.e. the amount of force) and strain (i.e amount of tensile force) acting on a muscle. Feedback from GTOs probably contributes to a 'sense of effort'.

When forces exceed a certain level, GTOs trigger a spinal reflex that inhibits force production, known as an *inverse stretch reflex* or *autogenic inhibition reflex*. When excessive loads pass through a muscle, the GTO reflexively inhibits muscle contraction, reducing the amount of force that muscle can produce, in effect turning down a volume dial on the power we can produce.

*Autogenic inhibition* is an in-built mechanism that regulates force production, protecting us from lifting excessive loads (Jami, 1992). You may have experienced that sensation of incrementally increasing the weight on a bar. Suddenly, even though the increment is very small, your strength suddenly gives way and you can't start, let alone complete the lift. Or you may have experienced that point in an arm wrestling contest when the opponents arm suddenly gives way. This is probably the point at which autogenic inhibition triggers, switching the power off.

One potential mechanism by which strength training works is to desensitize GTOs to load, down-regulating autogenic inhibition and meaning that an inverse stretch reflex is only triggered at heavier loads. Strength training essentially decreases neurological sensitivity to load. Progressive exposure to heavier loads may gradually dampen the inverse stretch reflex. This may be one of the key mechanisms by which novices experience rapid improvements in strength at the start of training.

Whilst muscle spindles and GTOs embedded within muscle are considered the primary source of proprioceptive feedback, all tissues contain sensory receptors and supply the brain with proprioceptive information. Connective tissue and fascia in particular are densely populated with mechanoreceptors. In fact, when it comes to movement and positon sense, connective tissue, fascia and skin are so richly innervated with nerve cells, these tissues may be our primary sensory organs.

One of the key mechanisms of functional training is to improve the brain's ability to collect and collate proprioceptive feedback, and interpret that feedback to construct an accurate position, motion and effort sense. A functional trainer has to consider what nature of exercise is best placed to develop the brain's ability to utilize proprioceptive feedback to coordinate complex movement and activate muscle.

## Multisensory Integration

Whilst the relative contribution of each source of proprioception is hotly debated, the brain exploits information at all levels and amalgamates that information to create a *sense of self*, a process known as *multisensory integration*.

Sensory information passes from sensory receptors via afferent nerves to the spinal cord before passing to the brain where it is processed, triggering various responses.

- At the spinal level, proprioceptive information stimulates reflex patterns of muscle activation
- At the brain stem, including the basal ganglia and cerebellum, proprioceptive information is

used to help maintain posture and balance of the body

- At the cerebral cortex, sensory information is received, processed and interpreted to provide position sense

The *sensory cortex* within the cerebrum is the key area of the brain tasked with processing sensory information. The sensory cortex has specific regions that receive information from specific parts of the body. The American-Canadian neurosurgeon Wilder Penfield mapped the sensory cortex, identifying which areas were dedicated to which parts of the body (see Figure 3.3).

Whilst performing brain surgery on patients with epilepsy, Wilder discovered that by stimulating part of the patient's brain using electrical currents, he could trigger sensations in different parts of their body. Since patients were awake during the surgery, they could tell Wilder what they were experiencing. Some areas triggered a sense of smell, others triggered memories. One patient heard a song so clear they thought it was being played in the operating theater. Using this type of brain stimulation, Wilder Penfield was able to map the motor and sensory cortex.

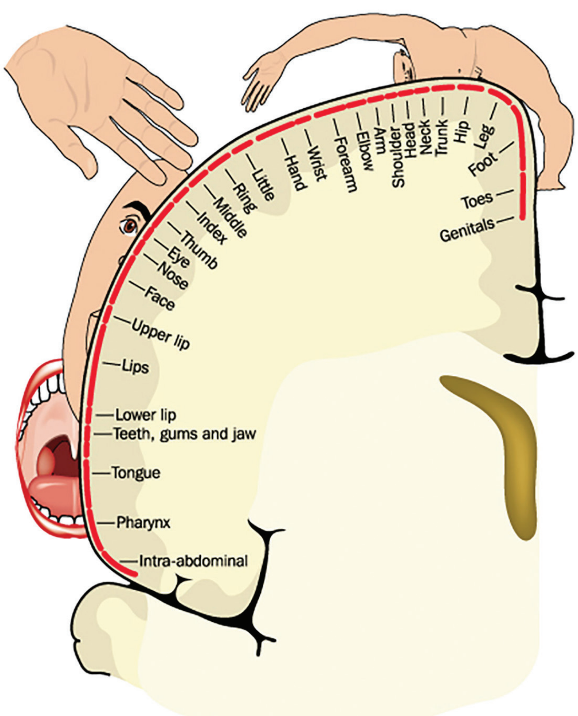


**Figure 3.3** The Sensory Cortex.

## Sensory Cortex

Wilder Penfield first drew the *Homunculus Man*, a distorted representation of the human body, based on a neurological map of the areas and proportions of the brain dedicated to processing sensory functions for different parts of the body.

The Homunculus Man is a visual representation of the 'the body within the brain'. The Homunculus Man has disproportionately large hands, feet, eyes, lips and face compared to the rest of the body. The Homunculus Man is distorted because the size of each body region of the Homunculus Man is related to the density of sensory receptors. Because certain parts of the body are more densely innervated by nerve sensors, the sensory Homunculus Man is distorted (see Figure 3.4).

Wilder discovered that the relative size of each portion of the sensory cortex was directly proportional to the density of proprioceptive sensors within the region, and consequently the

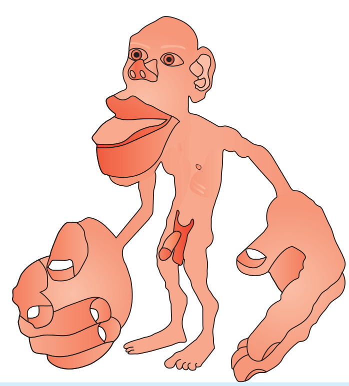

**Figure 3.4** The Homunculus Man.

amount of proprioceptive information coming from it. Areas that require more refined coordination tend to have a greater density of sensory receptors and therefore have larger portions of the sensory cortex dedicated to them. The brain listens more intently to larger areas compared to the rest of the body.

The Homunculus Man illustrates how the hands and feet are more densely populated with sensory nerves. The brain clearly receives more information from these areas. Try closing your eyes and sense the outline of your upper arm, it will probably feel fuzzy and indistinct. Now try and sense your index (pointing) finger, it should feel distinct and clearly outlined. Note the difference in quality in sensory feedback between the two. Now rub your finger for a while, then try and sense that same finger. Does the quality of your sensory image improve?

The sensory Homunculus can be developed and changed with training. If we learn to play the piano, the size of the area of the brain dedicated to the fingers grows in a matter of days. Piano playing quickly develops the sensory acuity to the fingers. The cortical representation of the fingers increases in size within mere weeks of starting to play the piano (Thomas, 2001). The nervous system is highly adaptive and therefore sensory adaptation is brisk.

## Internal Body Maps

Interestingly, there are no sensory signals that inform the brain about the size and shape of individual body parts. To make sense of proprioceptive information, the brain needs an internal representation of the body onto which it can lay proprioceptive information.

In 1911 Head and Holmes introduced the notion of internal schema, or *internal body maps*, stored within the brain. Internal maps are representations of the body within the brain, used to interpret sensory information. Internal maps could be thought of as our 'sense of self', onto which sensory information is laid. The brain needs accurate body maps to interpret sensory information and therefore accurate internal maps are essential for accurate and skilled movement.

Internal maps can become distorted. Pain, injury, poor posture, tight muscle, all distort the internal representation of the body within the brain. There is mounting evidence to suggest cortical representations distort in response to chronic pain, that extended episodes of pain make local internal maps fuzzy and incomplete. A patient suffering lower back pain, for example, will report their back feeling larger than it actually is. People often struggle to visualize and coordinate areas of the body experiencing pain.

Teenagers going through a rapid growth spurt often become ungainly and ill-coordinated. Rapid growth creates a mismatch between internal body maps and actual body shape, making coordination a challenge. Teenagers often become poorly coordinated as they grow and can benefit from functional exercise to maintain motion and position sense.

Internal body maps are even influenced by an individual's thoughts, attitudes and beliefs. Body dysmorphia is a condition in which negative beliefs distort an individual's perception of their size and shape. Negative thoughts can distort internal maps to the point that, when asked to place themselves in a line of people of increasing size, dysmorphic individuals often misjudge where they should sit in that line. They have lost sense of their own size and shape.

Distorted internal maps create a mismatch between perceived position and genuine position in space. This mismatch disrupts coordination, making skilled movement challenging. A lack of coordination is reflected in reduced speed, strength and power.

Improving internal maps is a key strategy for developing coordinated movement and for improving balance, coordination, strength and stability. The first step to improve internal maps is

**Figure 3.5** Side-Step to Target.

to address disruptive factors, such as pain, injury or immobility. Following rehabilitation, the best tool to restructure internal maps is skilled, functional movement augmented with high quality feedback regarding position, accuracy and precision.

Exercises in which clients have to skillfully orientate themselves in reaction to external targets is very effective. We might ask a client to step and reach towards a moving target or accurately place a foot on a target on the ground. As clients learn and skills develop, internal body maps and the brain's 'sense of self' improves (see Figure 3.5).

## Sensory Overload

Imagine walking down the street, crossing the road and walking to a nearby shop. As we walk, we have to coordinate our feet, navigate obstacles, avoid oncoming traffic and side-step passers by. To achieve this task, the brain relies on sensory feedback. The challenge lies in the shear volume of sensory information the brain has to process in any single moment.

Each and every waking moment, our brain is assaulted with a barrage of sensory information. To act in a timely and effective manner, the brain has to process and interpret that information in a mere fraction of a second. Take vision for example. As it strikes the retina, light energy is transformed into electrical signals that pass from the optic nerve to the brain. These electrical signals encode visual information that the brain has to process and interpret. Sensory perception is limited by the fact that the information entering the brain is beyond its capacity to process. This means that only a mere fraction of what is received can be used.

## Perception

Perception is the 'conscious recognition and interpretation of sensory information' (Schactor, 2011). Perception is a complex subject. What we sense and what we perceive are often two very different things. Imagine looking around a dense forest, all the complex images the brain has to make sense of. Images have to be formed instantly, forcing the brain to unscramble a flood of incoherent electrical signals sent from the optic nerve to construct an image that makes sense.

The volume of data and a lack of time means only a fraction of what is received is used. To create visual images the brain takes shortcuts – strategies to overcome sensory overload. The brain receives only a partial picture and then has to literally 'fill in the gaps'.

Firstly, the brain extracts only a fraction of what it receives, filtering and extracting what is important and pertinent. To create a complete image, the brain draws upon pre-existing knowledge, completing visual images using historical data. Neuroscience suggests as little as 20% of the information coming into the visual cortex originates from the retina. The other 80% comes from areas of the brain concerned with memory. As little as 20% of what we see originates from optic feedback, the other 80% is, for all intents and purposes, made-up – constructed from a patchwork of educated guesswork, past experience and pre-existing knowledge.

Sidney Bradford, who died in 1960, went blind at ten months of age, but regained sight in both eyes after a cornea transplant at the age of 52. Looking at people's faces with his new sense, he still was not able to distinguish what he saw. The brain had never experienced a face before, so could not make sense of it. Only until someone spoke did he understand that a person was standing in front of him.

Speech works in a similar way. When we listen to someone speak, the brain interprets noises using a lifetime of experience of language. Sentences are constructed in the brain, with the gaps between words accentuated as we listen. This is why an unfamiliar language can often sound like a non-sensical stream of noise. The brain has to learn to unpick and sort what we hear.

In 1970 Richard M. Warren observed that when certain parts of a spoken sentence were masked by extraneous noise, people could still comprehend what was being said. When parts of a sentence are filled with white noise, the brain literally fills in the gaps, using what it expects is being said. Many subjects were not even aware that parts of the sentence were missing. This perceptual phenomenon has become known as phonemic restoration effect.

The brain seeemlessly converts electrical signals from the senses into sights, sounds and experiences. Sensory perception occurs so quickly and smoothly that we are blissfully unaware of what is happening. The only problem is that 'sensory completion' makes the brain susceptible to errors and distortions.

Rather than a true representation of reality based on visual feedback, visual images are contructed from an assortment of sources. The way we construct reality in the brain leaves us susceptible to error. The impact sensory distortion has on perception is clearly illustrated by visual allusions. The brain attempts to identify objects and complete visual images based on expectation. But when visual images are indistinct and ambiguous, images can flip in the brain (see Figure 3.6). The study of illusions illustrates how the brain constructs reality.

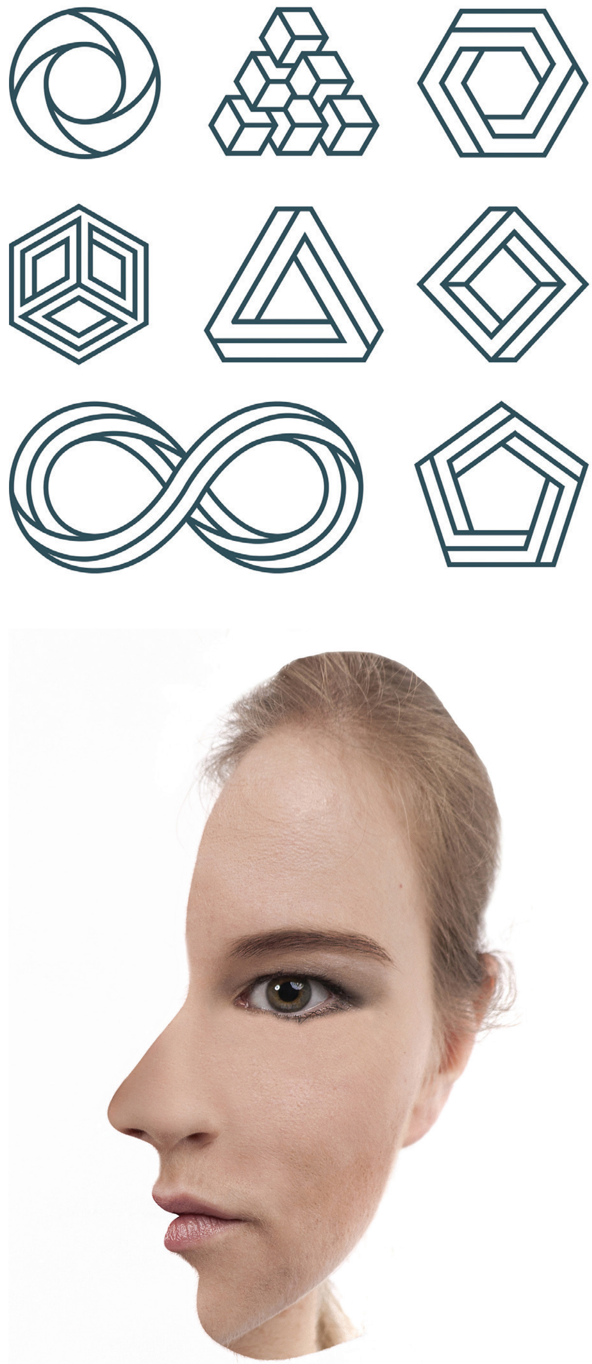

**Figure 3.6** Visual Trickery.

Richard Gregory, a leading researcher in the neuroscience of illusion, explains that 'bottom-up' sensory information is frequently superseded by 'top-down expectation'. Illusions illustrate how the brain can struggle to make sense of what we see and can change it from moment to moment.

What we perceive is not always an accurate reflection of what actually exists. The fact that the perceptual system actively constructs reality based on incomplete data leaves us susceptible to error and misinterpretation. Perceptions are constructed using pre-existing knowledge, past memories, pre-existing beliefs and expectations, all of which can become distorted and inaccurate, meaning perception can be equally distorted. If perception can be distorted and therefore innacurate, movement quality can be affected, as can our ability to make appropriate decisions, all of which are critical to functional peformance.

Perceptual errors are compounded by the fact that the brain distorts reality (what we see, hear and feel) to match prior expectation. People will often see what they expect or 'what they want to see'. This psychological phenomenon is known as confirmation bias. All of our senses work in this way. We see, hear and feel what we want to.

Confirmation bias is a huge problem. Imagine you have recently suffered an injury and you expect to feel pain or stiffness. The brain searches for sensory information to confirm these expectations. If you expect to feel pain, you probably will. Expectation has a powerful impact on sensory perception.

Parents manage children's expectations when they fall and hurt themselves. A child often looks up at their parent to calculate how hurt they are. The parent's reaction impacts a child's pain experience. Most parents tell their child they are fine, no harm done, dust yourself off and have fun. This advice is often enough to modify a child's expectations and alleviate pain.

I was always astounded that some of my biggest lifts in training have been when I had mistakenly put too much weight on the bar. I expected the bar to feel light and subsequently my proprioceptive system and sense of strain told me this was the case and I lifted far more than I believed possible.

Perceptions are influenced by the stories we tell ourselves, our beliefs and expectations, whether we believe we are strong and robust or weak and fragile. These beliefs profoundly impact what we perceive, how we feel and therefore how we perform. A functional trainer can improve a client's functional performance by managing their beliefs and expectations.

## Attention

In a crowded party visual images, sounds, noises, tastes and smells bombard the senses. To attend to everything happening in the room, we would become paralyzed by the effort. Listening to a friend's conversation would become impossible. To avoid overloading the brain, only a mere fraction of what is 'sensed' is passed onto consciousness.

*Selective attention* is a mechanism the brain uses to focus attention on key elements of the environment. To avoid overload, the brain prioritizes information, extracts what is relevant and discards the rest. The brain selects what is useful, relevant and vital to pass on to conscious attention.

The *reticular activating system* (RAS) is the part of the brain that guides attention. The RAS filters and extracts extraneous sensory information. The RAS is like a GPS for the brain, directing attention to where we need it. Selective attention is why it is easy to pick out our own name from a nearby conversation. Hearing our name alerts the brain that a conversation is relevant, attracting attention.

Do you remember the last time you bought a car? Did you suddenly see that same car everywhere you go, almost as if everyone else has decided to buy the same make and model? The RAS extracts what is 'useful, relevant and vital', allowing us to focus on what is important.

Selective attention means that in some instances, important information is missed – disgarded as being irrelevant. My girlfriend attests to this phenomenon frequently. We often heatedly discuss what has been said and what hasn't. The process of selective hearing is very real.

Simons and Chabris (1999) illustrated '*attention blindness*' in an experiment in which subjects were asked to watch a video of basketball players passing the ball. The subjects were asked to count the number of passes. After 30 seconds of counting, many people were totally unaware a man dressed as a gorilla had walked straight through the scene.

What information do we discount on a daily basis? What information are we filtering out as being extraneous? How much important information are we missing? Vision boards, goal-setting and visualization are fantastic ways of highlighting to the 'subconscious' what information is important. These tools highlight to our RAS what we want to achieve as we go about our daily life, so that it can extract information that is relevant and useful.

## Perceptual Filters

Attention is limited and the shear volume of information passing from the senses to the brain is beyond the brain's capacity to process, therefore perceptions are completed based on an individual's expectations and are susceptible to distortion based on that individual's past experiences and how they think. What an individual sees, hears and feels is greatly impacted by their thoughts, attitudes, beliefs and emotions.

- *Thought* is the conscious process of thinking and reasoning. What we think has a powerful effect on what we expect to see occur in any situation or circumstance.
- *Attitudes* are a settled way of thinking or feeling about someone or something that are typically reflected in our perceptions and subsequent behaviors.
- *Beliefs* are our 'personal attitudes associated with true or false ideas and concepts'. Beliefs are what we think despite immediate factual evidence – assumed knowledge born of past learning and experience.
- *Emotion* is a state of 'feeling' arising from an interpretation of any particular situation. Emotion has a large impact on behavior. Feeling joy, excitement, exhilaration, anger, hurt and anxiety can all have a profound impact on behavioral responses.

Everyone's perception of reality passes through perceptual '*filters*', subconscious biases that distort what we see and feel. Filters act like a framework on top of which the brain constructs and interprets reality. Each person's filters can have a profound impact on what they perceive because the brain constructs sensory images based on an indivuidual's expectations and their thoughts, attitudes, beliefs and emotions.

Individual expectations drive the brain to focus *attention* on different aspects of an image or conversation. The subconscious distorts images to match expectations, and can attach totally different meanings to the same events. Subconscious filters mean that two people can witness the same event and have totally different perceptions of what has occurred. Perceptual filters mean that two people can arrive at totally different conclusions based on what they see, hear and feel (Bubic, 2010).

We all scream at the TV as a referee makes a bad decision, or react furiously to political debate as politicans offer their opinion on topical events. It is easy to argue relentlessly with a loved one, describing the chain of events as we see it, bewildered as to why they won't agree on the chain of events. The hard thing to appreciate is that we all have a different perception of reality and have different experiences of events.

Be open-minded. Evaluate your beliefs and perceptions appreciating that we all have subconscious bias. Trying to see other people's perspective is fundamental for effective communication. A functional trainer should encourage clients to reflect and evaluate their own perceptual biases and see how their thoughts, attitudes and beliefs might impact behavior and peformance.

An individual's perception of reality is subject to interpretation and bias. As a result, behavioral reactions and decision-making can also conflict and vary. Two people can have totally different reactions to the same event. One person looks at a mountain and sees an amazing challenege, another sees a day of misery in the cold and wet. Whilst one person might see the gym as a place to have fun, another expects embarrassment and humiliation. You might look at a weight and feel confident or you might worry about injury. Your perceptions have a huge impact on subsequent behavior and performance. A trainer can try to manage a client's expectations to get the best results from training.

## Sensory Expertise

The brain can learn to process information more effectively. In sport, athletes develop their ability to extract and filter sensory information. For example, a goalkeeper can learn to extract visual cues on which way a striker will shoot the ball, based on the movement of hips, the angle of the foot and so on.

Elite performers do not have superhuman reactions, they simply learn to extract information and react faster and more efficiently to that information. Elite performers are often unware of the cues they extract. They develop a virtual sixth sense, honed over years of experience.

For any task or skill, and in any situation, experience teaches us what information is useful and relevant. We learn to instinctively react to certain sensory cues to generate an appropriate response. By disregarding extraneous data and fousing attention on what is important, the brain reduces 'computational load'. In other words, the brain is able to reduce the amount of work it has to do in terms of processing and decoding information to arrive at a decision about how to act.

The brain is designed to identify patterns and attribute meaning. The brain is almost like a 'meaning making machine'. It extracts useful information and builds patterns. It then compares these patterns to past similar situations to identify what events might occur in the future, an advanced form of 'pattern recognition'.

The better we extract the relevant information and the faster we chunk that information into meaningful patterns, the faster and more efficiently we can learn to react. Improved *sensory perception* relies on advanced task-specific knowledge, what is referred to in neuroscience as *domain expertise*. Domain expertise enhances a person's ability to extract and filter sensory information, providing an expert with an intuitive understanding of what information is relevant and useful.

Atheletes spend years developing domain expertise, honing sensory perception to develop an intuitive understanding of their sport. Sensory training is less about improving the quality of our senses, our eyesight or hearing, and more about learning to extract relevant information from any sensory experience.

Finely tuned perception allows experts to gather, process and interpret sensory information faster than less skilled individuals. Enhanced *pattern recognition* supports decision-making. As Syed (2011) states, 'good decision making is about compressing informational load by decoding the meaning of patterns derived from experience'. A professional poker player is able to read physical 'tells', behaviors that indicate when an opponent is 'bluffing' – dilation of the eyes, the shift in body language. Over years, a poker player develops the ability to intuitively recognize 'tells' and read when an opponent is bluffing.

Sensory perception is developed with task-specific training to enhance the underlying understanding of specific events. Learning has to be 'task-specific'. Transfer of learning between tasks and skills, or from one activity to another, is poor. Knowledge is also difficult to teach because the cues that experts rely on are often both subtle and complex.

We could dicuss how a boxer can 'bob and weave' to avoid attacks, but it takes years of practice to develop the brains ability to identify sensory cues, like the shift in an opponent's hips, or the twist in the shoulder that alerts the brain that an opponent is about to throw a punch. Only when the brain learns to read these cues, will they develop the *instinctive* and *intuitive* skills required to avoid a punch. Improving non-specific reaction times makes little difference. True knowledge is only gained through experience.

Knowledge is rarely generalizable, therefore non-specific or generalized training is of little benefit. Training should always reflect the tasks and skills we rely on in function, and domain expertise can be developed by teaching clients how to react in useful and relevant situations. Instead of working muscles on a resistance machine, a client should practice moving, balancing, stretching and lifting in the context of useful and relevant functional tasks.

## Bringing It Together

Elite athletes are able to identify what information is relevant and use this information to support faster, more efficient behavioral decision-making. Training allows individuals to better extract, analyze and interpret sensory information.

A functional trainer can help develop sensory perception and improve functional performance by:

- Helping clients build accurate internal body maps by prescribing skilled movement
- Developing domain expertise, a client's knowledge of both their own body and the specific tasks and activities they perform
- Modifying perceptual filters, including a client's thoughts, attitudes, beliefs and expectations

# ACTIVATION

- The Motor System
- Muscular Contraction
- Muscle Synergy
- Motor Strategy

Sensory signals pass through nerves to the brain, telling us where we are and how we are moving. The brain uses sensory feedback to coordinate the action of muscles, a process called *neuromuscular coordination*. Skilled coordination may be far more important than the size of muscles in determing how strong an individual is or how they perform.

An understanding of how the motor system organizes, activates and synergizes muscle should provide clues as to the most effective way to design functional training. In this section, we look at how the motor system controls and coordinates movement.

## The Motor System

The four basic components of the motor system are:

1. The brain
2. The spinal cord
3. Motor nerves
4. Muscles

A basic model of *motor control* describes how motor signals pass from the brain, via the spinal cord, through efferent motor nerves to drive muscle contraction. A single motor nerve innervates a number of individual muscle fibers. Together, the motor nerve and associated muscle fibers are known as a 'motor unit'.

To create movement, a single electrical impulse passes through the motor nerve, referred to as an action potential. A single action potential stimulates a 'twitch response', a single muscle contraction in the muscle fibers it innervates. A single twitch response is not enough to generate sufficient force for movement, so increased effort, referred to as 'neural drive', is required to trigger a greater frequency of action potentials and more twitch responses. With increasing neural drive, twitch responses start to aggregate and superimpose, producing ever-increasing levels of force. This process is known as *summation*.

*Rate coding* is the term used to describe the frequency of firing of motor units. Increased neural drive leads to higher rate coding, which in turn causes increased summation of twitch responses and higher force production (see Figure 3.7). Training can develop an individual's ability to generate greater levels of neural drive, improving their ability to produce more forceful contractions.

As neural drive increases, not only does the frequency of motor units firing increase, but also the number of motor units recruited. Greater recruitment of motor units results in more muscle fibers contributing to produce force. Training can develop an individual's ability to recruit more motor units simultaneously, enhancing strength.

The size principle states that motor units are recruited in order of size (Henneman et al., 1965). Small, low threshold motor units, which produce lower levels of force but have greater resistance to fatigue, are recruited first. As *neural drive* increases in line with the need for increased force

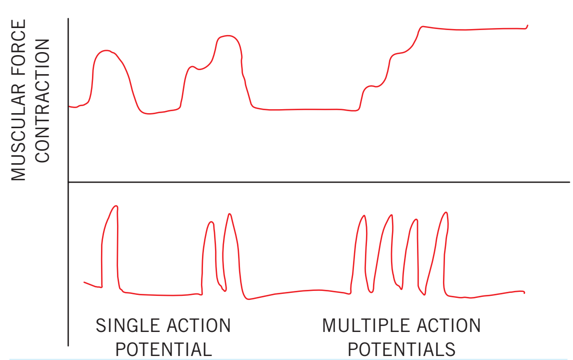


**Figure 3.7** Twitch Response, Summation and Recruitment.

production, high threshold motor units are recruited. These units produce greater force but are more susceptible to fatigue.

Under normal circumstances, the nervous system alternates the activation of neighboring motor units, resting some muscle fibers whilst others work. This pattern of alternating recruitment helps reduce fatigue, improving endurance. With increased neural drive, neighboring motor units start firing in unison, known as synchronization (Kamen and Roy, 2000). The greater the sychronization, the more force a muscle produces. Muscular force production is not solely determined by the size of muscles, but how muscle fibers are recruited. Recruitment and synchronization are forms of *intra-muscular coordination*, a major factor governing force produced (Knight and Kamen, 2001).

Training can develop intra-muscular coordination, increasing strength independent of muscle mass. The impact of improved coordination of muscles is evident in novice trainers, who experience great gains in the early stages of training despite little increase in lean muscle mass.

The human muscular system may be capable of almost superhuman strength, but research suggests that even with maximum effort, untrained individuals struggle to activate muscles near full potential. Under normal circumstances, the average person simply lacks the ability to drive muscles hard enough or recruit sufficient muscle fibers in 'sycronisity' to achieve maximal levels of force production. The maximal ability of muscles to produce force is rarely achieved (Folland and Williams, 2007).

The amount of force muscles can produce is largely determined by the way they are controlled by the brain (Bosch, 2015). Strength training can develop an individual's ability to recruit muscle fibers. Training at high intensities, applying protocols involving near maximal lifts for low numbers of repetitions, usually between one and six, is a popular strategy for improving intra-muscular coordination and enhancing strength, irrespective of muscle mass. Following extensive training, elite athletes learn to better *recruit* and *synchronize* motor units, enabling far higher levels of force production.

## Muscular Contraction

Whilst we generally think of them shortening, muscles 'contract' in three different ways:

- Concentric contraction – when muscular force production is greater than the resistant load that we work against. Muscular contraction causes tissues to shorten, drawing the muscle origin and insertion together.
- Eccentric contraction – when muscular force production is less than the resistant load we are working against. Muscular contraction is unable to prevent tissues lengthening, causing the origin and insertion of the muscle to draw further apart.
- Isometric contraction – when muscular force production is equal to the resistant load that we work against, creating a static contraction with no resultant movement.

Anatomical texts tend to classify muscles based on the movement they produce when they concentrically contract. The hamstrings for example, are described as flexing the knee and extending the hip. But a functional trainer should be aware that during dynamic movement, muscles rarely contract *concentrically*. As we move within function, muscles spend far more time contracting *isometrically* and *eccentrically*.

Huge biomechanical forces, such as momentum, inertia and ground reaction force, act on the body as we walk, run and jump. Each leg may have to absorb forces as high as 11 times our body weight on impact during these functional movement patterns. Gravitational forces have to be decelerated and stabilized before any useful locomotive motion can be produced.

Eccentric forces acting to decelerate motion tend to be far greater than those generated lifting weights. In function, muscles tend to work to isometrically and eccentrically stabilize dynamic loads. With this in mind, a functional trainer might emphasize exercise that requires a client to decelerate, stabilize or 'lower' load, rather than always focusing on lifting weights.

The myofascial system is designed to stabilize the isometric and eccentric loads we experience during dynamic movement. The *sliding filament* design of muscles, for example, means that muscles are far stronger working eccentrically than concentrically. This makes great biological sense. It means we can lower far more weight than we can lift.

The fascial system is also engineered to stabilize eccentric loads, running on long chains to absorb tensile stress. By emphasizing stepping, running, jumping and throwing movements, rather than lifting, a functional trainer can enhance a client's ability to isometrically and eccentrically stabilize gravitational loads, building their 'functional strength'.

## Pre-Loading

As a client runs and jumps, they must stabilize gravitational loads on landing before then propelling themselves forwards. For optimal performance, individuals need to learn to harness these powerful forces. According to the laws of physics, energy cannot be created or destroyed, only *transformed*. The elastic elements embedded within fascia make it perfectly adapted to absorb mechanical force and 'transform' that energy into force for locomotion.

On heel strike during gait, bones shift as forces pass through them, stretching the long chains of fascial with which they interact. These fascia chains tension under load and act like elastic bands, absorbing, storing and then returning elastic kinetic energy in a form of *elastic recoil*.

The elastic elements embedded within myofascia recycle kinetic energy, making subsequent movement easier and more efficient. This '*catapult mechanism*' was first discovered by Kram and Dawson in 1998 who recognized that kangaroos and gazelles can jump far further than could be explained by the contraction of leg muscles alone (Sawicki et al., 2009).

As well as elastic recoil supporting locomotion, stretch reflexes also support locomotion. When the heel strikes the ground on landing, gravitational forces drive bone motion. The motion of bones stretches myofascial chains. As muscle spindles detect rapid stretch, they trigger a powerful reflexive contraction in the muscle they are embedded within. Stretch reflexive supports subsequent motion, especially in explosive movements like jumping and throwing.

Stretch reflexes increase the efficiency of functional movement, especially in cyclic activities such as walking, running and swimming. Functional performance within dynamic tasks relies on the ability to transform mechanical forces and the ability to harness stretch reflex contractions during stretch-shortening cycles. None of this can be learnt by statically lifting weights, especially on fixed resistance machines, or working within an inner range of motion. Harnessing gravitational forces can only be learnt within the context of dynamic motion.

Clients can learn to harness the power of stretch in the lower body by running, jumping, skipping and hooping. In the upper body, clients should be encouraged to use momentum by swinging or throwing resistance and by shifting their weight. Clients need to learn to '*pre-load*'. A pre-load involves a counter-movement, a shift and stretch in the direction opposite to that of the intended motion. Pre-loading stretches fascia chains, loading them with kinetic energy and activating stretch reflexes prior to movement to improve performance.

'Pre-loading' is evident in many sport-specific skills. Basketball players swing their arms and body downwards to eccentrically load leg muscles prior to jumping. Golfers shift the hips before striking the ball, tennis players reach with their opposite hand to stretch the fascial chains in their back before serving, baseball pitchers 'wind-up' before throwing. These are all examples of counter-movements to stretch and pre-load fascial chains for enhanced performance.

Efficient athletes transform elastic energy and maximize stretch reflexes within movement, enabling them to conserve energy and produce extraordinary power. Plyometric training using jumping, hopping and bounding movements was a popular methodology in the 1980's to develop plyometric power. But be aware, the forces created in eccentric loading are huge. Plyometric training caused many an athlete to be injured.

Pre-loading and plyometric movements should be integrated into functional training, but be aware, training should be systematic and eccentric loads should be progressed gradually to avoid 'over-load' injury. Get clients to move dynamically, ask them to use gravity – to swing, shift, stretch and pre-load as they move.

## Muscle Synergy

Most anatomical texts depict muscles working in pairs across a joint. An *agonist* or '*prime mover*' working against an opposing *antagonist*. Two types of muscular contraction are possible in this model: *reciprocal inhibition* and *co-contraction*.

### Receiprocal Inhibiton

To create movement at a joint, one muscle must contract and the opposing muscle must relax. If the antagonistic muscle contracts at the same time as the agonist, it opposes movement, making that movement slower, less powerful and less efficient. The faster the antagonist relaxes, the more effective movement becomes. *Reciprocal inhibition* (RI) is a short-loop spinal reflex designed to facilitate timely relaxation of antagonistic muscle during dynamic movement. As the agonist contracts, RI causes a reflex relaxation of the antagonist, supporting easy and efficient cyclic motion.

Training can enhance the reflex mechanisms that relax muscle. If muscles can be trained to relax faster, performance improves, independent of physiological factors like muscle mass. To enhance antagonistic relaxation, training might integrate exercises in which clients rapidly change direction. RI cannot be developed moving slowly, as is characteristic of conventional gym training.

Whilst conventional training often emphasizes muscular work, functional training may be better served focusing on how well muscles relax. Rather than obsessing over muscular exertion, functional training should focus on ease, efficiency, relaxation and flow. Asking clients to 'flow' between different postures and positons would be a fantastic way of safely developing coordination and developing efficient agonist and antagonistic coordination.

### Co-Contraction

Whilst dynamic motion relies on opposing muscles relaxing in a timely fasion, there are tasks, skills and situations in which individuals need to hold themselves static, maintain posture and positon, or stabilize body weight, balancing on one leg to reach onto a high shelf, for example. In this situation, muscles on both sides of a joint contract in unison to create rigidity and postural stability. The simultaneous contraction of agonistic and antagonistic muscles is called *co-contraction*. When muscles 'co-contract', they work to keep joints in place, preventing motion.

Many conventional gym exercises encourage co-contraction of muscles. The 'plank' for example is a popular core exercise in which individuals hold themselves in a static, horizontal, 4-point position, 'bracing' abdominal muscles to create stability. Trainers often encourage clients to maintain a posture as they lift weights, to 'brace' muscles and keep still, avoiding movement or momentum – but is this 'functional'?

Within function, we rarely hold ourselves entirely still. Even as we stand, the body naturally sways in a pendulous motion, shifting weight from one foot to the other. Being completely static is unusual unless we are at rest or asleep. As such, co-contraction is rarely beneficial.

When muscles contract simultaneously they resist motion and create stiffnes and rigidity. Excessive co-contraction means muscles are working against each other, rather than working in synergy. They are expending energy and effort with little benefit. Excessive co-contraction hampers movement, hinders performance and reduces efficiency.

From a rehabilitation perspective, co-contraction, rigidity and stiffness is often a sign and symptom of pain and dysfunction, and is often associated with injury. The nervous system will revert to a co-contraction pattern of recruitment when it feels movement could cause a problem, when it could exacerbate pain or injury. In this instance, co-contraction is useful because it prevents motion, almost like a splint, preventing injury. Muscles will often 'spasm', a powerful co-contraction around an injured or dysfunctional joint.

During functional dynamic movement there is always complex and subtle interplay between patterns of reciprocal inhibition and co-contraction. The motor system constantly strives for efficiency but also has to balance the demands of safety and performance, stability and mobility, contraction and relaxation.

In optimal performance, movement is easy and efficient. Risk levels are understood to be low and confidence is high, and therefore stabilizing muscles can relax, co-contraction reduces and the effort required to move becomes less. This high level of performance only comes with practice, experience and a high level of confidence, but is not developed by bracing or over-contracting muscles in a slow, controlled and safe manner. Whilst the plank 'tones' muscles, it does not encourage optimal and efficient patterns of contraction and relaxation around the core.

## Complex Synergy

The concept of muscles working in pairs across a joint is exceedingly simplistic. In any functional task or skill, countless muscles work together in teams. For any movement, there will be literally hundreds of muscles working synergistically to create movement. In any moment, any muscles may have to fulfill a role as:

- Agonists – the main muscle responsible for creating motion
- Antagonist – opposing muscle group to the agonist
- Synergist – a muscle assisting motion
- Stabilizers – a muscle reducing unwanted motion

Even these terms are arbitrary and over-simplistic. During any movement, a muscle might fulfill one, or many of these roles, and this role could change instantaneously as demands for motion and stability adjust.

'Isolation exercise' is common in conventional gym training. When trainers attempt to isolate muscles, they restrict motion to purposely emphasize and overload a specific muscle or muscle group. When we isolate muscles, we separate them from their natural synergists, remove gravitational loads that may support movement like momentum and then place them under an unatural load to facilitate the rapid onset of fatigue.

The result of isolation training is a rapid accumulation of lactic acid, causing that all too familiar 'lactic burn' we feel in muscles when they are working to their extrmeme. Whilst overload and lactic acid is great for triggering hypertrophic growth in those muscles, it does little to develop the synergistic relationships between muscles that are so important for functional performance.

In function, muscles are designed to work in synergistic teams, cooperating to produce force and share load. The group action of muscles is known as *inter-muscular coordination* or *muscle synergy*. Muscle synergy is key to functional performance, both in terms of force and efficiency. When muscles work in cooperative teams they rarely 'burn' because they are working to share and shift load.

If the goal is to improve ease, efficiency and flow, and to develop functional strength and performance, trainers would be well advised to move away from 'isolation' and towards a model of integrated movement that promotes muscle synergy and the cooperative action of muscles.

## Motor Strategy

Imagine throwing a ball. To throw, the brain has to organize movement, decide how to stand, how to cock the arm, 'wind-up' and release. To achieve this complex task, the brain coordinates hundreds of different muscles, as well as the relative timing of contraction and relaxation of those muscles. For this or any other task or skill, the brain formulates a *motor strategy* – a plan of action or way of moving. This motor strategy details which joints to move, which muscles to contract, in what order and with what levels of speed and force. The more appropriate the motor strategy, the more efficient and effective performance is. How does the brain decide which muscles to work and when?

Early models of *motor control* proposed that the brain creates a whole motor strategy from scratch. The brain identifies what we want to do, our intention you might say, then constructs a plan of action before executing that plan – simple. In this model, motor strategies are constructed prior to movement, with minimal reliance on peripheral feedback. This is referred to as a *feed-forward model of motor control.*

There are several issues with a feed-forward model. Firstly, there are almost an infinite number of different tasks and equally an infinite number of different ways of performing each task. Imagine touching your nose with your index finger, for example. Although this is a seemingly simple task, one that we all peform in a relatively similar manner, there is in fact millions of different ways to achieve the same end result. Admittedley, many of the strategies would look ridiculous, but nonetheless, the options are almost limitless. How does the brain decide which motor strategy is most efficient and effective?

The challenge posed by the fact that the motor system has so many options to choose from is referred to as the '*degrees of freedom problem*'. Creating a new motor strategy from scratch each and every time we decide to move creates a huge 'computational load'. There are far too many calculations to make and factors to consider when deciding how to move. The brain lacks the time or capacity to create movement strategies on the fly. It needs to take shortcuts.

One theory for how the brain reduces computational load was proposed in 1975 by Richard Schmidt. Scmidt suggested a schema model of motor control – the idea that the brain stores a plan or 'schema' for the most important or most frequently used movement tasks. A schema is a set of rules that guides action in the face of a specific problem. Movement schemas have since been called *motor programs* (MP).

Schmidt suggests the brain stores motor programs or '*templates*' for specific movement tasks. These templates act like scripts, prescribing how to organize movement and activate groups of muscles to produce movement. Based on our initial *intention*, the brain would select the relevant *template* and use this to activate muscles. If this *template* provides all the relevant information, the brain could plausibly coordinate movement without the need for any additional feedback.

Neuroscience has found evidence that certain movement patterns are so deeply embedded within the nervous system of humans and other animals, that they can control movements with negligible input from higher centers of the brain. Fish can swim, hamsters chew, snakes crawl and humans can walk, almost subconsciously, with little input from higher, conscious areas of the brain. Neuroscientists refer to these fundamental templates as ‘central pattern generators’ (CPG). CPGs act from within the spinal cord and brain stem, coordinating rhythmic movement patterns to such an extent they can almost take care of themselves. You might have seen gruesome films of decapitated frogs still kicking their legs as if they are swimming. We also retain templates for basic movement patterns like walking, running and crawling.

But does the brain store templates for every different movement task? Considering the countless different tasks we perform on a daily basis, surely even our powerful brain eventually reaches capacity and experiences ‘storage issues’? What happens when we learn a new skill? What program do we use then?

Schmidt expanded his theory to incorporate the idea of generalized motor programs (GMP). GMPs are templates for different classes of movement. We might have a template for lifting, bending, twisting, pushing and pulling, and so on. He proposed that GMPs are downloaded and then adapted to match the specific situation or circumstance we find ourselves in – the way in which we need to lift, what we need to lift and why we might be lifting.

Schmidt proposed that pre-prepared templates reduce computational load, but quality movement relies not only on the quality of these GMPs or movement templates, but also on how well each GMP is adapted to match the situation and circumstance. Functional training should engage and enhance useful and relevant movement templates to improve movement quality without increasing demands on coordination.

Training should also develop an individual’s ability to adapt each of these templates to different situations and circumstances. Therefore, training should challenge adaptability by asking clients to lift, bend, step, reach and so on, from lots of different positions and lots of interesting and unusual ways – the more awkward the better.

If we assume many of the gains in performance associated with training arise from neurological adaptations, improved activation and patterns of coordination etc., and many of these adaptations will be directly associated with a specific movement template, the implication is that abstract exercises such as the Leg-Press or Chest-Press may essentially be a waste of time, because they fail to engage useful or relevant movement templates and therefore fail to trigger the neurological adaptations that underpin performance.

The Leg-Press is physiologically and neurologically dissimilar to anything we do in the real world, so is it any surprise that training adaptations fail to transfer to function? Whilst the Leg-Press works relevant muscles, it does not engage the relevant movement templates we rely on when we move in the real world. Therefore, the neurological and behavioral impact of training is lost.

If we teach a client to Leg Press, the brain simply builds a new template. The only time this template will be of any use, is the next time we use the gym. Rather than teaching clients to Bench Press or Dumbbell Curl, we should be asking them to lift, bend, reach, push and pull.

The next question we have to ask is, if the brain programs movement based on pre-fabricated movement templates, how does the motor system adapt to unexpected variations in the task or environment? How does our brain account for unforeseeable or unexpected situations and circumstances? In the next section, we analyze how the brain *adapts* and *reacts* to awkward, unusual and unexpected disruptions to maintain accuracy and precision.

## Bringing It Together

Performance parameters and biomotor skills like strength, speed and power have a large neurological component. Strength, for example, is associated with:

- Intra-muscular coordination, neural drive and rate coding
- Inter-muscular coordination, muscle synergy and improved agonistic and antagonistic contraction and relaxation
- Movement templates and generalized motor programs
- The adaptation of movement templates to match the specific task we are performing and the environment we are performing in

A functional trainer should adapt training to improve neuromuscular coordination by:

- Training at higher intensities
- Training at increased levels of complexity
- Pre-loading
- Engaging relevant and useful movement templates

# ADAPTATION

- Variation and Adaptation
- Reaction Times
- Perception and Choice Reaction Times
- Anticipation
- Predictive Processing
- Reflex Adaptation
- Balance, Equilibrium, Righting and Tilting
- Reflex Modulation
- Dynamic System Theory of Coordination

The brain senses and analyzes the tasks we want to perform, downloads relevant *movement templates* and adapts these templates to match the specific demands of the situation or circumstance. The brain stores templates for the most relevant and useful tasks and skills, and the quality of these templates plays a large role in determining functional performance.

There are times when unexpected variations and disturbances act to undermine accuracy and precison, and disturb stability and balance. The ability to *react* and *adapt* is fundamental to functional performance. In this section, we investigate how we *'react and adapt'*.

## Variation and Adaptation

In conventional training, each and every exercise has a specific *form* and *technique*. Each repetition looks much the same as the last. In contrast, when we lift, bend, push or pull in real life, we move in countless different ways, different postures, positions, in unusual environments and at different speeds, distances and forces. When we consider each minute variation in the position of each and every joint, and the differences in timing of each individual muscle contraction, the variations are beyond imagination. A task as simple as reaching onto a shelf could be performed in a million different ways. When it comes to coordination, variation is one of the biggest challenges the human brain faces.

The generalized motor program (GMP) model proposes that the brain stores ready made 'templates' that act as scripts for movement. To perform a specific task, the brain downloads the relevant template, then adapts that template to suit the specific situation or circumstance.

Movement templates are adapted to match the specific task we wish to perform. The template is tweaked in accordance with the environment in which we perform that task, taking into account variation in terrain, for example, or any obstacles and barriers in our path, as well as an individual's capacity to move, their strength, flexibility and mobility, and finally, adapted to match how that person feels about the task – their emotion.

'Combinatorial explosion' is a concept that illustrates how combinations of minute variations can lead to limitless possibilities. Imagine folding a piece of paper into two, making the paper twice as thick. Now repeat the process 100 times, folding the paper over and over. How thick do you think the piece of paper will be after 100 folds? Most people tend to guess in the range of a few inches to several feet. In fact, the thickness of the paper would stretch 800,000 billion times the distance from Earth to the Sun. Albert Einstin described compounding as the most powerful force in the universe and the '8th wonder of the world'. Combinatorial explosion explains how variations in movement can create countless possibilities.

**KEY POINT**

The brain has to adapt motor strategy in response to:

- Task – what we do
- Environment – where we are
- Capacity – movement ability
- Emotion – how we feel

Whilst the brain formulates *movement strategies* based on templates, these templates lack the detail to fully coordinate movement. A pre-scripted plan could never account for all the minute variations that act to disturb and disrupt movement. We have a movement template for walking, but the foot still has to adapt to undulations in terrain and shifts in the surface to maintain balance. The ability to account for all these turbulences is called *motor adaptation*.

The simplest explanation for how the brain adapts is that it uses sensory feedback to identify descrepancies between intentions and subsequent outcomes. To catch a ball for example, the brain formulates a strategy – how to stand, where to hold the hands and so on, then adjusts that strategy based on visual feedback, watching the ball as it flies through the air. The use of feedback to maintain accuracy and precision is referred to as a *closed-loop model of motor control* (Adams, 1971).

The problem is, most of the tasks we face in function happen so fast that the brain lacks the time to extract, analyze and interpret sensory data. Feedback has to pass from peripheral receptors, through sensory nerves to the sensory cortex, to be processed by numerous higher corticol areas of the brain. A new plan has to be formulated and motor signals sent to muscles to contract. The whole process takes a great length of time, frequently far too long to be effective.

## Reaction Times

Imagine driving down a road and a child suddenly runs out in front of the car. We have fractions of a second to save that child's life. To generate an appropriate response, the brain receives sensory feedback (i.e. the girl running in front of us), interprets that feedback (i.e. the level of danger based on where they are and the speed we are going), selects an appropriate response (i.e. break or swerve out of the way) and sends a motor signal to activate muscles (i.e. to turn the wheel). The time it takes for all this to happen is known as *reaction time*. Scientists measure reaction times using various methods:

- Reaction sticks that are dropped and have to be caught as fast as possible. The test can be replicated using a ruler.
- Light board reaction tests assess the time taken to touch lights appearing in a random order on a light board in front of the person. This test has been used as one of a panel of tests by American Football League Teams to test players before they enter the draft.

The average human reaction time is typically 0.25 seconds to a visual stimulus, 0.17 for an audio stimulus and 0.15 seconds for a touch stimulus. Reaction times are 'hard-wired' and depend on the time it takes for sensory signals to pass from the periphery to the brain and from the brain to the muscles. Reaction times are not changeable or trainable.

Hick (1952) discovered that reaction times increase proportionally to the number of possible responses, what is now known as Hick's Law. In complex scenarios, it takes roughly 80 milliseconds for the brain to process information, and a further 150 milliseconds to make a 'conscious' decision. To be effective, athletes have to reduce the time it takes for them to make decisions.

When a goalkeeper pulls off a miraculous save, we call it a 'reaction save'. Do top athletes have faster reactions than the rest of us? Non-specific tests of reaction times show little variation between elite athletes and non-sporting counterparts. If athlete's have similar reaction times to the rest of us, how do they perform so much better?

## Perception and Choice Reaction Times

*Perception time* is the time taken for a stimulus to trigger attention and for our brain to identify the significance of that stimulus. Perception times can vary from one quarter to three quarters of a second, and can be reduced with *task-specific training*. *Choice reaction time* is the time taken between recognizing a stimulus and choosing an appropriate response.

Both perception and choice reaction times can be decreased with training. Elite athletes learn to extract and extrapolate meaning from sensory information faster than novices. A deeper understanding of contextual cues allow experts to process information faster, reducing perception and choice reaction times. Experts draw upon experience to reduce the time taken to 'react and adapt'.

## Anticipation

Functional performance relies on the ability to match behavior to the situation or circumstance. Ordinarily, the time taken to consciously '*reflect and correct*' action can be as long as three to four seconds. Many tasks and skills, especially those in sport, rely on much faster reactions. Performance relies on the ability to adapt and react in a compressed time frame.

One theory is that athletes '*anticipate*' events before they occur. Experts build a database of experience that allows them to anticipate events. There is a story of a Fireman looking at a burning building who immediately orders his team to pull-out. Seconds later the building collapses. Although the fireman could not explain how, his *instinct and intuition* told him the building was not safe. The fireman was able to extract meaning from various levels of sensory feedback regarding the state of the building and severity of the fire. A wealth of experience of similar past situations told him, 'the building is not safe – get out'. These reactions can be so intuitive that it is difficult to describe what cues gave the game away.

We all anticipate events. Good drivers see danger ahead of time. Good friends predict what each other will say. A farmer senses when the weather will change. *Instinct* and *intuition* develop over time and experience. Sometimes an expert's understanding of future events can be uncanny. Anticipation, perception and choice reaction times can all be improved with task-specific training. By developing an individual's deeper understanding of the task they perform, a trainer can develop a client's ability to extract meaning from sensory feedback and react with appropriate behaviors to improve funtional performance.

Generalized, non-specific training is of little benefit. The abstract, slow, controlled movements typified by conventional gym training does not contribute to an individual's useful database of knowledge about anything applicable in real life. As a result, training fails to transfer to function. Abstract strength does not improve functional peformance. A trainer should focus on developing a client's *task-specific coordination* and *domain expertise*.

## Predictive Processing

When a cricket ball pitches, it often strikes the stitching, moving one way or the other 'off the seam'. The time to react to the altered motion of the ball is far shorter than human reaction time, so how is a batsman able to react and adapt? A player cannot anticipate a change in direction. It would take far too much time and skill to 'consciously' decide which way the ball is going to move. Neuroscience suggests something far more impressive is at work.

The brain seldom relies on sensory feedback to make timely decisions (Shadmehr et al., 2010). Rather than reacting to sensory feedback, the brain categorizes each situation we find ourselves. It then compares that situation to past experience of similar situations. The brain then makes educated predictions of what events might transpire based on those past experiences. The brain then plans a reaction or movement strategy based on these predictions and what actions led to a favorable outcome in the past.

Take a footballer dribbling a ball and waiting to time a pass. The player watches strikers making runs in front of them, extracting sensory information. The player draws upon past experience to predict where players will run and how defenders will react. More skillful players develop relationships with teammates that facilitate ever more accurate predictions. The footballer's brain slowly learns when and where to make the killer pass. Elite athletes develop an intuitive understanding of their sport, enabling them to almost see into the future. This skill is almost impossible to teach because it relies on the players intuitive understanding of the game.

The brain 'predicts the future' in all manner of situations (Kitago and Krakauer, 2013), preparing *behavioral responses* ahead of time. Rather than 'reacting', the brain 'predicts' events and makes 'pro-active' decisions. Experience is essential. Prediction relies on domain expertise developed over years of experience that is largely non-transferable.

The drawback is that 'prediction' leaves us susceptible to error. Just because events have unfolded a certain way in the past, does not mean they will again in the future. History does not always repeat itself. To make timely decisions, the brain is forced to rely on a best guess and adapt quickly when things don't play out as we expect.

The brain struggles to predict subtle variations in tasks or environments. Small discrepancies undermine accuracy and precision, and trigger instability and imbalance. Imagine a foot suddenly striking a rock as we walk, twisting an ankle. Unless we adjust immediately, powerful forces could stretch ligaments, spraining the ankle. How does the brain react and adapt to sudden and unexpected changes in the environment? Micro-corrections cannot be planned or predicted and are essential to maintain 1) posture and stability, 2) accuracy and precision and 3) safety and well-being.

In these cases, adjustments have to be made so fast that retrieving, interpreting and reacting to sensory feedback takes far too long. There simply is not enough time to 'sense' disturbances in movement, construct an appropriate reaction and then send a motor signal to action an appropriate response. The lack of time means that to be effective, adaptive reactions have to be '*reflexive*'.

## Reflex Adaptation

A *reflex* is an involuntary, spontaneous reaction to a specific sensory stimulus. Reflexes work on 'short neurological loops', acting to and from the spinal cord without the need for central processing. *Short-loop reflexes* are extremely fast, making them extremely useful when we lack time to adapt and react.

Reflexes have five distinct stages, a 'sensory stimulus', detected by a 'sensor' that sends an electrical impulse via a 'sensory nerve' to the spinal cord. An 'interneuron' within the spinal cord then relays another signal to the motor nerve, telling it to send a signal to a 'target' muscle or gland, triggering a specific response. This loop is called a *reflex arc* (see Figure 3.8).

1. A stimulus
2. A sensor
3. A sensory nerve
4. An interneuron
5. A motor nerve
6. A target (e.g. a muscle or gland)

There are numerous reflexes acting to regulate movement and helping us avoid harm. Some of these reflexes maintain homeostasis, activating autonomic reflexes that regulate heart rate,

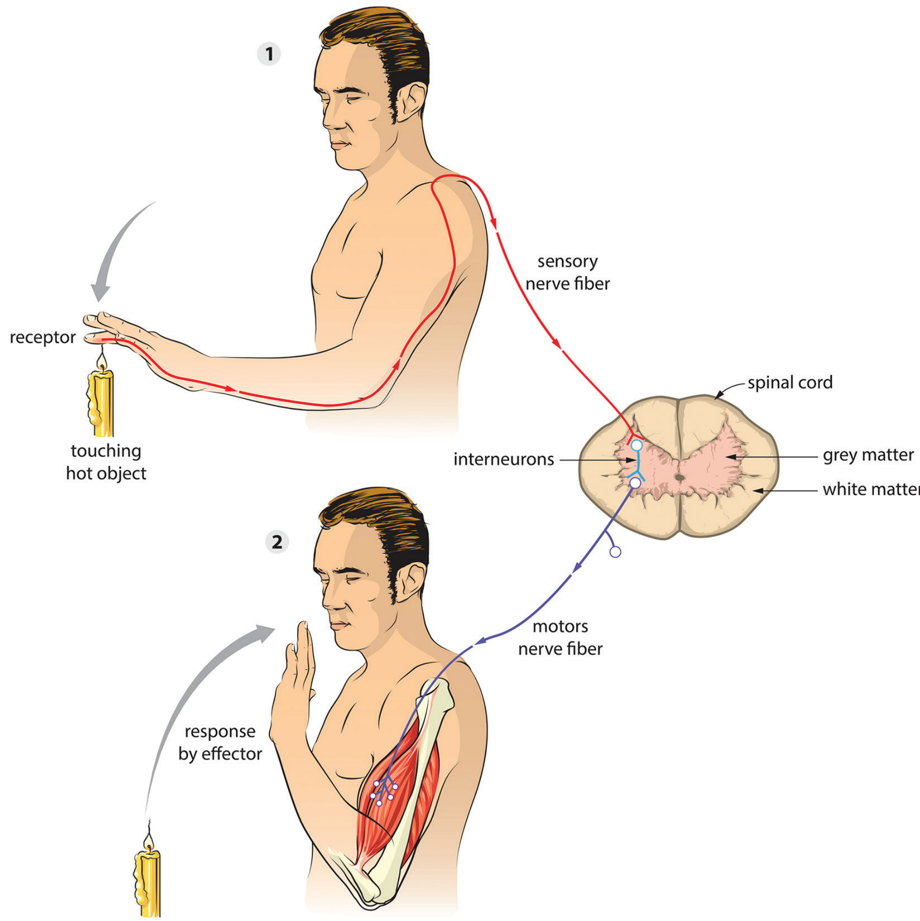


**Figure 3.8** A Reflex Arc.

breathing, blood pressure and digestion. Others initiate involuntary actions like swallowing, sneezing, coughing and vomiting. Here are a few examples of '*protective neurological reflexes*':

- Crossed extensor reflex – activation of nociceptors detecting intense pressure on the sole of one foot activates a reflex activation of extensor muscles in the opposite leg, designed to assist weight transition from one foot to another.
- Flexor or withdrawal reflex – pain sensed in any part of the body activates a reflex contraction of local musle, causing a reflex withdrawal of that body part from the stimulus (e.g. touching a hot plate will cause pain, reflexively causing us to withdraw the hand).
- Startle and blink reflexes – defensive response to sudden or threatening stimuli to the face or eyes, causing the raising of the arms, turning the head and blinking to protect the head and eyes from threat of injury.
- Arthrogenic reflex inhibition – irritation or stress on a joint stimulates a reflex inhibition of local muscle. This is known as the arthrogenic reflex inhibition. Pain or stress from compressive or sheer forces acting on the joint

complex may predispose injury if the load on the joint continues to increase. Arthrogenic inhibition prevents us overloading joints when they are under threat or unstable.

Reflexes have roles to play in almost all aspects of movement, including:

- Correction – maintaininig accuracy and precision
- Protection – preventing injury from stretch, load or instability
- Position – maintaining body position by adjusting muscle tone
- Righting – maintaining position, equilibrium and balance
- Power – force production within dynamic motion

Whilst thought to prevent injury from over-stretch, emerging research now suggests that stretch reflexes regulate motion throughout all ranges. Stretch reflexes react to disturbances throughout inner-ranges, micro-correcting motion, making it smoother, more fluid and less 'jerky' (Hall, 2005). Stretch reflexes likely play a far greater role in regulating movement than previously considered and may be one of the body's principal safety mechanisms, especially when reaction and adaption has to be quick.

## Balance, Equilibrium, Righting and Tilting

Reflexes help maintain posture, position and balance. *Balance reflexes* act as an essential safety mechanism, firing 85 to 90 milliseconds before we are consciously aware of instability. Balance reflexes can be divided into two groups, *righting reflexes* and *equilibrium reflexes*:

- Maintain balance
- Maintain vertical orientation of the head
- Bring the head and trunk into alignment with each other

Balance reflexes integrate sensory information from various sources, including proprioception (especially the dense pockets of proprioceptive sensors found at the base of the neck and spine), *vestibular feedback* and *vision*. Balance reflexes are essential during standing, walking, hopping, skipping, running and jumping movement patterns, and especially within complex tasks, like cycling, climbing or playing games. Balance is an essential skill for the elderly, for whom falls are potentially life-threatening.

In the inner ear, the *vestibular apparatus* consists of three semi-circular canals, each one containing fluid. The motion of this fluid activates mechanoreceptors within the vestibular apparatus. Each semi-circular canal lies at a different angle. The motion of fluid in each canal provides the brain with sensory feedback regarding the rotational motion of the head, equilibrium and spatial orientation.

*Righting reactions* maintain the upright vertical orientation of the head and the position of the body in relation to the head. Righting reactions include:

- The *neck righting reaction* triggers motion of the body to bring it into alignment with the head when the head turns.
- The *labyrinthine head righting reaction (LHRR)* is responsible for maintaining the head in an upright position with eyes facing forward level with the horizon. If the body moves forwards, the chin lifts and head tilts back and vice versa. If the body tilts to the right, the neck flexes/bends to the left, sufficient to keep the eyes horizontal.
- The *oculo-head righting reaction (OHRR)* maintains the stability of the head as the body moves, allowing the gaze to remain focused and fixed.

### RIGHTING REACTIONS IN BABIES

*Righting reactions develop from birth as babies learn to control head motion as they learn to roll, sit, crawl and, eventually, to stand. In babies lying on their back, the neck righting reaction causes their body to turn as their head turns, causing 'a log roll', bringing the body into alignment with the head. Babies also have a palmar grasp reflex that causes them to close their hand around anything that strokes their palm, and also reflexes that help them swim.*

*Equilibrium reactions* help maintain posture and restore lost balance on stable surfaces. Equilibrium reactions work by:

- Moving or widening the base of support using either a step or hop
- Weight shifting from one leg to another, into one hip or another
- Moving arms, legs or spine to maintain balance within the base
- Lowering the center of gravity by bending the knees
- Using the arms in protective extension to soften a fall

There are various strategies working to maintain upright static balance, including:

- Foot and ankle strategy – adjustment of the foot and ankle
- Hip strategy – shift in the hips
- Arm strategy – moving or waving the arms
- Step strategy – stepping to adjust our base of support

*Tilting reactions* are simiar to equilibrium reactions, but they help maintain balance on moving surfaces. Imagine keeping upright on an accelerating train, or whilst surfing or skiing. Tilting reactions maintain the orientation of the body and head in space in these unstable, shifting conditons.

Try this balance challenge

1. Stand on one leg
2. Turn eyes side to side and note the increase in instability
3. Turn your head from side to side
4. Close the eyes
5. Feel the movements of the foot, i.e. foot and ankle strategy

A functional training program should develop balance, tilting and righting reactions, challenging balance from different postures and positions. Exercises should challenge a client's ability to maintain balance as the eyes track moving targets, as the head moves and on both stable and unstable surfaces.

A trainer should always remember that balance is task-specific. In other words, balance training will only tranfer to function if it is developed 'within-task' – within tasks, environments and situations that reflect those the client will find themselves within real life.

To train balance in a useful and relevant way, the client should be made to maintain balance as they step, bend, lift, reach, push, pull and so on. Balance can be challenged by simply changing posture and position, primarily by narrowing the base of support, even by working single-leg stance or by asking clients to move at unusual speeds (i.e. faster or slower than is natural) or into awkward positons (e.g. crossing legs, reaching behind etc.).

## Reflexive Power

Reflexes contribute to force production during dynamic motion. We all instinctively bend the knees before jumping to *pre-load* the hips, knees and ankles. In most explosive movements it is natural to lengthen, eccentrically 'loading' muscles, before 'exploding'.

Stretch-reflexes contribute to power and efficiency, especially in movements involving a *stretch-shortening cycle*, such as walking, running or swimming. A stretch-shortening cycle involves:

1. An eccentric 'pre-load'
2. Isometric stabilization
3. Force 'transformation'
4. Stretch reflex
5. Concentric force production

To feel how much a pre-load supports movement, try standing next to a wall and then jumping as high as you can. You will intuitively bend the knees and swing the arms down, pre-loading fascial chains. Now repeat, but this time start at the bottom of the knee bend. See how much jump height decreases without dynamic 'pre-load'.

Golgi tendon organs (GTOs) monitor load passing through muscles. When loads reach a certain point, GTOs trigger an *inverse stretch reflex*, dampening force production and reducing power production. The inverse stretch reflex acts as a safety mechanism, preventing overload injury.

As well as regulating force production, research suggests GTOs support the efficient and effective switch of muscles from a contracted to a relaxed state. Improving the agonistic and antagonistic relationships between opposing muscles enhances fluidity of motion and is a key factor in improving functional performance (Kistemaker et al., 2013).

## Reflex Modulation

Even though they work on a short-loop, with neurological signals pasing from the periphery to the spine and back, the action of reflexes are still influenced by higher brain centers. The brain modulates reflexes to match the demands of the specific situation. *Central modulation* of sensory feedback could have broad-reaching implications.

In times of increased psychological stress, central mechanisms increase sensory acuity, amplifying sensitivity to stretch and exaggerating *protective reflexes*. Exaggerated stretch reflexes could potentially increase explosive power, but also restrict freedom of movement by increasing sensitivity to stretch. In extreme circumstances, this mechanism could trigger protective muscle spasm.

In times of elevated stress, increased sensitivity of GTOs could regulate *inverse stretch reflexes*, inhibiting force production under high loads, making us weaker and less powerful. In extreme

### EXTREME STRENGTH

*The body has a huge innate capacity and a vast functional reserve in terms of being able to generate force. It is estimated that the average person can only recruit approximately 20–30% of their power at any given movement. Under normal circumstances, autogenic inhibition means that we utilize only a small percentage of our full capacity in order to prevent injury. If the average, deconditioned person was to recruit 100% of their muscle fibers, the forces created could literally rip their body apart, causing extreme injury.*

circumstances, when the brain perceives we are under threat, the brain may even inhibit protective reflexes, allowing extreme levels of force production. From a theoretical perspective, we might say the higher levels of the nervous system are able to regulate performance by 'fine-tuning' sensory acuity under conditions of threat, galvanizing and inhibiting protective reflexes, whatever the situation and circumstance matches.

Central modulation of reflexes is one mechanism by which the brain regulates performance to maintain safety. Experienced athletes may better modulate reflexes, matching protective reflex responses to the demands of the situation to optimize performance. Whilst a novice climber might perceive a situation to be threatening, experiencing psychological stress and elevated protective reflexes, a more experienced athlete would not suffer the same anxiety and so would not suffer the restriction in performance like the novice.

Emotion can have a powerful impact on protective neurological reflexes. One of the keys to opimizing functional performance is maintaining emotional control. Stress is good, but too much stress hampers performance and the better athletes learn to control emotional stress, the better they will perform. Controlling emotion maintains the levels of power the nervous system will allow them to produce. It may be that the abstract, safe and secure environment of the gym fails to teach clients to control their stress or anxiety, and so performance levels suffer in real life.

## Dynamic System Theory of Coordination

Coordination is complex. The models we have discussed so far suggest the brain downloads pre-prepared movement templates, 'tweaking' those templates to match the demands of any situation or circumstance. Corrections are then made using either sensory feedback or reflex reaction.

Movement is complex and varied and we frequently lack time to adapt movement strategies or react to sensory feedback. In an attempt to improve performance, the brain *predicts* events before they occur, making decisions based on past situations that are suitably similar. But prediction leaves us susceptible to error.

To maintain accuracy and precision, the motor system relies on a complex blend of reflex reactions. These reflex movements act to correct movement in response to unexpected variations that act to destabilize and disturb movement. It is impossible to quantify to what extent movement is 'pre-planned and scripted' or 'reactive and reflexive'. The respective balance probably depends on what we are doing, where we are and on an individual's level of knowledge or skill. In trying to understand how this process works, Esther Thelen proposed an alternative model of motor control.

During her time working with babies as they learn to walk, Thelen observed that you cannot 'teach' babies to walk – babies simply experiment and explore, learning from their own experience and mistakes. Esther proposed that human movement works in much the same way. Rather than being planned or scripted, Esther proposed motor control behaves much like a '*complex dynamic system*'.

A *complex dynamic system* (CDS) is a multifaceted entity in which multiple components interact and interrelate to determine performance (Torrents and Balague, 2006). CDSs are not controlled centrally but 'self-organize', reacting to complex interactions between many different '*sub-systems*'.

There are many CDSs evident in the natural world. Weather systems, stock markets and sports teams all self-organize. Weather systems shift in reaction to changes in temperature, humidity and geographic topography. The stock market fluctuates with changes to the global markets, consumer attitudes and political events. The performance of sports teams depends on the attitude of the players, the behavior of coaches, opponents, pitch conditions and so on. There is no central control system. The behavior of complex systems is difficult to predict. In fact, many people make careers forecasting the weather, predicting the stock market or gambling on the outcome of sports events.

Esther proposed that human movement self-organizes, much like a CDS, rather than being planned or scripted – movements '*emerge*' in reaction to various *sub-systems*, or what we like to call '*drivers*'. In movement, powerful drivers might be the nature of the task we wish to perform, the environments in which we move, how we *feel* and so on.

Much like other CDSs, multiple drivers combine to determine the resultant movement. Whilst we think movement is conscious and centrally controlled, movement actually emerges in reactions in complex and interesting ways to determine how we move.

Acording to Dynamic Systems Theory, teaching and instruction may not be the most effective approach because it assumes we consciously coordinate movement. In reality, movement is not conscious or considered, it simply emerges. We describe movement as being *instinctive* and *intuitive*. We know how to walk, bend and lift – there is never really any significant conscious control in 'how' we decide to perform these movements. They just happen all by themselves.

Whilst most movement tasks can be performed in countless different ways, a CDS self-organizes itself based on what is 'easy and efficient'. In DST, the easiest and most efficient strategy is referred to as the '*attractor state*' (Miller, 2002; Spencer et al., 2006).

Movement strategies are selected based on what expends the least energy and effort (Kamm et al., 1990). The motor system gravitates towards:

- Positions of ease
- Paths of least resistance
- Ease and efficiency

Watch a group of people picking up a golf tee and they tend to perform this task in a similar way. Each person arrives at a similar movement strategy for the task. No one ever taught these people to pick up a golf tee, but over time each person drifts towards a comparable strategy. No one will pick the tee up in exactly the same way but the key characteristics of how they approach this task will be similar. This is because each person intuitively discovers what is 'easy and efficient'.

Complex systems are difficult to predict. The smallest change in any sub-system can dramatically impact behavior. In terms of movement, this means a small change in situation or circumstance can dramatically impact how we move. Understanding how different sub-systems or drivers impact movement is difficult, and maybe not even possible. This has geat implications for teaching, instruction and rehabilitation. It is debatable whether we can

**MOVEMENT STRATEGIES EMERGE IN REACTION TO THE:**

- Task – what we want to achieve
- Environment – where we are
- Capacity – what we are capable of
- Emotion – how we feel about that task

teach someone to lift correctly, for example. There are simply too many variables to account for.

The world in which we move is highly complex and varied. To be successful, human movement has to be equally complex and varied. To be successful, an individual has to be able to *adapt* and *react* to fluctuating conditions and disturbances that act to destabilize movement. As Bosch (2015) states, flexibility is a natural consequence of having to adapt to a wide range of different situations and circumstances.

To be successful, movement strategies require both stable and flexible elements (Miller, 2002). The flexible elements of any skill are known as the *fluctuator states*. Fluctuator states are the adaptable elements within a skill that allow an individual the freedom to react to unusual, awkward and unexpected conditions.

Any skill contains a balance between stable and flexible elements, between *attractor* and *fluctuator states*. For example, a tennis player may hit a forehand. There is an ideal technique for hitting a tennis forehand (attractor states), but a player needs to be able to adapt this technique to allow him or her to react to the ball approaching at different heights, speeds and angles.

The relative balance between attractor and fluctuator states may vary for any skill and is almost certainly impossible to teach. What is clear is that in a complex world, rigid form and technique is seldom appropriate because the further conditions deviate from ideal, the worse the performance becomes. Teaching 'correct' form and technique to lift, or as some would teach it to 'deadlift', may be worse than futile, it may even be counterproductive. Taught strategies rarely emerge because they tend to be overly simplistic and expend additional energy and effort.

Just as we cannot 'teach' babies to walk, trainers should abandon the idea of instruction in favor of '*self-guided exploration*'. Clients should be encouraged to discover the movement strategies that work for them. Each person is different, each task is different and each situation is different, so clients have to learn to adapt and react, moving functionally in response to the environmental, biomechanical and morphological constraints they encounter.

A functional trainer must learn to set movement tasks, provide restrictive conditons and allow a clients movement strategies to simply 'emerge'. The ability to adapt and react is fundamental to functional performance. Trainers should build adaptability by slowly laying variation and complexity of movement – challenging clients to lift, not just in one way, but in countless different ways, from different postures and positons, under varying loads, using awkward and unusual tools, obstacles and targets.

1. Challenging stability in various positions and postures
2. Encouraging weight shifting
3. Challenging visual tracking
4. Training on unstable and moving surfaces

## Bringing It Together

Functional movement is complex and varied. Performance relies on a deep understanding of the task or skill, allowing a level of *anticipation* and subconscious *prediction* to plan strategies ahead of time. When disturbances are unexpected, performance depends on the ability to adapt and react. To improve performance, functional training should:

- Develop task-specific knowledge
- Challenge a client's ability to adapt and react
- Train reflex reactions that maintain balance, stability, accuracy and precison
- Learn emotion control
- Promote instinctive and intuitive patterns of movement

# LEARNING

- Neuroplasticity and Learning
- Memories
- Augmented Learning
- Learning in Dynamic Systems

*Learning* has been fundamental to the success of the human species. The science of learning crosses many educational fields, including behavioral and psychological sciences. The brain is the fastest adapting tissue in the body. Unlike the physiological systems, the brain has unlimited capacity for growth.

Only in the last 20–30 years have tools like fMRI and CT allowed scientists to map the brain and comprehend how it regulates movement, pain and performance. Functional training should engage the brain as well as the body. In this section, we see how learning is fundamental to performance. We investigate how functional trainers can optimize learning and enhance neuroplastic adaptation.

According to Steers and Porter (1979), learning is defined as a 'change in behavior resulting from practice or experience'. Learning encompasses the neurological processes leading to semi-permanent changes in an individual's capacity for skilled movement (Schmidt, 1991). When we learn, we acquire new knowledge, develop skills and abilities – we adapt thinking and become more able to plan and organize behavior. Learning allows us to draw upon past experience, to repeat success and avoid failure.

In terms of improving funtional performance and movement ability, *motor learning* can develop position sense, motion sense, balance, sensory perception, and improve patterns of *recruitment*, *coordination* and *decision-making*. Functional training can:

- Develop *internal body maps* – re-sculpting the brain's 'sense of itself'.
- Enhance muscular recruitment – increasing *neural drive* and developing *intra-* and *inter-muscular coordination.*
- Refine *generalized motor programs* – creating efficient and effective templates for movement.
- Develop *domain expertise* – improving the extraction and processing of sensory information, enabling individuals to better recognize, interpret and react to sensory information for improved decision-making.

## Neuroplasticity and Learning

As little as 30 years ago, scientists lacked the tools to investigate the brain and understood little about how we learn. It was assumed the majority of learning occurred in a 'critical' sensitive period early in life, becoming relatively stable and unchanging in adulthood (Merzenich, 2001, 2013). We now know the brain changes constantly in response to experience, long into adult life. The only thing that changes with age is the pace of learning. The young learn effortlessly compared to adults, for whom learning is regulated by behavioral outcomes. For adults, learning is far more reliant on being reinforced by punishment and reward.

The brain is formed from over 100 billion neurons, 1 trillion glial cells and over 1000 trillion synaptic connections. Each connection contributes to the overall perception of our world. Learning restructures the brain, reorganizing it in response to thought and experience. The ability to reform and reorganize synaptic connections is known as *neuroplasticity*. Neuroplasticity is the basis for learning.

Certain conditions support neurogenesis, the growth of new brain cells. Brain-derived neurotrophic factor (BDNF) is one protein that promotes healthy brain development and the proliferation of new brain cells (Gordon et al., 2003). Studies show that low levels of BDNF are problematic and have even been linked to neurological diseases, such as Alzheimer's, accelerated aging, poor neural development, neurotransmitter dysfunction, obesity, depression and even schizophrenia (Duman and Monteggia, 2006).

Scientists measure BDNF to gauge the potential impact of an intervention on neurological development, and therefore the degree to which that intervention may support learning. According to recent research, various factors have the potential to increase BDNF.

- Sensory stimulation – the brains of children deprived of sensory stimulation are 20–30% smaller for their age (Nash, 1997)
- Exercise – intense exercise in particular has been shown to stimulate BDNF production and preserve existing brain cells (Cotman, 2007)
- Play – play has been shown to be especially beneficial for stimulating BDNF (Gordon et al., 2003)
- Calorific restriction – fasting for more than 12 hours supports BDNF (Mattson, 2005)
- Vit-D – sufficient Vitamin D is essential to maintain BDNF – get your 15 minutes of daily direct sunlight
- Social enrichment – socializing increases BDNF production (Branchi et al., 2006)

Trainers can apply research to create training scenarios that support learning. To promote healthy brain development, transform training into 'play' and introduce social interaction. Group exercise and 'game-play' support learning and promote a healthy brain.

## Facilitation

The process by which the brain learns is complex. There are likely countless processes involved, many of which are not fully understood. There are billions of neurons communicating via synapses within the brain. Each synapse acts like a neurological handshake, linking, interacting and connecting to form the basis of personality and subsequent behavior.

Synaptic networking is one of the key foundations of learning. Even infants have billions of different synaptic connections. Over time and use, connections either strengthen or weaken. Whenever we think or act, electrical signals pass through synapses. Just like ramblers walking through dense forest, the passage of electrical impulses through chains of synapses carves a furrow, reducing electrical resistance to future signals, making certain pathways more accessible in the future. This process is known as '*facilitation*'.

As we think and act, some pathways become 'facilitated', increasing their strength and making those pathways more likely to be used in future. At the same time, other pathways lay dormant and fade. Dormant pathways slowly deteriorate and then disappear. Facilitation is one process that shapes and molds the architecture of the brain. In practical terms, whatever we think or however we behave, those thoughts and behaviors become facilitated, making them more likely to occur in the future. This is how behaviors become habitual. The neurological pathways that trigger us to brush our teeth in the evening become furrowed until we brush our teeth before bed without even thinking.

Perform any task or activity and that pattern of synaptic recruitment becomes 'facilitated', making it more likely to *emerge* in the future. The manner in which we organize movement, synergize muscle and integrate the various systems of the body also becomes habituated and ingrained over time and with use. Whatever we do, and however we move, we become more likely to repeat this in the future. Facilitation is why repetition is so important for learning.

## Association

The brain not only constructs synaptic 'pathways', it also *associates* patterns of neuronal activity. Any thought, action or experience triggers a distinct neuronal fingerprint, known as a *neurotag*.

Whenever two neurotags fire at the same time, the brain starts to connect the two, pairing patterns of firing and making that connection more likely to occur in the future.

Carla Shatz (2009) first coined the phrase, 'cells that fire together, wire together'. Carla was describing how two neurons firing in sync become more likely to fire together again in the future. Neurotags inter-connect, so that when one fires, so does the other. Pair two sensations frequently enough and one will trigger the other.

We might associate a song with a past memory, a certain smell with a loved one or relative, the smell of fresh bread with feeling hungry. These are all examples of how the brain builds links between different sensations and experiences.

During the 1890s, Russian physiologist Ivan Pavlov observed that each time a dog was fed, they salivated. Pavlov described this association between the food and salivation an un-conditioned response – a stimulus-response connection that required no learning. Pavlov discovered when he rang a bell and then gave the dog food, over time the sound of the bell was enough to trigger salivation. Pavlov called this a *conditioned response*. The dog's brain had created a neurological 'link' between the bell and feeding time. Pavlov's dog experiment led to the notion of *classical conditioning*.

The association between certain stimuli is accelerated with repetition and reward. If behaviors are 'frequent' and 'rewarded', associations form more quickly. Carla Shatz states that 'neurons that fire apart, wire apart … neurons out of sync, fail to link'. If pathways or associations lay dormant, are not rewarded, or are 'punished', they weaken and diminish. Fail to feed a dog after ringing the dinner bell, and the dog quickly loses interest in the bell.

## Chunking

The brain builds associations to reduce 'computational load'. By 'chunking' information together, we make it faster and more efficient to process. *Chunking* makes information easier to process and recall. For example, it would be difficult to remember a sequence of letters like 'IHOPBUTCANJOG', but we could remember 'I HOP BUT CAN JOG'.

Chunking is an efficient use of neurological capacity by grouping information into recognizable patterns. The brain constantly looks for patterns and builds associations. Our brain constantly strives to catagorize, pigeon hole and simplify, to make decision-making easier. The human brain is a 'meaning machine' – it looks for patterns and connections, often where none exist. This is why people quickly build superstitions. I had a friend who scored his first century, 100 runs, and after that he always wore the same pads when playing. His brain associated his success in that game with the gear he wore.

Facilitation, association and chunking help the brain organize movement. The muscles we use to perform any task are chunked, so that when one fires, so does the other. Over time, patterns of activation become facilitated, making coordination easier and more time efficient. 'Chunks' are stored within the brain as movement templates.

As we learn, our brain chunks code together, making movement automatic, and allowing muscles and movements to be activated without thought or effort. To teach a novice, a coach will often break a skill down, *chunking-down* complex skills into smaller parts for ease of understanding. Chunking-down helps coaches simplify a skill, allowing the learner an opportunity to *reflect* and *correct* biomechanical form and technique. As skill develops, techniques are put together, chunking-up to make movement more fluid.

Skilled movements should not be broken-down. 'Chunking-down', as it is known, increases *conscious coordination*, which increases the opportunity for error, increases sense of effort and generally reduces performance in terms of speed, fluidity and power. Gym instructors frequently 'chunk-down', asking clients to consider form and technique and focusing on very specific elements of a task or skill, when there is really no need. Chunking-down should only be employed if a movement pattern is in some way dysfunctional – when movement patterns are incorrect and new associations and neuronal pathways have to be constructed.

## Schema

The brain chunks information into *schema*. A schema is a collection of rules or assumptions – implicit ideas and expectations for how the world works that help us make sense of our sensations, perceptions and experiences. Learning builds various schema. We learn to recognize patterns and build associations. We develop assumptions about how the world works.

We buld schema for all sorts of different situations and scenarios. If we see steam coming from a pan on the stove, an internal schema tells us the pan is probably hot. This schema is useful because it prevents us getting burnt. We build social schema, ways of behaving around other people. We learn to recognize when someone is angry, upset or aroused. We learn to recognize patterns of behavior, body language, facial expressions, tone and language. We learn how to react in certain situations, in public, at work. We learn how to make friends and how to avoid upsetting each other. We learn how to play different sports, the rules of the game, but also how to beat opponents. Some people have better schema than others – more accurate or effective ways of thinking and perceiving reality. Millionaires have developed schema to make money or build businesses. Athletes develop schema to play sports.

Each and every experience we have is filtered through our own personal schema. We make sense and attach meaning and significance to different events by passing them through our individual schema. Our individual biases and expectations, our different ways of chunking information and perceiving reality. Schema dictate how we think, act and the decisions we make.

Learning and experience help build schema. We learn from significant others, from teachers, friends, family. We build schema based on our individual thoughts and perceptions. We chunk experiences and collate patterns to determine the significance of events. Schema are like stories we tell ourselves about how the world works. These stories are critical to how we behave and react in different situations.

Many of the beliefs and assumptions we hold onto are subconscious and are susceptible to distortion – false assumptions based on defective *pattern recognition*. Just like superstitions and fairy tales, beliefs can quickly become disordered and unconstructive. We have to constantly reflect on and re-evaluate on beliefs to make sure internal schema are both accurate and effective. Building accurate and effective schema is fundamental to successfully negotiating life. What are your personal schemas? Are your schema helping or hindering your experience of the world?

## Memories

Experiences are stored as memories. The brain stores in the region of 280 quintillion memories, formed from different thoughts, movements, sights, sounds and smells. Certain sensations trigger memories of past experience, causing impressions to re-surface into consciousness. A song can remind you of a friend or loved one, or a familiar situation can trigger pain.

There are different types of memory. *Declarative (conscious) memory* is all the knowledge that we can call into conscious awareness – facts, figures, concepts and principles. *Non-declarative (subconscious) memory*, also called *procedural memory*, is the sum of subconscious knowledge, including skills and talents like riding a bike, driving a car, hitting a golf ball or playing the piano. Declarative memory could be thought of 'knowing what' and procedural memory 'knowing how'. The declarative memory can also be considered as conscious memory and the procedural memory as subconscious memory.

We retain only a fraction of past experience in conscious memory. There simply isn't the storage capacity to make all experience available to conscious awareness. Roughly 99% of experience is stored within subconscious memory, preventing us from being overwhelmed with information.

By acting *instinctively* or *intuitively* we access procedural or 'subconscious' knowledge, retrieving information from an abundant archive of subconscious memories. Instinctive and intuitive decisions tend to be faster, more fluid and more efficient than those made using conscious processes. By acting instinctively and intuitively we access a wealth of subconscious knowledge.

Whilst the goal of education is to build conscious awareness, the goal of practice or training is to shift conscious knowledge into the 'subconscious working memory'. In doing so, we make that information available without conscious thought and consideration.

In function, decisions have to be made quickly, efficiently and often without any conscious thought or consideration. In terms of movement tasks and skills, to be of any use, knowledge has to transition from the declarative, conscious memory to the procedural subconscious memory. Teaching form and technique is of little use without the practice needed to transition that knowledge into subconscious memory. Knowledge has to transition through several distinct stages of learning:

1. Cognitive – skills are controlled consciously
2. Associative – skills are part conscious and part automatic
3. Autonomous – skills are largely automatic

When teaching a new skill, we want our client to transition from *unconscious incompetence* to *unconscious competence*.

- Unconscious incompetence – clients are unaware of erroneous patterns of movement
- Conscious incompetence – clients are made aware of erroneous patterns of movement
- Conscious competence – clients can correct patterns of movement, but corrections have to be made with conscious attention
- Unconscious competence – through practice and repetition, patterns of movement are performed correctly without need for conscious attention

Education and instruction are inefficient and ineffective strategies for transfering knowledge from conscious to subconscious memory. A trainer needs to consider the most effective ways to help a client transition knowledge into the subconscious memory. Consider the last time you learnt something, what helped you retain information?

## Augmented Learning

Trainers should structure a client's training experience to maximize learning by enhancing *neuroplastic adaptation* and facilitating the transition of knowledge into the subconscious memory. There are various strategies to support learning.

### Attention

The brain learns when we are *actively engaged*. The more focused and *attentive* we are, the faster we learn. To promote learning, an individual has to be actively engaged, attentive and focused on what they are doing.

The concept of '*mindfulness*' is becoming increasingly popular. To be 'mindful' is to be fully engaged in a task – to act without distraction. Functional training should be *mindful*. The client should be fully engaged in the tasks and exercises they are performing.

**MASSAGE AND MOVE**

*Whilst there is value to passive techniques like massage or passive stretching, the client is not actively engaged in the process, and therefore learning may be negligible. Therapists using passive techniques may be well served to combine treatment with active technique that facilitates learning. After passive treatment, try introducing an active element like a functional exercise.*

## Relevance

The brain has limited storage space. It tends to discard information that is irrelevant or surplus to requirements. Only information that is relevant, useful or vital tends to be stored in the non-declarative subconscious memory. To help engage attention and increase the probability information is committed to memory, training should be useful and relevant to the individual.

Exercises should reflect what a client does in the real world, and this relevance should be explained from the outset. Exercises that are not *useful* or *relevant* should probably be discarded. We might discard the 'leg-press' in favor of lifting, bending and twisting movements.

## Repetition

Learning occurs through *repetition*. New exercises and skills have to be practiced to support their transition to long-term, subconscious memory. Repetition strengthens synaptic links and builds associations within the brain. Without regular and repetitive use, synaptic relationships weaken and erode, hence the saying 'use it or lose it'.

## Feedback

Learning is enhanced when we explore a number of different solutions to a problem and then evaluate those solutions based on high quality *feedback*. Feedback is critical to learning and the impact of feedback is associated with its *nature*, *immediacy*, *accuracy* and *frequency*.

## Nature of Feedback

We cannot learn without feedback. There are two types of feedback, *outcome* and *process*. *Outcome feedback* is often referred to as *knowledge of result*, how successful we were at the task. *Process feedback* is the *knowledge of process*, instruction, corrections and teaching points.

Coaches often emphasize *process feedback*, explaining to the client what they feel they have done wrong or what they should do differently. Research suggests *knowledge of outcome* is far more critical to learning. Learning is facilitated by feedback on *how we are doing* rather than *what we are doing*. Too much attention on *process* rather than *outcome* slows the transmission of knowledge to the *non-declarative subconscious memory*.

A range of strategies may be used to provide feedback. Feedback can be *visual* (e.g. seeing where a ball lands or seeing yourself in a mirror), *verbal* (e.g. feedback from a trainer or coach), *physical* (e.g. sensations such as pleasure or pain) or *written* (e.g. written outcomes and goals).

### Immediacy

Feedback should be provided in a timely manner, as close to the point of performance as possible. Feedback provided longer after performance has less of a psychological impact.

### Accuracy

It is essential that feedback provides an accurate reflection of performance. If feedback is vague or indistinct it loses its value. Feedback is ideally *measurable* and *objective*, and *written* and *recorded*. This way results can be used to set future goals and targets.

### Frequency

Optimal *frequency of feedback* depends upon the skill level of the individual. For novices, a greater level of feedback and an emphasis on *process feedback* may be appropriate. As skill levels improve, feedback frequency can be reduced and more emphasis can be placed on *performance feedback*. Too much feedback can impede learning and clients need to reduce reliance on instructors or coaches for support and learn to make decisions independently. Gradually lowering the volume of feedback is known as '*fading*'.

### Reward

The most powerful form of feedback is *reward* (aka *positive reinforcement*) and *punishment* (aka *negative reinforcement*). Rewarded behaviors persist and punished behaviors tend to recede and diminish. *Reward* can be *intrinsic*, beneficial in and of itself (e.g. play is often fun and social so is therefore intrinsically rewarding), or *extrinsic*, beneficial because we gain something from the behaviors (e.g. we gain money from work or applause from an audience).

## Variation and Novelty

Repetition should be balanced with *variation* and *novelty*. The brain is wired to shift attention onto anything that is *novel* or *new*, and shifts attention away from any stimulus that is repetitive and unchanging. Changes in task and environment spike attention and engage the brain. To enhance learning, trainers should continually introduce elements of the new, untried and untested.

## Sensory Enrichment

The brain learns when the environments and activities we are engaged in are interesting and varied. Research shows that *enriched environments* enhance learning outcomes (Van Praag and Gerd, 2000). Environmental

### CONVENTIONAL EXERCISE AND MOTIVATION

*Exercise can pose a motivational challenge. Exercise can cause pain (negative reinforcement) and the benefits are not always immediately forthcoming. Trainers can help motivation by making exercise intrinsically rewarding by making it fun and social, and can provide extrinsic reinforcement in the form of verbal encouragement and evidence of successful outcomes.*

### VARIATION AND NOVELTY IN LEARNING

*Michael Merzenich, pioneer in the field of neuroscience, believes that 'stereotypy is the enemy of learning' (2013). The brain is best exercised with a variety of movements and challenges. For example, it is preferable to 'move to a point in space in 100 different speeds in 100 different ways … than to move 200 times in the same way to get to that point in space.' Novel stimuli are more likely to get the brain's attention and excite neural activity in more areas of the brain. Mike Merzenich states that 'surprise is a trigger for the brain to learn and change'.*

enrichment boosts neurogenesis and environments that lack sensory engagement slow motor learning (Cai et al., 2006). Rather than sterile, unimaginative training environments, trainers should spend time creating stimulating, engaging training settings.

## Choice, Control, Exploration

Learning improves when we are given choice over how to practice and how much feedback we receive (Wulf et al., 2000). We can augment learning by giving clients control over the tasks they perform. Rather than stringent form and technique and rigid guidelines on exercise, clients should be afforded the opportunity to explore movement strategies independently.

## Emotion

*Emotion* is closely associated with memory. Emotional events are given priority within the brain. The *amygdala*, located in the *limbic brain*, which is associated with emotion, assigns the emotional significance of any event or feedback. This in turn dictates how quickly and efficiently that experience is committed to memory.

Emotional events are regarded as important, maybe even critical to survival, and are therefore committed to memory quickly and in great detail.

### LEARNING IN RATS

*As early as 1949, Donald Hebb found that rats raised in a rich sensory environment, filled with toys and places to explore, learnt faster than animals raised in more sterile environments. In 1964, Marian Diamond and her colleagues performed experiments on rats and their ability to negotiate mazes. She found rats learning to run through a maze experienced neural growth in the one specific area of the brain.*

*In contrast, rats placed in an enhanced environment and provided opportunities to play experienced global brain benefits and developed thicker cortexes as a result. Rats raised in stimulating environments had bigger brains (Diamond et al., 1964) and found their way through mazes more quickly (Greenough and Black, 1992). The brains of rats respond better to complex tasks, compared to simple tasks.*

### FUTSAL

*In Brazil, children and adults play Futsal, a street version of football. In Futsal, there are less players on each side, the pitch and goal are reduced in size and it is played using an undersized ball. These tweaks mean each player touches the ball many times. The emphasis is on fine ball control and accurate passing. Brazil is one of the most successful footballing nations and part of their success has been attributed to the popularity of Futsal. Futsal may be a fantastic example of how learning can be enhanced through sensory enrichment and the adaptation of a training environment. Training needs to occur in environments, and under conditions, that are conducive to learning and that facilitate neuroplastic change.*

**EMOTION AND MEMORY**

*The fact that emotion stimulates memory is useful. Imagine you are a hunter-gatherer and ate a poisonous plant that made you violently ill. Feeling ill is a powerful emotion. Next time we see that same plant we need to remember that it is bad for us. We are not likely to eat this food again. I myself had food poisoning after eating Thai green curry. Even the sight of Thai green curry makes me feel physically sick to this day.*

Emotion supports the transition of knowledge from the declarative to the non-declarative memory and, therefore, if we want to learn a new skill or retain information, link that information with emotion. Make learning fun, exhilarating, exciting, stressful, even inject a little tension or apprehension. Unfortunately, conventional gym training is often sterile and boring, and lacks emotional content.

Other factors that support learning include appropriate sleep and nutrition. Getting a good eight to nine hours of sleep is critical to learning. Sleep is when the subconscious processes new information. Eating carbohydrates at the time of learning also feeds the brain and assists retention of information.

The aim for the FT is to enhance learning by structured training environments, keeping clients actively engaged, using new and novel tasks that evoke an emotional response. An FT should ensure intrinsic and extrinsic reward by making exercises enjoyable and social, providing encouragement whilst giving feedback regarding performance and highlighting progress towards goals. My perception is that this is in stark contrast to what we see in most conventional training.

## Learning in Dynamic Systems

Humans organize movement in a similar manner to many of the complex dynamic systems (CDS) we see in daily life. The behavior of a CDS is difficult to predict and even harder to influence. Movement behaviors '*emerge*' from an instinctive and intuitive reaction to the tasks, tools, obstacles and targets we encounter.

Teaching and instruction is often ineffective because movement is rarely conscious or considered. The complexity we see in function means that form and technique cannot be taught precisely (Bosch, 2015). We cannot 'prescribe' how to lift a bag out of the trunk of a car or place a child into his or her cot – there are simply too many variables. Trainers have to find more effective ways to teach that facilitate subconscious learning.

*Dynamic Systems Theory* (DST) proposes that, given time and practice, movement strategies emerge that reflect the easiest and most efficient way to approach any given task or skill. To support learning, trainers should encourage varied practice and allow individualized solutions to movement problems (Torrents and Balague, 2006). Clients should be encouraged to find their own way through a process of guided exploration using augmented feedback.

Whilst learning is facilitated by accurate *outcome feedback*, it is hampered by instructors being overly prescriptive. Rigid instructions restrict the ability of the learner to explore. Coaching should encourage clients to explore and discover for themselves what is easy, accurate and flowing, whilst highlighting improvement and supporting positive mind-set.

Coaching clients is far more effective than teaching and instruction.

## Bringing It Together

*Motor learning* describes the various neurological processes leading to an improvement in an individual's capacity for skilled movement. To learn, the brain has to restructure its own architecture, building new schema and ways of organizing and interpreting information.

To be of use, knowledge has to transition from the *declarative* or *conscious memory* to the *non-declarative, subconscious memory*. This can take time and effort. Functional training can facilitate learning by:

- Focusing attention
- Being useful and relevant
- Building repetition
- Encouraging variation and novelty
- Providing feedback
- Stirring emotion

Movement strategies should not be taught – they should be allowed to '*emerge*'.

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# 4 STRIVE PRINCIPLES

A healthy dose of functional movement is essential for physical and mental well-being. The human body is designed to perform basic movement tasks in a complex variety of different ways, cycling through each of these throughout any normal day.

Functional training is designed to improve the ease, accuracy and efficiency of functional movement, developing an individual's ability to walk, run, jump, bend, lift, twist, reach, push and pull in lots of different directions and in lots of interesting and unusual ways. Whilst conventional training focuses on the physiological factors that underpin performance, muscle mass and lung capacity and the like, the brain is the coordination center of the body. The functional mind regulates movement, pain and performance, and therefore if we want to improve performance, we have to engage the mind.

Scientists have a thorough understanding of the physical brain and the role each area of the brain plays in coordinating movement. Less understood is how each of these areas communicate and cooperate. Science has been limited in its understanding of the complex network that is the *functional mind*.

Emerging neuroscience provides amazing new insights into how neurons network during movement. This knowledge can be applied to training, to design exercises that engage the neurology as well as the physiology, exploiting the brains remarkable ability to adapt and learn. Whilst neuroscience is still in its infancy, the evidence seems to suggest that to engage the brain, training should be:

- Subconsciously Controlled
- Task-Orientated
- Reactive
- Intelligently Varied
- Emotional

In the following sections, we analyze each of these STRIVE principles, discussing how they inform exercise and program design.

# SUBCONSCIOUSLY CONTROLLED TRAINING

- Conscious Intention, Reflection and Correction
- Subconscious Coordination
- Subconscious Behavior
- Instinct
- Intuition
- The Alien, the Student and the Chimp
- Biological Priorities
- Threat Perception
- Regulation and Modulation
- Threat Inoculation

*Coordination* is incredibly complex. Something as simple as catching a ball requires processing vast quantities of sensory information, coordinating literally hundreds of different muscles and organizing dozens of joints. The ability to catch a ball does not rely on the size of a person's muscles, it relies on *task-specific coordination*.

The brain is the coordination center of the body. Up until recently, scientists have been limited in their understanding of the brain. Scientific investigation of the brain has been limited to prodding and poking the surface of the cortex, recording the reactions triggered in patients. Knowledge of how the brain coordinates movement has been imperfect and incomplete.

The evolution of amazing new tools, like functional Magnetic Resonance Imaging (fMRI) and Computer Tomography (CT), has provided fresh insight into how the brain functions. Rather than a rudimentary understanding of the physical brain, neuroscience has provided a profound insight into the inner working of the 'functional mind'. As functional trainers, we can apply neuroscience to improve movement, reduce pain and enhance performance.

## Conscious Intention, Reflection and Correction

It was René Descartes who first said, 'I think, therefore I am'. We are all self-aware organisms, capable of logical thought and reasoning. We go about our daily lives conscious of where we are and what we do. Most of the time, our brain is filled full of trivial nonsense – what to have for tea, how to attract the girl at work, what is on TV and so on. If we feel thirsty, we might get up and walk to the kitchen to get a glass of water, tired and we might decide to sit and rest. We consciously set goals and prioritize actions based on what we think and how we feel.

On occasion, a task might require specific attention. We concentrate to thread a needle or put the key into the ignition on a dark night. Conscious 'reflection and correction' utilizing sensory feedback is a valuable strategy for performing subtle tasks that require accuracy and precision. These types of intricate tasks are infrequent. Most of the time, people act without thinking.

Most movements, tasks and skills are so ingrained and habituated that they occur absent of conscious attention. Placing the key into the ignition, typing your pin or signing your name, these tasks all occur without any real conscious thought or attention. Most movements are so automated that conscious attention actually makes them feel odd and unusual. Try writing with your non-dominant hand, cross your arms the wrong way around, cross fingers with different fingers interlaced – these actions can all feel bizarre. We are not accustomed to *conscious coordination*.

In function, most events unfold so quickly it is almost impossible for the 'conscious mind' to keep track. A lack of time or ability means that the majority of coordination is *subconscious*. We are blissfully unaware of the systems that act to maintain homeostasis – the body's internal and external balance. Vital functions like breathing, digestion and excretion are all coordinated beneath the surface of consciousness. Muscles work synergistically to maintain balance and coordinate to create movement. How they achieve this is almost beyond imagination. Whilst our conscious brain reflects on a stream of trivial nonsense, the 'subconscious mind' works hard to keep us alive and moving.

To understand coordination, it is useful to separate the *functional mind* into two distinct parts, the '*conscious*' and '*subconscious mind*'. Just like a giant iceberg, conscious awareness represents only a mere tip of the iceberg, a small portion sitting above a far more powerful subconscious intellect.

It is easy to be convinced of the power of our own conscious intellect, but when it comes to coordination, the conscious mind (CM) is actually extremely limited. Every time we step, walk, reach, push or pull, the brain has to synergize various muscles and integrate the various systems to supply energy, deliver oxygen and remove waste. The conscious brain lacks the ability to consider these countless operations. Imagine actually having to decide which muscle to contract, which bones to move, in what order and at what speed. Imagine having to think about when to breathe. The shear complexity of this task is beyond imagination.

We can consciously focus attention on a specific skill, but do you remember the last time you tried to learn a new skill, like serving a tennis ball for example? If a coach provides too many teaching points you freeze, overloaded with information. I call this '*paralysis by analysis*'. The conscious brain is able to focus on only two or three teaching points at any single time. The conscious mind quickly reaches the limits of its ability to coordinate movement.

Movement is far too complex for *conscious control*. As a result, conscious coordination makes movement slow and inefficient (Peh et al., 2011). Direct attention degrades skill, heightens sense of effort and increases energy consumption (Lewis and Linder, 1997). Too much attention interferes with a person's ability to move, hampering speed, fluidity and power. The more complex the skill, the less effective conscious coordination becomes. For functional performance, coordination needs to be 'subconscious'.

## Subconscious Coordination

It was the psychologist Pierre Janet (1859–1947) who first coined the term 'the subconscious mind' (subCM) to describe the hidden intellect working beneath conscious awareness. The subCM has enormous processing capacity – said to be 30,000 times more powerful than the CM, taking up 88% of the human brain's capacity and able to process 40 million bits of information per second, compared to 40 bits of conscious processing. If the brain were a computer, all the processing power would be allocated to the subconscious.

> If it could speak, the CM would be able to say 200 to 300 words per minute, the subconscious can think at the rate of 1000+ words per minute.

The subconscious is able to perform millions of operations in mere fractions of a second, gathering, processing and interpreting vast sums of sensory information to organize movement, synergize muscle and integrate all the various systemic functions of the body. The incredible power of the subCM is essential for coordination.

In function, events unfold quickly. We barely have enough time to reflect on *what to do*, let alone *how to do it*. We can decide where to walk but don't have the time or capacity to consider 'how to walk' – where to place each foot, how far to stride and so on. Walking is a subconscious movement behavior.

Benjamin Libet performed a fascinating study in which subjects were asked to voluntarily press a button in response to a dot moving across a screen. The subjects were also asked to record at what point they felt they made a conscious decision to press the button. Electrodes were attached to their head, monitoring electrical activity occurring within motor areas of the brain. Libet showed that unconscious activity within motor areas of the brain fired roughly 350ms prior to any conscious decision to act. Motor signals triggering movement appear well before the conscious decision to move.

This experiment brings into question the notion of 'free will'. Do we really decide to act or are decisions pre-programmed? Does conscious awareness occur before or after the decision to move is made? Is the conscious mind actually the driver or are we just passengers during intentioned movement? These are huge questions that are beyond the scope of this text.

## Subconscious Behavior

'*Behavior*' is the manner in which we approach any situation or circumstance. The clothes we wear, the program we watch on TV or the food we eat. These are all behavioral decisions we assume are under conscious control. Whilst we think behavior is conscious and considered, many scientists suggest as many as 95% of the decisions we make are under 'subconscious control'. How we drive the car, where to cross the road, how we hold our hands, how we carry a bag – these behaviors are all subconsciously controlled. You will probably have experienced that feeling of driving to work and being totally unaware of how you got there. Imagine all the decisions that were made without a great deal of conscious awareness.

How we move is a form of behavior. How we step, walk, bend, twist, push or pull – these are behaviors referred to as *movement strategies*. Whilst we assume that we decide if, how and when to move, movement strategies are fundamentally subconsciously controlled.

To catch a ball we have to position the hands and feet, stabilize the core and track the ball with the eyes. These movement strategies all have a huge impact on functional performance, far more so than the size of muscles or the capacity of lungs. When deciding how to approach any task or skill, the subCM analyzes what we have to do – it extracts, processes and evaluates huge sums of sensory information and analyzes this information alongside a vast database of past memories and experiences. A movement strategy is then formulated based on:

- What we want to achieve – task
- Where we are – environment
- What we are capable of – capacity
- How we feel – emotion

The subCM considers, 'the last time I was in this situation, what actions were successful, what strategies were rewarded?' Movement strategies are formulated ahead of time. We don't stop to think about how to unload the car, unpack the shopping or scoop a child off the floor. Decisions were made well before conscious awareness – a subconscious '*pre-action*'.

Not only does the subconscious coordinate movement, it also regulates performance. When we move, the subCM decides if, how and when, and with what speed, force and power. When we 'lift', the subCM regulates power, fine-tuning a virtual volume dial and turning the dial up or down to regulate performance, depending on the situation and circumstance. If the subconscious decides a weight is too heavy, power is switched off, avoiding the risk of injury or harm. To un-tap huge reserves of power and performance, engage the subconscious mind and take the handbrake off.

The decisions regarding what we do and how we do it are blurred within the brain. In actual fact, the decisions regarding movement strategy are formulated well ahead of time, well before any conscious decision to move. Movement strategies emerge from an *instinctive* and *intuitive reaction* to where we are, what we are doing and how we feel. Only when we slow actions down and make them simple do we have some degree of conscious control.

## Instinct

*Instinct* comes from the word *instinctus*, or 'impulse', and refers to innate predispositions programmed into our DNA. Instincts are innate inclinations in specific situations, tendencies passed down through the generations that help keep us alive – much like a genetic survival kit.

Flinching is an example of an instinctive behavioral response designed to protect us from objects flying in our direction. If a bug flies towards the eye, we have an inbuilt instinctive response that closes the eye, shifts the head away and raises the arms in defence. The same fly has an inbuilt instinctive response to a strong breeze sensed on the hairs of its back, like that created by a fly swot. The sensation makes the fly instantly take flight, making it very hard to hit.

Instinctive responses help us avoid danger, especially in situations where the time to react is brief. The brain has inbuilt instinctive responses to many situations. These instinctive responses are ancestrally programmed. The problem is that in many cases, instinctive behavioral reactions do not produce favorable performance outcomes. Flinching when a ball is thrown in our direction is not an effective response, especially if we are a baseball catcher. Athletes spend years re-programming instinctive reactions in a way that supports their sport. Athletes learn to reprogram instinctive responses to evade punches, return serves, save penalties and all manner of other complex sports skills.

## Intuition

*Intuition*, comes from the Latin *intuir*, referring to 'knowledge from within'. Intuition is knowledge held without apparent evidence or conscious understanding of where that knowledge has come from. When we understand *intuitively*, we do so without logic or reasoning, much like a gut feeling or hunch.

Rather than being imagined, intuitive knowledge derives from the accumulation of years of experience, stored with the subconscious, procedural memory. When we reason intuitively, we extract subconscious memories and engage sophisticated *pattern recognition*, allowing the brain to *anticipate* and *predict* future events. Subconscious anticipation and prediction allow motor planning to occur ahead of time – decisions can be made instantaneously without overt thought or effort.

Instinctive and intuitive reactions are inherently faster, more fluid and more flowing, because they negate the need for lengthy planning, reflection and correction. To improve performance, trainers should encourage instinctive and intuitive patterns of movement. Rather than teaching clients to perform an unnatural movement like a 'Cable-Press', for example, why not ask for an instinctive reaction by reaching towards a target. Instinctive and intuitive movement patterns tend to be easier and more efficient – stronger, faster and more powerful.

We all know how to step, bend, reach and so on. Instinctive and intuitive exercises are far easier to learn than a series of abstract exercises with complex teaching points. By allowing 'subconscious control' and by making movement patterns instinctive and intuitive, functional trainers can enhance performance with respect to speed, fluidity and power. The 'functional mind' regulates movement, pain and performance. Functional trainers have a fantastic opportunity to improve functional performance by engaging the subconscious mind.

## The Alien, the Student and the Chimp

As Sigmund Freud once said, the subconscious has a 'will and purpose all of its own'. Our genetic code is hardwired as if we are still living thousands of years ago. Prehistoric man was 'hungry and hunted', having to walk 5–9 miles a day to find food whilst surviving predation and harsh environments. The brain is geared to *survive* in hostile conditions.

Appreciating how a prehistoric inheritance influences behavior is useful in designing exercise. We have created three simple metaphors to explain subconscious motivation:

- The Alien, the Student and the Chimp
- Biological Priorities
- Threat Perception

It is convenient to divide the subCM into three fictitious subdivisions. Each subdivision influences behavior in a different way and predominates at different times, depending on what we think and feel. We call these subdivisions the *Alien*, the *Student* and the *Chimp*:

- Alien – the alien super-computer
- Student – rational and problem solving
- Chimp – emotional

## Alien Mind

The *Alien mind* represents a subconscious 'super-intelligence' responsible for controlling and coordinating movement, as well as monitoring and regulating homeostastatic functions, such as breathing, respiration, digestion, thermoregulation and metabolism. The Alien mind is ever-present, ever-watching, listening and calculating, tring to keep us safe and sound.

For the Alien, the priority is not performance but *survival*. As we go about our day, the Alien observes, comparing everything it sees against a database of past experience, stored knowledge and unseen information. It shifts *attention* onto anything *new* or *novel*, and evaluates the potential for danger. Whenever it senses *threat*, the Alien triggers a range of emotional centres within the brain, intended to alter behavior.

The Alien monitors vital signs, regulates body balance and regulates behavior to ensure health and well-being. If we are hungry, hot or cold, the Alien triggers a range of hormonal and neurological responses designed to change behavior and maintain homeostasis. As blood sugar lowers, hunger centers activate to encourage us to eat. Physical threat causes pain and discomfort, changing how we move. Any significant danger triggers a sense of apprehension and fear, so strong it can make us aggressive, freeze until trouble passes or run away.

The Alien stores vast sums of information, but discards that which is not useful, relevant, repeated or vital for survival. Information linked with a high level of emotion is considered to be particularly important. The Alien mind retains information deemed to be:

- Relevant
- Useful
- Vital

The Alien is *outcome focused*, not process focused. It evaluates outcomes alongside initial *intention* and learns what is effective based on *outcome feedback*. The Alien prioritizes learning and experience when it contains:

- Novelty
- Outcome feedback
- Emotion

We utilize Alien knowledge when we 'listen to our gut' and rely on instinct and intuition. The Alien communicates with the conscious mind using emotion.

**KEY POINT**

To affect behavior the Alien mind can influence emotion, perception and performance. To engage the Alien:

- Trust your intuition
- Act instinctually
- Move naturally

The Alien has two associates with whom it consults to make decisions. We call these the *Student* and the *Chimp*.

**Subconscious Anatomy**

It is not often useful to think in terms of anatomy of the subconscious, but:

- The Alien lives everywhere else, the entire central and peripheral nervous system

- If the Student lives anywhere, it lives within the prefrontal cortex, located at the front of the cortex
- The Chimp lives in the limbic system, the emotional centre of the brain

## The Student Mind

The Student mind is rational and logical – geared for planning, evaluating and problem solving. The Student acts as the voice of reason, over-riding impulsive and emotional actions. The Student mind has a large part to play in moderating impulsive behaviors through discipline and self-control.

In the anatomical brain, the Student is most associated with the *prefrontal cortex (PFC)*. Patients damaging their PFC become overly emotional, losing their ability to make rational, reasoned decisions.

In training, we can engage the Student mind by incorperating learning, planning and strategy. A trainer might ask a client to learn a new skill, master a new movement or solve a puzzle. Training engages the Student when it involves:

- Learning
- Planning
- Strategizing

## The Chimp Mind

Whilst the Student mind is calculating and rational, the Chimp mind is emotional, irrational and impulsive. Whenever we experience high levels of emotion – have fun, play games or lose our temper – we shift into Chimp mind. The area of the anatomical brain associated with emotion is the limbic system. The limbic system is one of the oldest parts of the brain and one of the first to develop. Many decisions are made using the limbic emotional brain – we behave based not on what we think but on how we 'feel'.

The Chimp is un-inhibited and un-restrained, prone to aggression and bad behavior. The Alien shifts into Chimp-mode whenever it feels threatened or in danger. The removal of physical constrainsts has a profound effect on performance, providing 'gorilla-like strength' and resistance to pain. A person in 'chimp-mode' is a formidable opponent. To activate the Chimp:

- Build in emotion
- Have fun
- Socialize
- Compete

*Emotion* is closely associated with memory. Information and associated events that contain high emotion quickly shift into long-term, non-declarative memory. A Chimp brain learns quickly, but also reverts to old, established patterns, attitudes and behaviors under stress and duress. This makes it difficult for someone in Chimp mode to learn new or complex skills.

Behavior is influenced by each subdivision of the subconscious, and each can dominate at any

**RESEARCH**

*The Student brain works to suppress urges. Young adults whose prefrontal cortex is still developing are especially prone to rash choices and emotional responses. The prefrontal cortex appears underdeveloped in adults with addiction, gambling problems and anti-social behavior, and has been seen to be underactive in people who over-eat.*

time. Choice of *movement strategy* will vary depending on which sub-division of the subconscious mind, the Alien, Student or Chimp, dominates thinking at that time. Engage the Alien mind and movement becomes fluid and flowing, Chimps tend to be powerful and aggressive, Students precise, conscious and considered.

A trainer should be aware of a client's mental state at any time and reflect on what mode of training may best suit them on that day. By allowing clients to be instinctive and intuitive we engage their Alien subconscious mind. By emphasizing novel and complex skills, we drive their Student mind, building discipline and self-control. By introducing game-play or competition, we 'stir the Chimp'.

The Alien, Student and Chimp are simple metaphors explaining how the subconscious regulates movement, pain and performance, and can be useful tools for guiding exercise prescription.

## Biological Priorities

The human genetic code has barely changed for over 1,000 years. The subconscious is hardwired as if we are still hunting for food and wandering deserts, jungles or swamps, as if in prehistoric times. Whilst the conscious mind is consumed with the hundreds of trivial motivations and desires, the subconscious strives to keep us alive.

The subconscious has a clear hierarchy of needs, what we call its *biological priorities*. The subCM regulates instinctive behaviors to maintain these biological priorities:

1. Homeostasis – maintaining internal balance
2. Survival – avoiding threat
3. Ease – conserving energy
4. Legacy – genetic survival through offspring

### Homeostasis

*Homeostasis* is the drive to maintain a stable internal cellular balance. To survive, the body needs (among other things) a stable temperature, alkaline/acidity levels, energy availability and oxygenation. Whilst the external environment fluctuates, the subCM works to balance internal conditions. Lose homeostasis and cells start to die, after which point, we die. Maintaining homeostasis is a fundamental *biological priority*.

### Survival

After short-term homeostasis, the subCM's next biological priority is long-term survival. In prehistoric times, exposure to the elements, dehydration, starvation, injury and predation were all real threats. Survival had to be a priority and, as such, is a powerful subconscious driver. The subCM activates motivational and emotional centers within the brain to influence behavior to avoid threat and ensure survival.

### Ease

In prehistoric times, food and resources were scarce. It was normal for individuals to have to survive long periods without eating and travel long distances to forage and find food. Metabolism is geared to conserve and store energy. It is why in today's calorie-rich society people struggle to lose weight. We are metabolically and emotionally geared to survive in times of scarcity.

When resources are scarce, efficiency is key. The subCM strives to conserve energy and effort wherever possible, selecting the easiest and most efficient ways of approaching any task or activity. We instinctly and intuitively seek 'positions of ease' and the 'path of least resistance'. The subCM regulates movement and behavior to conserve energy and withdraw effort, despite any conscious drive we might have.

### Legacy

The last biological priority is *legacy* – the act of passing on our genetic code via offspring. Having survived threats to survival, spare resources are invested in increasing the chances of meeting a partner and having children. When we relax, feel

**PATH OF LEAST RESISTANCE**

*When you watch a client move naturally without thought or consideration, you are watching what their subCM perceives to be the easiest way of achieving that task. This may not be the most effective, but it is what their subconscious perceives as being the most efficient at that moment in time.*

stress-free and maintain caloric excess, we are well-placed to grow, gain muscle and compete. Under these circumstances, the body produces a range of sexual hormones geared towards growth, sexual health and reproduction.

The subCM is geared towards achieving biological priorities. Instruction is a poor strategy for changing behavior because it fails to appreciate subconscious biological priorities. Imagine teaching a client to 'lift'. If form and technique is not easy or efficient, it is unlikely to emerge within function.

The subCM is constantly monitoring, processing and evaluating sensory information to ensure its biological priorities are met. The subconscious activates powerful motivational and emotional centers within the brain to change behavior accordingly. Over time, it is very hard to overcome subconscious control.

## Threat Perception

One of the keys to mankind's success has been our inquisitive nature. Like children, we are hardwired to seek out new experiences and explore boundaries. It is human nature to explore, climb trees, swim out a little further, touch a hot plate, ride a roller coaster. But, on occasions, this inquisitorial nature places us in harms way. As the saying goes, curiosity killed the cat. We are prone to take risks and place ourselves in harm's way.

To save us from ourselves, the subconscious continually assesses the situation, anticipating the potential for danger. To avoid harm, the subconscious regulates behavior, triggering powerful emotions and inhibiting performance to change behavior and avoid danger. There are many potential threats to homeostasis and survival:

- Threats to homeostasis
  - Infection
  - Excessive heat or cold
  - Altered chemical imbalance
  - Low blood sugar
  - Lack of oxygen

**WEIGHT LOSS PROGRAMS**

*95% of weight loss programs fail long-term because caloric restriction activates centers within the brain designed to trigger apprehension and hunger. Caloric restriction is perceived as a potential threat to survival, and therefore the subCM triggers a range of hormonal and emotional reactions designed to conserve energy and drive behavior, making us find food and eat. Hunger reduces metabolism, causing the body to conserve energy and restrict performance. Weight loss programs should ensure the body's nutritional needs are met in terms of vitamins and minerals to avoid hunger, and foods should be selected that are low in calories but that maintain blood sugar.*

- Threats to survival
  - Starvation
  - Exposure
  - Injury
  - Social exclusion

For prehistoric man, injury could potentially restrict function, undermining the ability to escape predators, hunt and forage for food. Careless movement also has the potential to cause injury. The subCM identifies certain movements as threatening, including movements that are:

- New or novel
- Unexpected
- Overly complex
- Uncontrolled
- Overloaded
- Unstable

In predicting the potential level of threat, the subconscious evaluates the movement task, situation or circumstance conditions and then reflects on past experience. The subconscious even considers individual expectations, thoughts, attitudes and beliefs. Negative expectations heighten *subconscious threat perception*. Negative emotions like fear, apprehension or anxiety all impact subconscious threat perception, increasing the likelihood of triggering a protective, guarding response.

The subCM has various strategies to alter behavior to avoid threat of hurt or harm. The subconscious regulates performance, making movement slower and less powerful. The subconscious triggers emotional centers within the brain, heightening apprehension, which tends to reduce risk-taking. Pain is one of the most powerful mechanisms the subconscious uses to alter behavior to avoid danger and prevent injury.

## Regulation and Modulation

Under threat, the subconscious alters how we process and prioritize sensory information. Under conditions of threat the subCM will:

- Shift Attention
- Regulate Perception
- Modify Perception
- Generate Pain
- Modulate Sensation

### The Subconscious Shifts Attention

The subCM is geared to constantly monitor the environment and identify potential sources of threat. The subconscious filters sensory images, identifying what information is useful, relevant and vital to survival and shifting attention onto anything that could pose a potential threat. We become instantly aware of hunger, thirst, cold or pain.

Any new stimulus or change in the environment has the potential to be threatening because we do not yet know what it is. Therefore, any new event is highlighted, catching attention. Stimuli or sensory feedback that remains unchanging is downgraded and discarded as irrelevant.

### The Subconscious Regulates Perception

Many of the sensory images we perceive are constructed from a combination of actual sensory feedback, past memories and expectations. The brain literally fills in the gaps in sensory feedback. Because perception is constructed from various different sources, not just sensory feedback, we are susceptible to *sensory distortion*. In the same way that we can stare into a fire and construct images from the flames, the subconscious constructs perception, molding sensory feedback and often creating 'threats' where none exist.

Distortions in sensory feedback impact how we act and behave. If we are asked to walk across a rope bridge, the brain can regulate the degree to which we feel the bridge swaying, heighten awareness of the wind or exaggerate any sensory feedback that indicates the bridge is unsafe. Distorted sensory feedback increases the perception of danger, stopping us walking across the bridge.

## The Subconscious Generates Pain

One of the most powerful mechanisms the subconscious uses to influence behavior is through pain. Under conditions of immediate threat, the subconscious can trigger pain perception causing a change in movement behavior. Most people will adapt movement to avoid pain and change behavior to avoid activities that caused pain. Pain is a highly complex mechanism that is covered in greater depth in the second half of this book.

## The Subconscious Modulates Sensation

The subCM *modulates* sensory feedback to match the degree of perceived threat in any situation or circumstance. *Sensory modulation* acts like a volume dial, increasing (i.e. *activating*) or decreasing (i.e. *inhibiting*) sensitivity to sensory stimuli. Under threat, the subconscious amplifies sensory acuity, *facilitating* sensory feedback to the nervous system. Heightened sensory feedback can have a range of consequences.

Heightened sensory perception can be useful in times of danger. Walking through a dark forest we are suddenly aware of every sound or disturbance, useful if we want to identify potential predators. Whilst increased sensory acuity is useful in terms of identifying and avoiding danger, there are potentially a range of consequences of reflex coordination of movement.

Heightened sensory acuity affects sensory feedback from proprioceptors like the *muscle spindles* and *Golgi tendon organs* (*GTOs*). Increased sensitivity to proprioceptive feedack could have a range of potential consequences. Increased sensitivity of muscle spindles could increase sensitivity to stretch, for example heightening:

- Stretch reflex contractions
- Underlying muscle tone
- Force production

Under more severe conditions, following pain and injury for example, increased sensitivity of muscle spindles and heightened sensitivity to stretch could

### SUBCONSCIOUS MODIFICATION OF PERCEPTION

*I walk home one night and see a hooded figure walking towards me carrying a bag. From a distance, the man looks muscular and menacing. My proprioceptors might have sensed the levels of strain in my hips and ankles as I walk, my ears register the passing cars and my vision senses the entire road ahead (sensation), but I am only acutely aware of the menacing figure coming towards me (perception).*

*I watched the news a few days ago about a spate of muggings and I am sure this is not a good street to be walking on alone at night (attitudes and belief). I feel my pulse start to race (altered perception). Muscles tense as a small burst of adrenaline activates my fight or flight response (behavior). I feel a little anxious and wary, as I have never had a fight in my life (emotion). I reason that if I think 'look straight ahead, act confidently', I am confident that would dissuade a would-be assailant (thought). I walk tall, tense muscles ready for confrontation (behavior). The man then walks under a streetlight and it turns out the gentleman is 60 years of age and is just carrying some shopping. I feel embarrassed as well as a little relieved (emotion) and carry on walking home, at which point I notice what a beautiful full moon there is tonight.*

impact movement to such a degree that even normal levels of movement trigger intense reactions, resulting in:

- Joint rigidity
- Loss of mobility
- Muscle guarding
- Muscle spasm

Golgi tendon organs sense levels of load passing through muscle. Increased sensitivity of GTOs could facilitate *inverse stretch reflexes* working to inhibit muscle. Under these conditions, even moderate loads could activate GTO, triggering an inverse stretch reflex, reducing force production and inhibiting strength.

Each of the adverse reactions highlighted above could potentially be the result of a heightened subconscious sense of 'threat'. Feeling threatened by a situation has the potential to make us tight, stiff, weak and unstable. A loss of performance in reaction to feeling unconfident or insecure is probably an experience most of us have felt. Improving functional performance can be as simple as feeling more confident.

## Threat Inoculation

Whilst strength is associated with the size of muscles, more critical to performance is an individual's ability to *recruit* muscle. Muscular recruitment is inhibited under conditions of perceived threat or harm. Certain factors, such as if a resistance appears heavy, the environment is unfamiliar or we are using a new grip, all have the potential to undermine confidence. Novelty is threatening, therefore any change in what we are doing or where we are has the potential to undermine performance. Performance is less about muscle mass and more about how we think and feel about a specific task or skill.

Training is the process of progressively gaining confidence. As confidence grows, neurological restraints on performance recede and strength increases. Feeling confident and assured in extreme situations is a major factor that contributes to why elite athletes can perform seemingly incredible feats whilst still having similar physiques to the rest of us. Training is a process of '*threat inoculation*' – systematically exposing ourselves to progressively increased levels of threat. As a client gains confidence, subconscious threat perception reduces and performance improves.

Cognitive Behavioral Therapists use threat inoculation (CBT practitioners call it 'stress inoculation') to treat patients with phobias. A patient with agoraphobia is fearful of unfamiliar environments and situations in which they perceive a lack of control, such as wide-open spaces or crowds. Irrational fear relating to this lack of control can have a profound impact on behavior, strong enough even to trigger panic. Therapy involves systematic exposure to situations in which they feel threatened and sense a lack of control, starting with less threatening situations before progressing to more threatening scenarios. Progressive exposure is designed to desensitize their stress response.

Physical training works in a very similar manner. Training is the systematic exposure to threatening tasks, skills or activities to progressively build both conscious and subconscious confidence. As sense of threat recedes, sensory modulation normalizes and the client experiences:

- Desensitization to load, resulting in increased strength
- Desensitization to stretch, resulting in increased flexibility
- Decreased apprehension and expectation of injury, reducing chance of pain

*Self-efficacy* is the term used to describe *task-specific confidence*. To transfer to function, training has to reflect the specific task or skills we are training for. There is very little point gaining confidence in abstract exercises like the 'Chest-Press', 'Leg-Press' or 'Bicep-Curl', because these exercises are of little use in real life. 'General confidence' is less effective than building task-specific confidence.

Imagine training to scale a climbing wall. Conditioning the arm muscles is beneficial, but better is to build a client's confidence climbing. Performance is influenced by the strength of arm muscles, but more important is the individual's task-specific coordination and climbing confidence. For a novice learning to climb, a fear of falling and lack of skill are the real factors limiting performance.

To learn to climb a wall, training has to be progressive. A novice should start on an indoor wall, learning how to move the body, reach for handholds, step onto footholds, twist the spine and hips and get into 'functional' postures and positions. A coach should match the grade of climb to the ability and should encourage the novice to experiment and explore different directions of movement, different body positions, handholds, and climbing strategies, without being overly concerned about teaching points and instructions. If the client experiences difficulties, a trainer can highlight options, suggest alternative strategies and support learning by encouraging and highlighting success.

To build fitness, a climber should *overload* specific elements of performance – climb at different speeds, hang for long durations, pull-up on different handholds and grips, practice different courses and gain expose to different situations and scenarios. A trainer provides a safe environment to develop coordination and build confidence, providing progressively more challenging tasks. As coordination increases, aptitude improves. As confidence grows, performance improves.

There is little variation in conventional training. There are only a small handful of exercises to perform and programs remain consistent over weeks of training. A client's strength increases quickly as they become confident and assured in what they are doing. The problem is that strength fails to transfer into function, where the inherent variation in the tasks and environments in which we move means that every situation has the potential to feel untried and untested.

The subconscious views novelty as threatening, down-regulating performance to avoid injury in conditions that are untried and untested. We cannot train to prepare for every different situation or circumstance we might encounter in real life. The only answer is to de-sensitize a client to novelty. By performing exercises and training within environments that are varied and complex, we desensitize that client to novelty. We improve a client's functional performance by improving their ability to *adapt* and *react*.

Functional training should not be progressed merely through increasing sets, reps and load, but through the systematic exposure to varying:

- Types of load
- Speeds of loading
- Ranges of movement
- Direction of movement
- Complexity of movement

Exposure to *intelligent variation* desensitizes clients to novelty, variation and complexity, developing performance in a way that will transfer to function. To improve functional performance, expose clients to situations that are:

- New or novel
- Complex and interesting

## Bringing It Together

Movement, pain and performance is all under subconscious control. To improve performance we have to engage the *subconscious mind*.

- Functional exercise encourages subconscious control by reducing emphasis on instructions and teaching points and encouraging instinctive and intuitive movement, whilst also developing a client's deeper understanding of the specific tasks and activities they perform on a daily basis.
- Interventions should support the subconscious biological priorities of homeostasis, survival, ease and legacy. Any instructions or interventions that threaten these priorities are unlikely to emerge in function.
- The subconscious reduces performance in conditions of threat, making us weak, stiff and inflexible. An FT should apply threat inoculation to progressively expose clients to movements and exercises that are:

    - New or novel
    - Complex

    And should gradually expose a client to increasing:

    - Speed
    - Range of motion
    - Load
    - Complexity

An FT might want to adapt training to take advantage of the characteristics of the *Alien*, *Student* and *Chimp*.

- To engage the Alien:

    - Keep training relevant and useful
    - Make exercises complex and varied
    - Make exercises task- and environment-driven

- To feed the Chimp:

    - Make training emotional
    - Have fun
    - Play
    - Socialize
    - De-stress
    - Remove threat, apprehension, fear and anxiety
    - Make training environments safe and familiar
    - Give beginners control and choice
    - Introduce challenge, pressure and competition progressively
    - Avoid 'bad' pain

- To engage the Student:

    - Have a plan and process
    - Have goals and outcomes
    - Provide opportunities to learn
    - Keep teaching points to a minimum

In the following sections, we look at how to influence subconscious decision-making and modify instinctive and intuitive responses to movement challenges. We see that the subCM is particularly receptive to exercise when it is:

- Subconsciously controlled – encouraging instinctive and intuitive movement
- Task-orientated – making exercise relevant, useful and vital
- Reactive – using tools, obstacles and targets
- Intelligently varied – changing speed, distance and direction
- Emotional – managing thoughts and feelings

# TASK-ORIENTATED TRAINING

- Isolation Exercise
- Train Movement, Not Muscle
- Train Movement Tasks
- Relevance in Training
- Language

Conventional training is physiologically focused. The ‘Chest-Press’ works the pectoral muscles, the ‘Leg-Extension’ works the quadriceps and so on. Instructors target specific muscle groups or physiological systems in the hope that improvements in ‘general fitness’ supports subsequent performance.

To improve a client’s ability to jump or throw, a conventional approach might be to prescribe a Leg-Press or Chest-Press. A rugby player uses a rowing machine to build endurance, or Deadlift to develop power. The problem in this approach is that these conventional exercises bear little resemblance to the *functional tasks* they aim to support.

In function, the whole is greater than the sum of the parts. Muscles do not work in isolation, but in cooperative, synergistic teams, running in complex *kinetic chains* throughout the body. Functional performance is determined not by the size of muscles but how these muscles cooperate and coordinate. To enhance functional performance, functional trainers need to move away from general fitness and start focusing on task-specific coordination.

In this section we discuss how to engage the brain by making exercise ‘*task-orientated*’, learning to coordinate movement rather than build muscle.

## Isolation Exercise

*Isolation exercise* is popular. To isolate muscles, instructors impose strict guidelines on form and technique. During a Bicep Curl, for example, the client has to fix elbows against their side and restrict motion of the hips to eliminate momentum before curling a weight. The biceps are disconnected from their natural synergistic networks, robbed of the ability to take advantage of movement or momentum to overcome mechanical sticking points.

When we isolate muscles, they fatigue quickly. Repetitively loading muscles this way within a restricted range of motion ceates an overload that causes a rapid build up of lactic acid, the by-product of muscular work. Physiological fatigue overloads tissue, causing micro-trauma, which acts as a powerful stimulus for hypertrophic growth of individual muscle fibers. Lactic build-up is the side-effect of muscles unable to recover or share load.

Isolation exercise is a great way to ‘tone’ and build dense layers of aesthetically appealing muscle. But muscles working in isolation do not learn to communicate or cooperate. Isolation exercise develops ‘stupid’ muscle. Research suggests isolation exercise can even have a detrimental effect on performance. Investigating the impact of leg strength training on performance, Baratta et al. (1988) found that isolated knee-flexion exercises negatively impacted performance in terms of knee stability. Baretta concluded that the negative impact on performance was caused by the disruption of muscle synergies, undermining the cooperative action of muscle.

The key to functional performance lies not in developing large muscles but developing *task-specific coordination* – the ability to recruit muscles in complex synergies. To truly develop functional performance, muscles need to learn to work in complex synergistic teams.

## Train Movement, Not Muscle

Anatomists dissect muscles, labeling each one individually. Instructors have designed exercises to ‘isolate’ each of these individual muscles. The ‘Dumbbell Curl’, ‘Lateral Raise’ or ‘Tricep Extension’ are conventional gym exercises designed to work specific muscles.

To perform a Lateral Raise, a client would simply lift the arms up to the side to work the deltoid muscle. To emphasize other shoulder muscles, instructors might tweak the position of the hand or shoulder. Trainers can 'tweak' movement to bias certain muscle groups, but a client cannot activate individual muscles without co-activating that muscle's natural synergists.

The brain does not distinguish between individual muscles. As far as the brain is concerned, we do not have hamstrings or quadriceps. The motor system is designed to coordinate movement, not activate individual muscles. You can experience this for yourself. Try to activate your deltoid independently of the other synergistic rotator cuff muscles and you see it is impossible. We can intentionally flex the elbow, tilt the head or wriggle the toes, but we cannot isolate specific muscles. True isolation exercise does not exist. To design exercise in a way that the brain understands, we have to program *movement, not muscle*. But which movements should we focus on?

## Train Movement Tasks

Take the 'Lateral Raise', for example. A Lateral Raise is a movement with a particular form and technique. The Lateral Raise builds strength in shoulder muscles and develops coordination, but to what end? Does a Lateral Raise develop useful, task-specific strength and coordination?

The Lateral Raise takes little skill compared to, say, a javelin throw or the skill to kick a ball. The form and technique for the Lateral Raise can be mastered in a matter of moments, but this movement pattern has little or no functional relevance. The Lateral Raise bears little resemblance to anything we do in the real world. As a result, the form and technique for the Lateral Raise is soon forgotten as soon as we leave the gym. A Lateral Raise will build muscle, but there is little transferable benefit. To develop coordination, functional exercises have to be complex and skilled, and reflect the tasks and skills we rely on in daily life.

The human body is capable of an almost infinite number of different movements, postures and positions. Despite this, most of what we do is repetitive. We bend, lift, step, reach, push and pull repeatedly throughout any day. The skill with which we perform these fundamental movement patterns therefore has a large impact on how our body functions day to day.

For ease and efficiency, the brain stores pre-prepared plans or 'templates' for the most useful, relevant and vital functional tasks. In neuroscience, these movement templates are called motor programs. Motor programs are neurological blueprints – basic plans of action or schema for how to organize, synergize and integrate a specific movement pattern. Movement templates stipulate the relative timing of muscular contraction as well as the force those muscles produce. In other words, when muscles fire and how hard they fire.

Movement templates are stored within the subconscious (procedural or non-declarative) memory. Rather than designing each movement from scratch, the subCM simply downloads the relevant movement template and adapts it to match the specific needs of any situation or circumstance.

Movement templates reduce the computational load associated with moving, reducing the volume of calculations required to coordinate a specific movement task or skill. Superior motor templates theoretically produce more efficient and effective patterns of motion. In which case, functional training should focus on refining the *movement templates* for the most useful and relevant movement tasks.

Exercises like the Romanian Deadlift or Barbell Back Squat are regarded as '*functional*' because they involve using free weights rather than fixed resistance machines – they recruit large muscle groups and even resemble functional tasks like bending, lifting and sitting. The problem is, these exercises may not engage relevant movement templates.

Ask a novice to Deadlift and they likely have little notion of what you are asking them to do. Novices have no inbuilt template for performing a Deadlift. Instructors have to demonstrate the exercise and provide the relevant teaching points. As they learn, a novice constructs a new *movement template* for performing a Deadlift. With time, repetition and practice, this *template* becomes refined and ingrained. As that client's Deadlift *template* becomes more established, speed, fluidity and power improve. This can happen quickly and novices will often achieve rapid improvements in performance despite little physiological adaptation. In the early stages of training, adaptation is fundamentally *neurological, not physiological*.

Most gains in performance relating to training are neurological, not physiological. Neurological adaptations are largely specific, associated with the specific movement template we engage. To a large degree these neurological gains are non-transferable, having little or no benefit to unrelated movement patterns. A Leg-Press has little transferable benefit, therefore, to say running or jumping, because they engage entirely different motor templates.

Most of the gains in strength we experience with training relate to how we feel, consciously and subconsciously, about that specific task, in that specific situation, and our ability to coordinate within and between muscle and muscle chains. For neurological benefits to transfer, training has to engage the specific movement templates we intend to rely upon within function.

Is the 'Kettle-Bell Swing' functional? The subconscious movement template for the Kettle-Bell Swing is unrelated to those we rely on in function. We do not Deadlift shopping bags out of the car or Kettle-Bell Swing across a road. Whilst the idea that a Kettle-Bell Swing may be 'extra-functional' is in opposition to the current prevalent belief, when we consider how the brain works, we might reconsider how 'functional' these exercises actually are. To transfer to function, trainers have to *train movement tasks, not muscles*.

## Relevance in Training

Consider the tasks we all perform throughout each and every day – the tasks we perform hourly, daily or weekly, either at work, at home or in sport – the movements important for survival. Some of these movement tasks and skills will be relevant to everyone. Some will be relevant specifically to us because we play a certain sport or have a particular job. Some movement patterns are of particular importance to us because we have suffered an injury and that movement pattern now triggers pain or apprehension. We can place *relevant* movement patterns into one of five categories:

- Primary patterns – relevant to all
- Secondary pattern – relevant to some
- Travel patterns – relevant for locomotion
- Play patterns – relevant for sport performance
- Pain patterns – relevant for pain and injury

### Primary Movements – Relevant to All

*Primary movement patterns* (PMP) are the most funadamental movements patterns, performed countless times throughout the day. PMPs should form the basis of a functional training program. It is useful to generate your own list of PMPs. Think about what movements are fundamental for survival, movements that we repeat throughout each and every day. Primary movement patterns may include:

- Lifting
- Sitting
- Bending
- Steping (lunge)
- Twisting
- Pushing (push-up)

- Pulling (pull-up)
- Reaching
- Shifting*

(*The ability to *shift* weight, either from one foot to another or from one hip to another, is a fundamental movement skill that helps us control weight, balance and momentum).
Figure 4.1 illustrates some examples of primary movements – a lift, twist and reach.

**Figure 4.1** Primary Movements Form the Basis of a Functional Program.

We can think of PMPs as letters in an alphabet. From letters we can form words and then sentences, combining movements to create an infinitesimal number of different patterns and complex movement tasks and skills. We can break these complex tasks into a combination of PMPs that blend seemlessly. Imagine lifting trunks out of a car or tackling an opponent in a game of rugby. If we can improve a client's PMPs, a trainer can enhance the ability to perform more complex movement patterns. A functional trainer's key focus should be to improve the quality of a client's primary movement patterns.

## Secondary Movement Pattern (SMP) – Relevant to Some

Some movement patterns, whilst not being useful to everyone, are relevant to specific people. We call these *secondary movement patterns* (SMPs). What does your client do on a regular basis, at work, leisure or play? What activities do they enjoy? What sports do they partake in? This may reveal a series of SMPs that are specifically relevant to them and can be introduced into a functional training program.

- A boxer punches, bobs and weaves, hooks and uppercuts
- A tennis player uses a forehand, backhand, smash, lob, drop shot
- A footballer kicks, passes and shoots

## Travel Patterns – Relevant for Locomotion

When we 'travel', we propel ourselves from one place to another. *Travel patterns* (TP) are particularly relevant in sport (see Figure 4.2). There are many ways to *'travel'*, we can:

**Figure 4.2** Travel Patterns, Jump – Crawl – Sit Up.

- Walk
- Run
- Jump
- Skip
- Hop
- Crawl
- Step-up
- Sep-down
- Get-up (and down)
- Sit-up
- Turn (change direction)

TPs are particularly relevant to sport performance. Look at different sports and consider which travel patterns are specifically relevant for each.

Think about how many different ways you can travel from one side of a room to another? Name each with a single descriptive word that anyone would understand. Try performing each one in 3-dimensions – forwards, backwards and sideways. Perform each one from a different posture or position, or staying as low to the ground as possible, creating variation in height. Perform each one super slow, varying speed. You have created an instant database of new functional exercises. Functional training is easy and instant and takes little time or instruction to teach.

## Play Patterns – Relevant for Sport Performance

*Play* is an instinctive mode of learning. All animals intuitively play from an early age, using play to develop the skills they need to survive. *Play patterns* are so innate they are ingrained within the subconscious. Watch children play and observe what movements, tasks and skills they practice.

Play is intuitive, varied and emotional. Regardless of age, everyone loves to play. Play is a fantastic way to make exercise motivating. Play is analyzed in greater depth later in this text, but here is a basic list of play patterns:

- Gather
- Throw
- Catch
- Strike
- Avoid
- Follow
- Climb
- Grapple
- Kick

A functional trainer should incorporate Play patterns into training. Imagine balancing on one leg as we throw and catch a ball, punching boxing pads or playing tag. Play makes exercise enjoyable and instinctively drives balance, speed and fitness. With play, the only limit is your imagination.

## Pain Patterns – Relevant for Pain and Injury

Everyone understands *pain*. We have all had episodes of pain or injury. Clients often arrive with conditions that hamper performance and that cause '*antalgic*' patterns of movement – movement patterns that have become distorted or altered as a consequence of pain or injury. A client may tell you they have difficulty squatting, bending, climbing stairs, turning their head to reverse their car or putting their socks on. These are all a client's *Pain Patterns*.

Pain is a highly complex phenomena and is discussed in the second half of this book. In this section we discuss how pain does not originate from within damaged tissue but is created within the subconscious mind. Pain is a tool the subconscious mind uses to modify behavior and adapt movement to avoid 'threat'.

Pain patterns form the basis of a *functional rehabilitation program*. In the functional rehabilitation section of this book we discuss how movement can be used to manage and reduce pain.

A functional trainer should discard exercises that have little or no functional relevance and, instead, introduce a range of primary, secondary, travel, play and pain movement patterns. By asking clients to walk, run, jump, throw, kick and punch, exercises engage subconsciously ingrained movement templates and therefore generate gains in performance in a manner that should transfer to a client's daily life.

## Language

*Language* is an extremely important aspect of functional exercise design. Language is a gateway into the subconscious. Whilst it is popular for instructors to develop new and interesting exercises with catchy names and using new fangled exercise machines, this may not be the most functional strategy.

Creating exercises with fancy names is appealing and good for sales and marketing because the subconscious is drawn to things that are new. Marketing draws attention and promises results, but if we want to improve functional performance, we might want to re-think.

Even when exercise 'looks like function', as soon as we introduce jargon, we disconnect the exercise from familiar and subconsciously ingrained patterns of movement. Whilst it might be trendy to use the new abdominal crunch machines that 'tone' the abs and guarantee a wash-board stomach, will this new exercise improve my ability to sit up or get up?

To engage subconscious movement templates, remove jargon and keep exercise familiar. I apply the 'little old lady test of function'. If my grandma couldn't understand what I am talking about, then the exercise is probably not 'functional'. If I asked my grandma to step up, onto a step, she would know exactly what I meant. Her subconscious would download an ingrained motor program for stepping-up and, as long as she was confident the step was not too high, grandma would step up with little thought or consideration. Ask grandma to 'Romanian Deadlift' and she would look at me blankly and ask 'why ever would I do that?'

Exercise should be simple and self-explanatory. Much like a joke, if I have to explain it, it isn't quite right. The more we have to explain an exercise, the less functional it is because the less likely it is to engage a pre-established, ingrained movement template.

- Replace 'deadlift' with lift
- Replace 'press' for 'push' or 'reach'
- Replace 'row' for 'pull'

By eliminating jargon and by making exercise 'task-orientated' we encourage instinctive and intuitive patterns of movement. By making exercise subconscious controlled, we enhance performance with respect to speed, fluidity and power.

## Bringing It Together

Making training task-orientated involves prescribing Primary, Secondary, Travel, Play and Pain Patterns. Familiar movement patterns engage useful and relevant movement templates ingrained within the subconscious. Task-orientated training is far more likely to transfer into function. An FT should:

- Prescribe functional movement tasks relevant to the client
- Remove jargon and keep movement instinctive and intuitive
- Engage Primary, Secondary, Travel, Play and Pain Patterns

In the next section, we discuss how to make these movement patterns *reactive*.

# REACTIVE TRAINING

- Reactive Movement
- Attention
- Internal vs. External Focus of Attention
- External Focus Improves Performance
- Reactive Exercise Design
- Distance
- Emotional Drivers
- Visualization and Imagery
- Drive Learning
- Internal Drivers for Rehabilitation

In the last section, we discussed how to make exercise *task-orientated* and why this should increase transfer of training gains into function. By prescribing *movement tasks* rather than abstract exercises we engage ingrained *movement templates*. By developing movement templates, a functional trainer can develop *task-specific coordination* for improved speed, fluidity and power.

In function, we rarely think or plan what we are going to do. We *react* to the environment, the situation and circumstance, and the tasks we want to perform. Rather than being conscious or considered, *movement strategies* simple '*emerge*' from a subconscious reaction to where we are and what we are doing. Functional training should reflect the reactive nature of functional movement. In this section, we discuss how to make movement '*reactive*'.

## Reactive Movement

Imagine walking down the road. To what extent are you thinking about how to walk, where to go, which path to take, how to place your feet? To what extent do we really reflect on the obstacles in our path, the passers-by or oncoming cars?

In *function,* we rarely reflect on actions. We don't stop to think about how to pull weeds out of the garden or how to throw a ball. We certainly do not stop to check form and technique as we step, bend, lift, reach, push or pull. Most movement strategies are instinctive and intuitive *reactions* to where we are and what we are doing.

In sport, we react to moving targets, adjust behavior in reaction to opponents and *instinctively* and *intuitively* adapt tactics to score a goal or win a game. In sport, events transpire so quickly there is rarely time to reflect and correct decisions. Behaviors are not planned or scripted, they simply emerge in reaction to the situation and circumstance. As instinctual reactions improve, so does functional performance.

Functional training should reflect the reactive nature of functional movement. Instead of prescribing pre-fabricated and overly prescriptive exercises, functional training should incorporate relevant tools, obstacles and targets that trigger instinctive and intuitive reactions (see Figure 4.3).

**Figure 4.3** Reactive Training, Step and Touch Cone – delaying when the client is told which different color marker to move towards reduces time for decision making and encourages more instinctive and intuitive patterns of movement. By placing the markers further away we can increase difficulty.

By asking clients to reach towards a marker, catch a ball, strike a target or avoid moving objects, and by removing the opportunity to consciously reflect and correct movement, a functional trainer encourages patterns of coordination drawn from a powerful subconscious intellect.

Imagine a trainer moving a soft rubber pole through the air that a client has to avoid. The client should instinctively react – stepping, squatting, bending and shifting to avoid being touched. Reactive drills drive patterns of movement that are often far more complex and intricate than any exercise we could hope to design using conventional methods.

Rather than teaching or instruction, movement tasks should trigger specific movement reactions. The nature of these reactions should be defined by the different goals and objectives a trainer sets. A trainer can define the area in which a client can move and specify the position of the feet, goals, obstacles and targets. A trainer can develop skill and coordination by making tasks more challenging, reducing the time clients have to react, placing clients under pressure or adding competition.

## Attention

A conventional approach is to 'teach' clients the best way to perform a task or skill. The problem is that the conscious brain lacks the ability to effectively coordinate movement. To consciously coordinate, movement has to be slow, controlled, simple and pre-meditated. Functional movement is none of these. To understand why conscious control is ineffective we have to appreciate the impact '*attention*' has on performance.

To create coordinated movement the brain has to process vast quantities of sensory information. The computational load involved is extraordinary. To reduce computational load, the brain focuses and extracts the essential elements of any sensory picture. Only a mere fraction of what we 'sensed' passes onto conscious awareness to be perceived. A lack of conscious processing capacity means we are only able to focus attention on maybe two or three things at any single time. The brain has to constantly prioritize and select where to focus attention.

Attention is the act of selecting a point of focus. In any situation, the brain has to decide what information and what tasks are of greatest importance. Whilst we might assume focusing attention is a conscious process, that we decide where to look and whom to listen to for example, attention is actually largely influenced by the subconscious mind. In any situation, the subCM scans sensory images, selecting which fragments to pass onto conscious perception and on what to focus attention.

The process of *selective attention* is one mechanism the subconcious mind uses to structure the world we perceive. In the large part, the subconscious decides what we perceive and on what we focus. It takes great mental effort and concentration to redirect and change focus of attention.

## Internal Vs External Focus of Attention

Attention has a huge impact on functional performance. Too much or too little attention on the right or wrong areas can have a huge impact on the decisions we make and therefore how we perform. Changing our focus of attention can have a profound impact on performance by impacting decision-making.

Instructors, trainers and coaches can play an important role in directing a client's attention. A golf coach might ask a client to think about how to hold the club or how to shift weight as they swing the club. A running coach might ask a client to focus on how they are driving the arms or reaching with the legs. In the gym, a trainer can direct attention to certain aspects of an exercise, such as the contraction of muscle or the pattern of movement, form and technique. In some circles, this is referred to as *spotting* (see Figure 4.4). How a trainer or coach guides attention has a huge impact on performance.

Attention can be directed inwards or outwards. Shifting attention either onto the internal or


**Figure 4.4** Spotting – Giving clients directions on form and technique is popular in conventional training and is sometimes referred to as 'spotting'.

external environment can have very different effects. Shift focus of attention inside the body, onto proprioceptive information regarding how we are moving and towards form and technique, and we are said to have an *internal focus of attention*. Direct attention outwards, away from our own body and onto the external environment, and we have an *external focus of attention*. It is a common misconception in training that internal focus of attention improves performance.

If you have ever been taught an exercise like the Chest-Press you might have been asked to:

- 'Keep your feet flat and shoulder width apart'
- 'Keep the chest lifted with the back and shoulders relaxed'
- 'Keep the elbows and hands at shoulder level'
- 'Push forwards in a slow controlled manner, pausing at the end of the movement'
- 'Move back for two, hold for one, push out for three seconds'
- 'Breathe out on the way out, and in on the way back'

Alterations in form and technique are encouraged to both improve performance and reduce biomechanical stress and strain, making an exercise safer and more effective. But when we analyze the research we see that an *internal focus of attention* actually undermines performance.

- If professional goalkickers pay direct attention to kicking mechanics, performance deteriorates.
- Zachry et al. (2005) looked at the effect of attention on basketball 'free throw' performance. They asked one group to focus on the 'snapping' movement of their wrist during the follow-through, while a second group were asked to focus on the rear of the basketball hoop. Focus on the mechanics of movement was shown to degrade performance, resulting in less accuracy.

Similar effects are seen within exercise, where an *internal focus of attention* appears to increase the sense of effort required to perform an exercise and decrease efficiency.

- Zachry et al. (2005) also showed, using Electromyography (EMG) of the biceps brachii and triceps brachii muscles, that muscular force increased with an internal focus, suggesting reduced movement economy. An internal focus was attributed to increased 'noise' or variation in the motor system.
- Direct attention on bicep contraction performing a bicep curl increases effort measured using EMG, increasing work and sense of effort – but is that what we really want? In functional training the goal is to make movement easier and more efficient, not harder.

If the goal is to make muscles work harder or increase the sense of effort, then an internal focus is effective. Encouraging an internal focus is a popular strategy in body-building. Body-builders focus attention on muscle contraction to increase sense of effort and build tension within a specific muscle group. This may promote hypertrophy of those muscle groups, but if the goal is improved performance, then an internal focus is not helpful.

**CHOKING**

*In sport, many athletes attribute 'choking' to thinking too much. Under the pressure of competition, they pay too much attention to what they are doing. They shift attention inwards, creating an internal focus of attention. Now, skills that should be automatic become consciously controlled. The result can be devastating and can cause a complete collapse in functional performance. Chocking may be caused by overt attention on what should be subconscious processes. The goal in elite performance is to think less, relax, and trust your instincts and intuition.*

As soon as we shift attention internally, performance in terms of speed, fluidity and power deteriorates. Teaching points can be difficult to remember. The conscious mind (CM) has limited attention and asking clients to focus on more than one thing at a time divides their attention, distracting attention away from what is truly important.

The *constrained action hypothesis* suggests that an internal focus promotes a *conscious mode of coordination*. Conscious control constrains the motor system and inadvertently disrupts automatic control processes (Vance et al., 2004). Direct attention disrupts instinctive and instinctual decision-making. What should be automatic suddenly becomes *conscious* and *considered*, decreasing performance in terms of fluidity, speed and power (Wulf and Prinz, 2001).

## External Focus Improves Performance

An *external focus*, in which attention shifts onto objects and targets outside ourselves, is extremely beneficial to performance. Imagine throwing a ball into a bucket. Rather than thinking about how to hold the ball, the position of the arm or the tension within the shoulder, an external focus of attention involves just aiming at the bucket and throwing towards it. The bucket acts as an 'external driver'.

Research suggests that by focusing on what we are doing, rather than how we are doing it, performance improves with respect to fluidity, speed and power. In her systematic review of literature, Wulf (2014) found that an external focus improves efficiency for functional tasks such as running, swimming, throwing and rowing. The benefit of external focus is even greater for more complex skills like kicking, juggling and gymnastic skills, and has even been shown to be of benefit in sports like golf and tennis.

An external focus improves biomotor skills, such as balance, accuracy, efficiency and endurance, across different tasks, independent of skill level or age. The more complex or challenging the task, the greater the advantage of an external focus. One study of novice golfers hitting driving tee shots split players into two groups. One group focused on shifting weight to the forward foot (internal focus), whereas the other group focused on pushing against the ground with that foot (external focus). It sounds like a fine distinction, but the second group performed better in a variety of outcome measures, including greater distance on the ball.

Try a standing long-jump, focusing on a good knee bend, strong arm action and powerful calf push (internal focus of attention). Note how far you jump and mark the distance using a marker or cone. Now repeat the experiment, but this time just try and jump past the original marker (external focus of attention). Did you jump further? Most people benefit from aiming at external targets like a cone or marker.

I used to train children to long-jump in schools. Rather than complex descriptions of how to jump, I just allowed them to build small sandcastles, which they then had to try and squash. The use of an 'external driver' made the lesson far more fun and almost always improved performance.

External targets encourage an *outcome focus*, rather than a *process focus*. The more outcome-focused we become, the more likely we are to shift towards a subconscious mode of coordination. The subconscious mind (subCM) has a far greater capacity to process information. Engaging subconscious control encourages instinctive and intuitive movement strategies that enhance performance with respect to fluidity, speed and power.

External drivers encourage self-organizing movement in which movement strategies emerge from an instinctive and intuitive reaction to:

- What we want to achieve – task
- Where we are – environment
- What we are capable of – capacity
- How we feel – emotion

Asking clients to focus attention outwards rather than inwards can have a profound effect on performance. Rather than giving instructions on form and technique, asking clients to maintain 'neutral spine', 'set the scapula' or 'engage the core', a functional trainer should manipulate external drivers to trigger functional movement strategies.

## Reactive Exercise Design

Instead of providing *process feedback* on form and technique, an FT should design *reactive drills*, driving movement using a client's immediate environment to trigger instinctive and intuitive movement reactions. Reactive drills reduce the emphasis on the instructor, minimizing the need for complex explanations and teaching points, and making reactive drills simple and time efficient. Reactive drills are simple and easy to create using a combination of:

- Task Drivers
- Body Drivers
- Environmental Drivers

### Task Drivers

The first simple step to create a reactive drill is to replace exercises like a 'Dumbbell Press' or 'Lat-Pulldown' with *functional tasks*. Whilst conventional exercises are laden with instructions and teaching points, clients intuitively know how to push, pull, twist or reach. Prescribing *movement tasks*, in which a client has to instinctively and intuitively react, reduces reliance on the trainer and minimizes long-winded instructions regarding form and technique.

The drawback of task-orientated exercise is a client still tends to pre-plan and prepare. They will consciously consider what they are going to do and how they will move. Asked to sit, step or walk, a client will still stop and consider how they will move. Conscious consideration makes movement slower, less powerful and less fluid. Asked to walk, sit or reach, a client will still ask 'walk where?', 'sit where?' 'and reach towards what?' In functional training, we would prefer to make movement more 'externally driven'.

### Body Drivers

In conventional training, instructors adjust a client's posture and position, educating them on where they should position their spine, feet, knees, shoulders and so on. It is not uncommon for instructors to instruct clients to 'set their scapula' as they exercise, or to 'find neutral spine'. How often do we reflect on the position of the shoulder blades or spine during normal daily life?

In function, we rarely consider where to place the body – we simply '*react*' based on where we are and the task we hope to achieve. In function, there is rarely any conscious thought or consideration. To walk somewhere, we simply fix the eyes on where we want to go and start walking. There is very little consideration of how to hold the body, which muscles to contract or in what order. Functional trainers need to limit as much as possible an internal focus of attention on obscure body parts and find different ways of driving movement that are more likely to enhance performance.

Look at the Homunculus Man and we see that certain areas of the body have a larger representation in the brain. The eyes, hands and feet are the largest areas in the sensory Homunculus. The shape of the sensory Homonculus suggests the brain dedicates more time and energy to processing information from these areas of the body. It also suggests that we receive greater amounts of sensory feedback from these areas during movement. The sensory Homunculus seems to hint at which areas of the body truly 'drive' movement.

The eyes, hands and feet are natural movement drivers. Movement tends to be triggered from one or all three of these areas of the body. Usually the eyes initiate movement, we look at what or where we want to go. The feet then move to travel to where we want to go and orientate to maintain balance, keeping our base of support underneath our center of gravity. As we approach an object, the hands then reach, grasp, push or pull. Functional exercise should drive movement in a similar manner.

### Eye Drivers

The eyes initiate and accentuate almost all movement. Wherever we look the body tends to follow. Postural muscles respond reflexively to prepare for movement in the same direction as vision, and the body will orientate itself to facilitate motion in that direction.

### Hand Drivers

Most upper body movements are initiated from the hands. First we look, then we reach as we push, pull, climb, throw or strike. The start and end position we refer to as the *handprint*.

### Foot Drivers

Lower body movements are initiated from movements of the foot when we step, climb or jump. The start and end position are referred to as the *footprint*.

In functional training, we can create countless exercises by driving movement from the eyes, hands and feet. As we squat, for example, we can drive movement from the hands, reaching in different directions. Try squatting and then turning the hands in a circle, like a large steering wheel. Feel how it changes the weight distribution on each foot. Try squatting again but this time, as you lower your weight, look in different directions and feel how this changes movement. Try squatting, but prior to each squat make a small step in different directions to alter footprint. Feel how this alters movement. These are very simple examples of driving movement in different ways using the eyes, feet and hands.

The same principles can apply with other parts of the body, like the hips, knees, elbows etc. We can shift bodyweight from the hips, or even drive motion using the knees or any other body part for that matter. Imagine performing a lunge, stepping forwards, but vary each rep by driving the knee in different directions, shifting the hips left and right or driving an elbow behind you as you lunge. Driving movement from these different body parts is less instinctive and intuitive and tends to encourage a more internal focus of attention, but can create some interesting and unusual patterns of movement.

The eyes, hands and feet are key movement drivers, while other areas are less instinctive and intuitive movement drivers. It is less natural to drive movement from the spine or shoulder blades, for example. Asking clients to focus on these areas tends to encourage an internal focus and undermines performance in terms of fluidity, speed and power. It is far better to drive movement of the spine or shoulder using other, more functional body drivers.

Rather than performing a standard hip-flexor stretch, for example, it would be more effective to 'drive' hip-extension by asking a client to step-backwards while at the same time reaching the arms upwards towards the ceiling (see Figure 4.5). Driving the arms upwards prevents the trunk from bending forwards. This task-orientated movement drives a powerful extension of the hip, stretching the hip-flexor muscles.

**Figure 4.5** Functional Hip Flexor Stretch – see here how a hip flexor stretch has been 'externally driven' by stepping backwards and reaching overhead at the same time.

By driving movement from the eyes, hands or feet, we take advantage of powerful subconscious reflexes that support power, mobility and flexibility. Rather than providing instructions and teaching points, use 'body drivers' as a more instinctive and intuitive way of triggering movement.

## Environmental Drivers

Task and body drivers still encourage a client to 'consider' what they are about to do. An internal focus undermines performance with regards to speed, fluidity and power. Rather than asking a client to *act,* it is far more functional to ask a client to react.

In function, we tend to react instinctively to the environment, climbing steps, reaching towards shelves, sitting in chairs. Functional movement is almost always an instinctive and intuitive reaction to the external environment – the tools, obstacles and targets we naturally interact with. Using *environmental drivers* is the easiest and most effective way of triggering functional movement in a way that improves performance. An FT can manipulate a client's environment, driving movement patterns using a combination of different:

- Tools – implements we are holding and manipulating
- Obstacles – objects acting as barriers or impediments to movement
- Targets – distance markers or physical goals

### Tools

Tools can be thought of as objects we hold or manipulate. This may be held resistance like Dumbbells, Barbells and cable pulley systems, ViPRs, Suspension-trainers, medicine balls, bands, sandbags or even rocks. The nature of the tool drives the type of motion you trigger. The most effective strategy is to introduce tools the client interacts with in normal daily life, making movement useful and relevant.

### Obstacles

Obstacles include objects such as steps, blocks, hurdles, ladders or any other object that a client has to move over, around, through or under. Imagine how much more interesting cardiovascular exercise becomes when we get off treadmills and start negotiating obstacle courses. Different obstacles can help create new and interesting movement patterns.

### Targets

Targets include markers that clients orientate themselves around or move towards. A trainer might use cones, pads, balls and balloons, amongst other things, to act as targets. Boxing is a classic example of how the brain instinctively reacts to moving targets. Any boxer will understand how much more fun it is to respond to targets rather than running on a treadmill.

Environmental drivers provide a fantastic opportunity to create externally focused, reactive drills. Tools, obstacles and targets help the client react rather than consciously consider how they are moving and will lead to more instinctive and intuitive patterns of movement (see Figure 4.6).

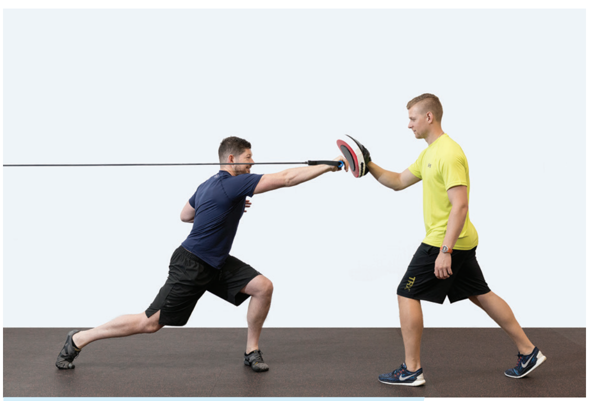

**Figure 4.6** Tools, Obstacles and Targets.

Imagine asking a client to climb (task driver) a set of stairs (obstacle) holding onto a heavy Kettle-Bell (tool driver). This interesting and challenging movement task is exceedingly simple and straightforward, but totally different from how we prescribe conventional exercise. Rather than following a series of manufactured instructions, the client simply reacts to the task and environment.

Core exercise is popular to tone stomach muscles. A common exercise is the crunch, a flexion of the spine from a supine position. A crunch looks nothing like any movement we perform on a daily basis, but clients like the lactic burn they experience in the stomach. Trainers teach a crunch, providing a range of teaching points. If we want to increase speed, fluidity and power it would be far better to ask the client to sit up from a lying position.

A functional trainer would drive a sit-up by asking a supine client to sit up and reach towards a target held above them. Even more power could be generated by asking the client to strike the target. A sit-up is a familiar functional task, useful and relevant to daily life. It needs no further explanation.

There are several other considerations when prescribing reactive training, including distance and emotion.

## Distance

Targets close to us tend to encourage a more internal focus of attention, whereas targets further away drive a more external focus of attention. Imagine a continuum, internal drivers at one end and external drivers at the other. The more we pay attention inwards, the slower and less fluid movement becomes, and the more external our focus into the distance, the more fluid movement becomes. To improve speed, fluidity and power as a client ‘reaches’ holding a band or cable, I would ask them to reach ‘into the distance’, towards a target on the other side of the room.

## Emotional Drivers

Many of the exercise programs we see people performing are boring and repetitive. *Emotion* is often overlooked in conventional gym training, even though thoughts and emotions have a powerful impact on movement. The subCM is particularly sensitive to changes in emotional state and adapts movement in response to how we *feel*. Feeling fearful and apprehensive, safe and secure, bored or exhilarated, cooperative or competitive, these emotions all profoundly impact movement behavior and performance.

There are many ways to inject emotion into movement – adapting the task, the language we use or the environment in which we train, for example. A functional trainer can reassure a client who feels nervous, introduce game-play or introduce targets, goals and objectives for clients who enjoy competition, play music to alter mood and galvanize movement. There are various ways to trigger the desired emotional response that impact performance.

## Visualization and Imagery

Creating an appropriate training environment can be challenging. We do not always have the space, time and equipment we want. But consider, the subCM does not distinguish real from imagined. Imagining a target in the distance can have a very similar impact to a real target, in terms of movement behavior. We do not always need actual physical objects to act as external drivers. To help drive movement and emotion a functional trainer can encourage a client to envisage different contexts, situations and environments. Visualization can have a powerful impact on performance. We can:

- Visualize performing certain movements – task driver
- Imagine objects to reach towards – environmental driver
- Imagine stressful situations – emotional driver

## Drive Learning

When we learn a new skill, it is commonplace for a trainer or coach to provide various instructions and teaching points, such as advice on the best way to ‘lift’, for example. Teaching points make the client shift attention inwards onto what they are doing and how they are feeling. An internal focus of attention not only makes movement less fluid, but instructions and teaching points rarely materialize within function.

Tuition is far too simple to be relevant within complex and varied functional movement. To emerge within function, learning has to influence instinctive and intuitive responses. A deeper understanding is best achieved using an explorative approach in which clients discover solutions to complex functional tasks and challenges.

An *external focus of attention* supports learning by directing attention onto the outcome of movement as opposed to the movement itself (Wulf, 2014). *Process feedback* should be kept to a minimum. Rather, a trainer should provide quality *outcome feedback*. To learn to serve a tennis ball, rather than providing teaching points, a coach might place markers on the other side of the net, asking a player to hit the target. A coach might provide hints and tips, like to throw the ball into the air, but teaching points should be kept to a minimum to allow the learner the freedom to explore.

Form and technique cues (i.e. internal drivers) can be useful in the early stages of learning, but be aware that too many instructions restrict exploration and innovation and therefore hinder learning. No more than two or three cues should be used at any time. Any more and a trainer runs the risk of overloading attention, hampering performance and restricting. For optimal results in terms of learning and performance, provide one or two hints or tips, then restore a client’s external focus on tools, obstacles and targets.

## Internal Drivers for Rehabilitation

EMG measurements of muscle activity have shown that internal focus on specific muscle increases the recruitment of those muscles. Bodybuilders use direct attention to increase recruitment, creating hypertrophy and inducing fatigue. In functional rehabilitation, an internal focus may be an effective strategy for re-activating or strengthening weak, atrophied or injured muscle. A trainer might focus a client's attention onto gluteal muscles to support stability of the hip, for example.

A trainer should still be aware that an internal focus hampers performance with respect to speed, fluidity and power. Whilst an internal focus may be useful to 'activate' a muscle prior to movement, the client should always follow that rehabilitation exercise with an external focused functional exercise. In the next section of this book, we look at how to structure this rehabilitation process.

## Bringing It Together

To encourage instinctive and intuitive patterns of movement for faster and more flowing patterns of movement, a trainer should not provide too many internal cues but should ask clients to react to external tools, obstacles and targets. To create reactive training, an FT should:

- Cue using external drivers
- Encourage an external focus of attention to promote instinctive and intuitive patterns of movement
- Use internal drivers sparingly in the early stages of learning or in rehabilitation
- Drive movement using different parts of the body, such as the eyes, feet, hands, hips and elbows
- Drive movement using tools, obstacles and targets
- Encourage clients to aim for targets in the distance – imagined or real

In the next section, we discuss the importance of *intelligent variation* in functional training.

# INTELLIGENT VARIATION

- Linear Motion
- Task, Individual and Environmental Variation
- Adaptability, Redundancy and Recovery
- Task Vs. Outcome Variability
- Variation and Learning
- Neurological Variation
- Intelligent Variation

By making exercise *task-orientated* and *reactive*, we encourage the *subconscious control* of movement, triggering instinctive and intuitive patterns of motion for greater speed, power and efficiency.

In this section, we discuss the concept of '*intelligent variation*' – the idea that the world is complex and varied. To be 'functional', exercise has to reflect the complex and varied nature of functional movement.

We discuss how functional training should not only be progressed using sets, reps and load, but through the systematic variation of position, posture, speed, distance and direction of movement.

## Linear Motion

Prehistoric man was well adapted to survive in challenging conditions, scaling mountains, climbing trees, negotiating rivers, traversing forests, jumping over ditches and swimming lakes to forage and find food. By comparison, modern life is comfortable and conveniant. Most of us sit at work, drive home and watch TV, sit on the sofa as food is delivered to the door. The floors are paved, we have shoes to walk in, chairs to sit on, cars to take us from one place to another. Life is easy.

Technological advancements have systematically reduced the need to move. The result is that people are becoming progressively sick and slow. Lack of movement is a key factor in a modern epidemic of obesity, ill health and chronic disease. The comforts of modern life have made the average person rigid, weak and prone to pain and injury.

Modern gyms are meant to be places to maintain 'health and fitness'. Gyms are actually designed to help people 'tone-up' and lose weight. Most gyms are filled full of expensive gym equipment, designed to burn calories and tone muscle – sterile and designed for comfort and convenience. The floors are even; equipment is safe and supported. Exercises like the chest press, mid-row and leg extension drive movement in one direction, usually forwards and back, with each repetition being much the same as the last. Even if we train in a place like this, our movement diet is still stale and repetitive.

In conventional training we develop strength in a very limited number of different ways. On an even surface, with feet parallel and spine in neutral with a balanced bar I can lift a certain weight, but what weight can I lift when my feet are twisted, when the spine is rotated and the weight we lift is awkward and unusual? Is it a surprise we rarely injure ourselves in the gym but often have problems in function? We should not 'lift' not just one way, but in hundreds of different ways.

Conventional training is a poor substitute for functional movement. Most clients look aghast if you ask them to run, jump, crawl, spin, and twist. Most people still do not have any sort of 'play' in their daily routine. The average person is unprepared to bend and stretch in different directions, at different speeds, or from different postures and positions. People are ill-adapted to cope with functional *variation*. To reverse this decline we have to re-introduce *intelligent variation*.

## Task, Individual and Environmental Variation

In healthy life, everything is *varied*. Walk in the woods and we climb over branches, up hills and through streams. The feet have to adapt to uneven ground, branches and mud. We might walk, jump, skip or hop, move quickly, slowly or change direction. In function we have to lift, reach, push, pull, throw or catch in lots of different directions and lots of interesting ways – *variation is everywhere*.

Functional variation means that each and every time we move, we do so differently. 'Lift' and we constantly vary the position of the feet, hips and knees – the spine can be twisted and we have to lift weights on uneven surfaces, at different heights, funny angles and unusual positions. *Task* and *environmental variation* mean that posture and position always vary.

No matter how similar two movement patterns appear, they are never exactly the same. If we ask the same person to perform the same task twice, there are always slight variations. Research shows that even as we walk, one stride is always minutely different from the next (Danion et al., 2003). A builder never lays a brick the same way twice. Variation is often imperceptible but never insignificant.

The body is anatomically, physiologically and neurologically adapted to cope with variation. Just look at the foot and ankle with its 26 bones, 33 joints and over 100 muscles, tendons and ligaments, or the spine with its 33 vertebrae and over 90 joints – the body is engineered to move. We are not designed to be rigid and immobile. Varied movement is essential for the health of each and every one of these joints.

The combined motion at each joint means we can move in literally thousands of different ways. 'Vari-ability' is essential to cope with the infinite number of different tasks and environments we have to be able to perform within function. Functional training needs to reflect the need to lift in varied ways. Whilst the average gym program might include a 'Squat', 'Deadlift' and 'Romanian Deadlift', these are just three different types of lift when, in function, we have to be able to lift in literally millions of different ways. The gap in variation between training and function is huge. Replicating the degree of variation seen within function is an extraordinary challenge for a functional trainer.

Each and every person also varies. We are all built differently (*structural variation*), have different levels of fitness (*physiological variation*) and think and behave differently (*behavioral variation*). Some people are naturally more flexible, others have better endurance, some are stronger or faster (*performance parameters*). The ability to bend, reach and lift varies from person to person (*functional capacity*). Variation is extremely normal and healthy.

'Vari-ability' has strategic benefit within a group or 'pack'. If we are to think of prehistoric man, having some members of a group better suited to foraging, others who could run for long periods to tire out prey and still others to sprint to catch that prey would be beneficial. A group with varied skills and abilities is more likely to survive and overcome challenges. Each member of the group can contribute in different ways and fulfill different functions.

Variation in structure and function means, '*what works for one, may not work for another*'. An effective movement strategy for one person may not be effective for another. A deep squat might be easy for a young child but seemingly impossible for an elderly adult. If we are all different, should we be prescribing the same exercise for everyone? How can we define perfect form and technique when we are all functionally different? Can we say that a certain *form* and *technique* is ideal for everyone? We are all different, so shouldn't training also be individualized and personalized?

## Adaptability, Redundancy and Recovery

Form and technique are regarded as the cornerstone of conventional training. Clients are taught how to lift and bend, but also to 'Bench-Press' and 'Calf-Raise'. Conventional thinking applies biomechanical principles that suggest variation is wrong, and in some cases dangerous. Deviation from perfect form and technique is discouraged – we are told to keep the knees and feet in line, the spine straight (no matter how impossible this is), the shoulders square. Individual variation is rejected as error. A 'functional' perspective is very different.

Far from being dysfunctional and problematic, 'vari-ability' is valued. It is good to be different. The ability to be varied delivers huge advantages, namely:

- Adaptability
- Redundancy
- Recovery

## Adaptability

Tasks and environments vary tremendously. We have to adapt to reach onto a high shelf, lift awkward boxes, walk over treacherous terrain. The body has to crouch, bend, balance, shift and twist in many different directions and in lots of unusual and interesting ways. *Adaptability* is the ability to '*adapt*' movement in reaction to different tasks and environments. Adaptability is not improved through simple repetition.

## Redundancy

*Redundancy* refers to the benefit of being able to find more than one soluation to a movement problem and the ability to perform the same task in many different ways. Fatigue, injury, obstacles and obstructions can all hamper performance. Functional performance relies on the ability to *adapt* and *react*, finding different solutions to the same problem. As Albert Einstein said, 'it is not the strongest of species that survives, nor the most intelligent; it is the one most adaptable to change'.

## Recovery

One of the key advantages of adaptability and redundancy is the ability to avoid fatigue. Perform a repetitive functional task, be it walking, running, bending or lifting, and if we only ever perform that task in the same way, tissues exposed to repetitive stress quickly fatigue. In conventional training, instructors ensure repetitive stress to overload specific tissues to trigger physiological adaptation. Strict form and technique precipitate that dreadful lactic burn associated with isolated exercise.

In function, the ability to vary movement means tissues can share work and delay fatigue. The body subconsciously shifts between different postures, positions and movement stratagies to delay the onset of fatigue. This is why 3 sets of 10 reps of 'Dead-Lifts' in the gym can be exhausting, but you can pull weeds out of the garden for hours on end. Variation supports endurance by allowing tissues to share, rest and recover.

Repetitive strain and overuse injuries arise from the gradual fatigue, overload and breakdown of tissue arising from 'un-varied' movement. Repetitive strain is commonplace in sport, where movement patterns are repeated over and over. Baseball players typically overload shoulders from throwing, golfers strain their back from repetitively swinging a golf club, cricketers blow out knees from repetitively landing hard on their front leg. Repetitive strain can be avoided by introducing variation.

As a functional trainer, we should enhance a client's 'vari-ability', improving their ability to adapt, react and recover. In doing so, we not only improve performance but also make clients more resilient and less susceptible to fatigue, pain and injury.

# Task vs. Outcome Variability

Athletes strive for consistency. Basketball players want to hit their free-throws, we want to get treble-20 in darts or bowl a consistent line and length. In sport, being consistent is highly cherished and athletes who can achieve consistency are handsomely rewarded. It pays to be consistent.

You would think that being consistent relies on perfect form and technique. We assume athletes drill over hours and hours to perfect their technique. But look more closely at how athletes and elite performers achieve consistency, and we see that form and technique is not all important. Consistent *performance* is not achieved through consistent *process*.

The famous study by Bernstein in the 1930s looked at blacksmiths moulding steel. Bernstein was interested in how blacksmiths were able to strike the same point over and over again. Bernstein plotted the trajectory of each hammer swing on film, expecting the path of each swing to be consistent. Bernstein found that the path of the hammer was actually highly variable. Expert blacksmiths displayed 'repetition without repetition' (Latash, 2012). The blacksmiths were striking the same point over and over, but each swing varied and every strike was different.

In another study, Arutyunyan et al. (1969) compared expert and novice pistol-shooters. As we might expect, expert marksmen hit the target more frequently. We might expect they achieved consistency with more perfect technique and that skilled shooters would be highly consistent in how they held the gun. But Arutyunyan found this was not the case. Expert shooters varied more in terms of the position of the shoulder, elbow and wrist each time they shot. Whilst the outcome of each shot was more consistent, the techniques employed to shoot were more variable than novices.

To achieve consistent outcomes, experts are more variable. We can refer to the output of an action as the '*performance outcome*'. More consistent outcomes could be referred to as *low outcome variability*. Skilled shooters hit a target (high performance outcome) more consistently (low outcome variability). 'How' an athlete performs a task could be referred to as their 'process'. It seems low outcome variability and high outcome performance is associated with *high process variability*. Skilled performers get from A to B in a very accurate manner, but the way they get from A to B can vary tremendously.

## Definitions

**Outcome variability –** uniformity in outcome of performance

**Process variability –** uniformity in method or manner of performance

Skilled performers find many different ways to be consistent. They are highly adaptable, able to vary movement and modify reactions moment to moment. As Glasgow et al. (2013) states, 'the ability to effectively modify responses under a broad spectrum of conditions is central to effective sporting performance and to long-term health outcomes'. Broadly speaking, the ability of humans to adapt is what makes us stand out.

Conventional thinking would have us believe that functional performance relies on ideal form and technique, but research suggests this is not the case. Functional performance relies, not on consistent process, but on high process variability – the ability to find a number of different solutions and strategies to solve a problem. This is why Michael Jordan practiced jump shots, making 1000 baskets a day, but shooting from ten different positions on the court.

Variability lies at the heart of functional performance – the ability to do something well, but in many different ways and in many different situations and circumstances. If you have ever played golf you understand that practicing on the driving range is very different from playing a game. In golf, the ground is uneven and feet sit at a different height relative to the ball. We tend to practice in ideal conditions but have to adapt skills to *task* and *environmental variations*, playing shots from varying lies and at different angles. As Bosch (2015) states, 'a key function is the ability of an organism to adapt to the greatly changing demands of the environment'. The better we adapt and react, the better we perform.

To enhance functional performance, a functional trainer needs to develop movement vari-ability, helping clients achieve the same task in different ways, from different postures and positions, at different speeds and directions, under varying loads. Functional performance relies on '*intelligent variation*'.

## Variation and Learning

Variation is essential for learning. Novel stimuli draw attention, with the brain quickly switching off from repetitive stimuli. Michael Merzenich et al. (2013), one of the pioneering researchers into neuroplasticity, believes that 'stereotypy is the enemy', that the brain is best exercised with a variety of challenges. Merzenich explains that it is preferable to 'move to a point in space in 100 different speeds in 100 different ways … rather than to move 200 times in the same way to get to that point in space.'

Behavioral and perceptual rigidity is the enemy of learning. If we always think and behave in the same way, closing ourselves off to new experiences, we potentially miss more effective strategies. We need to exercise the brain in a variety of different ways. Skilled repetition with variation coupled with outcome feedback is the key to learning. To understand the relationship between variability and learning, we can place learners into one of four categories:

1. Variable low skill (VLS)
2. Consistent high skill (CHS)
3. Variable high skill (VHS)
4. Consistent low skill (CLS)

### Variable Low Skill (VLS) Performers

Take an individual who is learning to play tennis. A beginner might have an *inconsistent* forehand. Shots fly in various directions, without control. This player has *high outcome variability* – sometimes the ball goes in, other times not. A beginner's technique also varies. How they place their feet, hold the racket, select shots, and their timing and control all vary from one shot to the next. Performance is unskilled and chaotic. We wouild describe this player as having *high process variability*. This athlete is a *variable, low skill (VLS) performer.*

*Variability* is essential at the early stage of learning. Chaotic motion allows a beginner to evaluate a range of different movement strategies. Using feedback, the beginner can learn which strategies are most effective. With time, practice and reinforcement, effective strategies gradually become ingrained. New movement templates are constructed within the subconscious that act as a blueprint for how to perform each tennis stroke. Some tuition is useful in this early stage.

Coaching based on sound biomechanical principles can inform the individual regarding what strategies have been useful for others, but a coach should be careful that instruction is not overly rigid for fear of interfering with the learner's ability to explore and experiment. Remember, what works for one, may not work for others.

### Consistent High Skill (CHS) Performers

With practice, skill develops. Movement templates (aka motor programs) become patterned and ingrained. Skills and movement patterns 'chunk' together and as they do movment becomes more fluid. Performance becomes more consistent, process and outcome variability decrease. *Consistent high skill (CHS) performers* have mastered basic technique, but lack the ability to adapt skills to different situations and circumstances.

A CHS tennis player is able to return shots when the ball is coming at a consistent and familiar speed, height and angle, but as *task variation* increases and the ball approaches at a faster rate, at different heights and angles, skill breaks down. CHS performers lack the ability to adapt movement templates, and therefore technique, to complex variation.

## Variable High Skill (VHS) Performers

To improve, a CHS performer has to develop *adaptability*. Elite athletes can adapt to varied and complex challenges. In the case of a tennis player, elite athletes are able to return balls coming at faster speeds, at different heights and unusual angles. Elite tennis players can vary shot selection and adapt strokes whilst still maintaining accuracy and precision. These elite performers are classified as *variably, high skill (VHS) performers*.

VHS performers demonstrate greater levels of process variability – the ability to maintain consistent outcomes, applying a variety of different strategies. VHS performers learn to adapt and react akills to various situations and circumstances, a process that takes time and experience, and cannot be taught.

## Consistent Low Skill (CLS) Performers

There is a fourth group, *consistent low skill (CLS) performers*, who are so named because they have developed a consistent, but poor, form and technique. A CLS performer has practiced poor technique, making movement patterns more ingrained and consistent. Consistency affords a modicum of improved performance, but form and technique remain fundamentally flawed.

It can take a great deal of time and effort to 're-train' a CLS performer. They have to literally unlearn what they have learnt and start again. CLS performers can often be the hardest to coach because they have to 'unlearn' previously ingrained patterns of movement. Movement templates have to be broken down. In regressing movement strategies, performance often gets worse before it gets better.

A trainer should consider at what stage of learning an athlete or client is at and adapt instruction accordingly, moderating the level of tuition, feedback and support to match the stage of learning. The more competent the client, the less instruction or guidance should be provided.

## Neurological Variation

The nervous system is wired for *variation*. The subconscious is always on the look-out for what is novel or new. The subCM looks to preserve *homeostasis* and *survival*, and any sudden change in the environment or alteration in the immediate situation or circumstance is regarded as a potential source of *threat* to be evaluated.

The subCM prioritizes novel sensory information over old information, directing attention to anything that is distinctive or new. You might have watched a spy movie in which the villain is always able to spot a victim who runs through a crowd. The subCM is geared to identify what is different or changing. To remain anonymous, spies try to blend in and act like everyone else.

### LEARNING TO PLAY GOLF

*I learned to play golf. I never had coaching and, as a result, my swing was biomechanically flawed – my form and technique was fundamentally unsound. I never realized how bad I was until someone filmed me. I had practiced poor technique for years, making my swing more consistent. I always hit the ball left to right, and in 18 hole I would often 'lose my swing', along with two or three balls. I got better, but always struggled to string 18 holes of good golf together and struggled to adapt when conditions were not perfect. I realized how much work it would take to reconstruct my swing and subsequently gave up golf.*

The subCM downgrades the importance of sensory feedback that remains constant and unchanging. We become less aware of sensations the longer we experience them. We get used to strange smells the longer we are around them. This is why it is easy to put too much aftershave on. We are totally unaware whilst others can be overpowered by the strong odor. We quickly get used to the noises outside our own house but can be kept awake by the unusual sounds when we stay away from home. The subCM quickly downgrades familiar sensory information, classifying it as trivial and unimportant.

The subCM continually scans for what is new or potentially threatening. A change in the surface we walk on, a new person appearing within vision, a change in temperature – these could all be potential threats. Sensory information is processed, interpreted and evaluated before the subconscious formulates an appropriate behavioral response.

When threatened, the subconscious heightens sensory acuity, activating *protective neurological reflexes*, which are designed to prevent injury and avoid harm. This is why functional performance deteriorates in unfamiliar situations and settings. It is why some athletes perform badly in big games. They fail to adapt to unfamiliar situations and pressure causes them to 'choke'. Rather than acting instinctively, emotional stress and pressures cause an inward reflection on what they are doing that hampers performance. Big game players feel less threatened by pressured situations and therefore maintain performance, trusting instincts they have honed over countless hours of practice.

Rather than training in a familiar way without stress, training should desensitize clients to novel and stressful situations, inoculating them against novelty, stress and pressure.

## Expanding Movement Vocabulary

Functional training needs to reflect the variation inherent in *functional movement*. It is not sufficient to prescribe a limited number of exercises because individuals need strength within many different movement patterns and in many different situations and circumstances.

Todd Hargrove, a Feldenkrais practitioner, describes movement as a form of language. Basic movement patterns like sit, squat, bend, reach, twist, push and pull, are letters or simple words that can be combined to form complex sentences. Whilst the English language has over 170,000 words, the average person uses only 600 different words each day. Movement is much the same.

In modern society, the movement behaviors of the average person are extremely limited. We drive to work, sit at a desk, relax on the sofa and watch TV. The average adult does not move nearly enough. Whilst conventional advice is to walk 10,000 steps per day, we should be moving 10,000 different ways, each day and every day. To keep healthy, explore the body's ability to move.

Try this simple task. Stand on one leg and draw a circle with the other toe around you on the ground. How large is this circle? Imagine drawing that circle with hands and feet in all directions around you, a three-dimensional movement bubble, if you like. Imagine if we could improve movement and expand that movement bubble. Now consider that we can move within the bubble in various different directions and speeds. The possibilities for movement become boundless. Functional training should expand a client's movement bubble, developing flexibility, mobility, strength and stability to increase their potential for movement.

## Intelligent Variation

STRIVE exercises develop a client's adaptability by placing clients into variation-rich environments, where they are encouraged to move in new, novel, awkward and unusual ways. Whilst varied, training should still be systematic and structured. Chaotically waving the arms and legs around in lots of different directions while holding dumbbells is not an effective strategy for developing coordination. Movement needs to have a specific and measurable goal or intention and should accomplish a recognizable, relevant and useful functional task.

To progress exercise and create *intelligent variation*, a functional trainer can manipulate a spectrum of different exercise variables, including:

- Intensity
  - *Load*
  - *Duration*
- Task
  - *Primary movement patterns*
  - *Secondary movement patterns*
  - *Travel patterns*
  - *Play patterns*
- Environment
  - *Tools*
  - *Obstacles*
  - *Targets*
- Pathway
  - *Posture and position*
    - *Start and end position*
    - *Handprint and footprint*
  - *Direction*
    - *Three-dimensions*
    - *Height*
  - *Distance*
  - *Speed*
- Complexity
  - *Combinations*
  - *Transitions*
  - *Sequences*

## Load and Intensity

Conventional training usually progresses exercises based on *volume* (sets and reps) and *load* (amount of weight lifted). The drawback of progressing exercise in this way is that as loads increase, so does biomechanical stress and risk of injury.

To avoid injury as loads increase, movement has to be restricted and rigid form and technique maintained. Whilst lifting near maximal loads develops *intra-muscular coordination*, strength training using very high loads can only be performed in a very limited number of different ways.

A more 'functional' approach is to maintain variation by loading movement using alternative *drivers*, such as direction, speed and range of movement. Dynamic, three-dimensional motion generates powerful biomechanical forces that load movement without the need for heavy resistance. In a functional approach, loads can and should be lighter, as body weight is amplified from biomechanical forces such as:

- Momentum – moving with greater speed or a more rapid change of direction
- Leverage – lifting a weight that is further away from you
- Ground reaction force (GRF) – landing at speed, such as during a run, jump or hop, produces massive loads that the body has to absorb

## Task Variation

A functional trainer can vary movement by programming different functional tasks – *primary patterns*, *secondary patterns*, *travel* and *play patterns*.

- Primary – relevant to all, e.g. sit, step, lift, bend, twist, reach, push, pull etc.
- Secondary – relevant to the individual
- Travel – relevant for locomotion
- Play – relevant for learning

## Environmental Variation

An FT can enrich training environments using interesting and unusual *tools*, *obstacles* and *targets*.

- Tools – develop a rich variety of resistances to offer unique challenges, introducing ropes, bands, bungees, water balloons, sandbags, boulders and so on
- Obstacles – barriers to movement, such as steps, hurdles, boxes, bungees, whether to step over, jump onto or duck under
- Targets – static or moving targets to move towards and touch, such as a cones, markers or

pads

Tools, obstacles and targets 'game-ify' training. Try constructing an obstacle course using steps, boxes and cables for a client to negotiate. I call this the 'Lava game'.

A trainer can add variation by varying the 'pathway' of an exercise. *Pathway* describes the *position*, *direction*, *speed* and *distance* of motion. We can create varied 'pathways' by:

- Changing start position
  - *Stance – the posture we adopt*
  - *Grip – how we hold any tool*
- Direction of motion
  - *Three-dimensional movement*
  - *Height*
  - *Distance*
- Speed
- Distance

## Position

We can vary *position*, altering the stance in which we start and finish exercise, as well as how we hold *tools*. We can hold a barbell overhand, underhand, alternated grip, wide-grip, narrow grip etc. Few trainers consider working with a barbell with just one hand, or even an uneven or off-set grip.

There are countless options in terms of posture, position and stance to explore. Imagine performing an overhead reach from each of these different postures and positions:

- Standing
- Squatting
- Split stance
- Kneeling
- Half kneeling
- Sitting
- Oblique sitting
- Prone (lying face down)
- Supine (lying face up)
- Quadruped or four-point stance
- Tripod or three-point stance

## Direction

Most conventional exercises like the 'Chest-Press', 'Mid-Row', 'Leg-Press', 'Crunch', 'Back Extension' and 'Squat', create sagittal plane motion, in which a client only moves forwards and back. Rarely do exercises encourage side-to-side motion in the frontal plane or twisting in the transverse plane. A trainer should vary movement by asking clients to move in different directions.

Within function, movement occurs in all planes at the same time. Trainers can start to combine motion in different planes. Imagine a clock face on the floor around where you stand. Step towards each number on that clock face, first with one foot then the other. The feet can face whichever way is comfortable. Next, place a number of colored markers on the floor around you at different distances. Randomly step towards each one, reaching with the foot and then touching each cone with the hand. Stepping and reaching towards cones is a very simple way to drive movement in different directions. As you reach towards one cone, try keeping your vision on another cone or reaching overhead in different directions. This is a simple strategy to drive movement in more than one direction at a time.

It is worth considering that most power is generated in the transverse plane, known as the '*power plane*'. If we want to generate extreme power, perform powerful twisting movements. Punching, throwing or kicking all integrate powerful rotational forces through the hips and spine, loading powerful core muscles.

Consider how to introduce forwards and back, side-to-side and twisting motions into primary movement patterns. Use the feet and hands to 'drive' motion without reliance on teaching points and instructions. Apply principles of intelligent variation to perform:

- A three-dimensional lunge
- A three-dimensional overhead reach
- A three-dimensional hip shift

## Height

A trainer can use *height* to vary movement. If a trainer prescribes an exercise in which the client steps and reaches, we can vary both the direction in which a client reaches – forwards, backwards, sideways – and also the height at which the client reaches. Try holding a dumbbell and then stepping and reaching at:

- Ankle height
- Knee height
- Waist height
- Chest height
- Head height
- Overhead

To vary the height of stepping, provide a rise to step onto or off of – varying the height of the rise will progress or regress movement. We can ask clients to step, jump or hop onto or off of a rise or step. We could also ask a client to step-sideways or step and twist.

## Distance

In conventional training, exercises have a pre-prescribed range of motion (ROM) and rigid form and technique. In functional training, form is fluid and flowing. Form, and therefore ROM, can be progressed or regressed to match ability.

An effective strategy is to give clients choice and control over how fast and how far they move. ROM/distance becomes a form of exercise progression in which clients are encouraged to move 'as far as they feel comfortable', and 'further if they feel able'. Clients should be encouraged to reach:

- From near to far
- Towards a target in the distance
- As far as possible

*Distance* is a fantastic strategy for expanding a client's 'movement bubble' – for increasing functional ROM. It is a common misconception that flexibility relates to physiological factors like the distensibility of muscle, that people cannot stretch because their muscles are tight and inflexible. In fact, flexibility relies far more on neurological factors like the underlying 'tone' of muscle.

Whilst stretching improves flexibility, the effects of stretching tend to be transient. Stretching causes a physiological creep of tissues like muscle and fascia. 'Crimps' or folds within muscle and fascia unfold as we stretch. But these 'crimps' quickly return as soon as we stop stretching and stand back up.

A person's ability to stretch and move in function is less about the distensibility of muscle and fascia and more about the underlying level of tone within myofascia. Muscle tone is low-level muscle contraction working to maintain postural and positional stability. Muscle 'tone' is regulated by neurological mechanisms working to prevent uncontrolled motion and injury.

Muscle tone is amplified in situations when movement is perceived to be uncontrolled and unstable. In these situations, tone increases to prevent excessive and unrestricted movement. Inflexibility and rigidity are byproducts of increased underlying muscle tone. To improve flexibility and mobility in a way that will sustainably transfer to function, mobility drills need to alter underlying levels of muscle tone. To achieve this, exercise needs to downregulate the subconscious mechanisms that control muscle tone.

If a client feels safe, secure and confident, then neurological mechanisms that restrict movement recede and mobility improves. Flexibility is best achieved by helping a client gain confidence in their ability to move over greater ranges. Confidence transfers to function if exercises reflect relevant tasks and skills that a client relies on in their daily life.

If a client feels restricted bending, then stretching their hamstrings may not be helpful. A client should practice 'bending' over progressively greater distances in a safe and secure environment until confidence improves. The client should then bend in different directions, at different speeds, interacting with different tools, obstacles and targets. Functional training really isn't very complicated or confusing.

## Speed

*Speed* is a fantastic form of movement variation. Exercise can be progressed by moving either slower or faster. Faster movements tend to increase momentum and power, whilst slower movements apply stress through '*time under tension*', the time spent under load. There are various strategies a trainer can use to change speed of motion. A functional trainer might use cues such as:

- Build speed as you feel able
- Build speed with each repetition
- Go super slow
- 'Pulse' through a mid-range
- Freeze mid-movement and hold stable
- Pre-load, rebound or explode into and out of a movement

Varying speed is a useful strategy for injecting variation into movement. It is generally wise to start slowly and then progress by gradually moving faster. The forces created during dynamic movements performed quickly can be large. The faster we move, the greater the biomechanical loads and therefore the greater the risk of injury.

It can be sensible to allow clients to control speed of movement. Tell the client they can select how fast they go. They can maybe start slow and build speed progressively if and when they feel able. The *sense of control* a client gains by being able to adjust speed of motion reduces subconscious threat perception, minimizing *subconscious protective neurological reflexes* and so reducing the risk of injury.

# Complexity

There are countless ways to vary, adapt and modify movement. The options provided above are only the tip of the iceberg. The only limit to exercise design is your imagination. Here are some other ideas for injecting variation and increasing the complexity of movement.

## Bilateral/Unilateral Movement

We can reach both limbs together or one limb at a time. Most conventional exercises involve holding resistance in both arms, but in most functional tasks the body is loaded asymmetrically, with more weight on one side than the other. Loading one side of the body is a functional strategy for engaging core muscles and developing dynamic core stability.

## In Sync/Out of Sync

Moving 'in sync', arms and legs reach in the same direction, however when moving 'out of sync', arms and legs move in opposite directions. For example, I can jump in sync with both legs moving together, or jump out of sync so that the legs jump apart. One arm can reach with the same side leg, in sync, or with the opposite leg, out of sync.

There is nothing to say that both arms need to be performing the same movement pattern. For example, you could ask the client to reach with one arm whilst pulling with the other arm. By performing multiple tasks in unison, a trainer can create a whole myriad of new exercises and challenges. Try 'curling' a dumbbell, at the same time as walking forwards. The challenge is greatly increased.

To vary into exercises further, a functional trainer can create a '*sequence, series or matrix*' of movement:

- Sequence – altering exercise with each set
- Series – increasing intensity within a set
- Matrix – altering exercise within a set
- Combination – multiple tasks within an exercise

## Sequence

A *sequence* involves changing a movement pattern between sets. For example, if we were asking a client to squat, the client might perform multiple sets, changing foot position with each set.

*E.g. Squat sequence*

*Set 1. Normal; Set 2. Narrow stance; Set 3. Split stance; Set 4. Alternative split stance.*

## Series

In a *series*, a client develops a movement pattern 'within' the set. For example, performing a movement task but building speed or range. Generally, the difficulty of the exercise would progress as the set goes on.

*E.g. Lunge stepping progressively further away, lifting whilst progressively adding weight, reaching overhead whilst building speed with each repetition.*

## Matrix

In a matrix, a trainer creates a set in which each repetition changes without necessarily changing intensity. We might change starting position, handprint, footprint or even vary the movement task within the same set.

*E.g. Press-up matrix*

*Reps 1–3 – normal hand position; Reps 4–6 – hands turned inwards; Reps 7–10 – hands turned out; Reps 11–13 – hands narrow; Reps 14–16 – hands wide.*

## Combining Movement

By combining movement patterns together a trainer can create progressively more complex exercises. A client can be asked to 'flow' smoothly from one movement pattern to another:

- Jump – Squat
- Step – Reach
- Bend – Swing
- Squat – Step – Push

… And so on.

Variation has to be progressive and matched to the needs and abilities of the client. One of the toughest challenges in functional training lies in providing a sense of progression and structure whilst also keeping exercises new, novel, interesting and unusual.

A client should always have a sense of order – the sense that a program is both progressive and matched to their ability. An FT should present a strategic plan for how a client's broader program will progress, highlighting wider goals and achievements. In Chapter 5 we look at principles of program design, applying intelligent variation to outline how this might be achieved.

# Bringing It Together

Variation is an essential part of functional training. Variation in movement is an essential skill that:

- Supports adaptability, redundancy and recovery
- Enhances adaptability to task and environmental variation
- Desensitizes novelty
- Supports learning

The goal of functional training is to move away from pre-prescribed, scripted exercise that emphasizes 'correct' form and technique and move towards a model of '*intelligent variation*'.

A functional trainer should provide a structured, systematic plan for varying a client's movement whilst developing 'mobility' or 'movement-ability'.

# EMOTION

- Understanding Emotion
- Emotion and Behavior
- Emotion and Performance
- Emotion and Learning
- Emotional Handbrakes and Accelerators
- Restructure Thoughts, Beliefs and Perceptions
- Cultivating Confidence
- Threat Inoculation
- Training the Alien, Student and Chimp
- Create Competition
- Train through Play

*Emotion* transforms movement, pain and performance. Some emotions make us sharper and more attentive, others make us incredibly strong and some make us freeze and shake with fear. The ability to manage, and even harness emotion can have a huge impact on functional performance.

Most conventional exercise programs tend to be repetitive and dull. In contrast, whether we are relaxing in the garden, playing sport or having fun with the kids, functional movement nearly always contains emotional content.

In this section, we discuss how emotion impacts performance and how a functional trainer can harness emotion to optimize the impact of training.

## Understanding Emotion

Emotion is one of the most powerful factors driving movement. In psychology, emotion, adapted from the French word 'emouvoir' (to stir up), is defined as 'a complex state of feeling that results in physical and psychological changes that influence thought and behavior' (Scirst, 2011).

In 1972, psychologist Paul Ekman proposed six basic emotional responses, universal throughout human culture – fear, disgust, anger, surprise, happiness and sadness. In 1999, he expanded his list to include embarrassment, excitement, contempt, shame, pride, satisfaction and amusement (Ekman, 1999). But what is emotion, and how and why is it created?

Emotion is complex. Physiological theories suggest emotion emanates from physiological and chemical changes occurring within the body. Cognitive theories argue that emotion emerges from the complex interaction of *thoughts*, *attitudes* and *beliefs*. Some theories propose that emotion is an intuitive interpretation of physiological and psychological status. When we are cold or hungry, we might feel irritable, depressed, angry or aggressive, for example. Neuroscience suggests emotions are created by neurological patterns activated within the brain. All these theories hold elements of truth, but the complete picture is highly complex and confusing.

It was Charles Darwin who first proposed the idea that emotion has a clear purpose, namely a mechanism designed to keep us alive and help us *survive*. For Darwin, emotion offered mankind an evolutionary advantage. It is clear that emotion:

- Influences behavior
- Transforms performance
- Supports learning

## Emotion and Behavior

Emotion has a powerful impact on our behavior – our *instinctive decision-making*. We all react differently depending on how we *feel*, whether we are happy or sad, angry or exhilarated. *Emotional intelligence* is the ability to manage emotion and is suggested to be even more important than IQ in determining life success.

As any good sales person knows, decisions are made not with the head but the heart. To influence behavior, a trainer needs to understand how to manage the emotional responses of their client, assisting them in making better choices or behaving in a more effective manner.

## Emotion and Performance

When an event causes an emotional response, the subconscious assumes the event is significant. The subconscious reaction to a significant event is to trigger a cascade of *physiological* and *neurological* reactions designed to support action and mobilize energy.

In response to elevated emotion, the brain triggers the release of a range of hormonal messengers from the *hypothalamus* and *pituitary gland*. These hormones cause a plethora of physiological reactions. Cortisol and adrenaline elevate the heart rate, dilate blood vessels and heighten neural sensitivity, for example.

Many of these neurological and physiological responses to emotion are designed to mobilize resources. In times of danger, the brain's priority is to make available every resource to enable us to stay alive – to 'fight or flight'. Under normal circumstances, the subconscious mind (subCM) inhibits performance, regulating force production to reduce the risk of injury. But in times of threat, neurological and hormonal reactions unleash vast reserves that make even the most deconditioned individual capable of almost superhuman performance.

There are various newspaper articles referring to times when normal people in extreme circumstances perform superhuman feats. You can find headlines like '*Man lifts car off pinned cyclist*', '*Kansas dad lifts car off 6-year old girl*' or '*Woman wrestles polar bear advancing towards son playing hockey*'. These are all examples of extreme performance under stressful conditions, a phenomenon that has become known as '*hysterical strength*'.

- In 2006, Tim Boyle watched as a car hit 18-year-old Kyle Holtrust. The car pinned Holtrust underneath. Boyle ran to the scene of the accident and lifted the car off the teenager.
- In 1982, Angela Cavallo lifted a car off her son, Tony, after it fell off the jacks that had held it up while he worked underneath the car. Mrs Cavallo lifted the car high enough and long enough for two neighbors to replace the jacks and pull Tony from beneath the car.
- Marie 'Bootsy' Payton was cutting her lawn in Texas when her riding mower got away from her. Payton's young granddaughter, Evie, tried to stop the mower, but was knocked underneath the still-running machine. Payton reached the mower and easily tossed it off her granddaughter, limiting Evie's injuries to four severed toes. Curious, Payton later tried to lift the mower again and found she couldn't move it.

Athletes learn to harness emotion to produce hysterical strength. You might have watched coaches slap weightlifters in the face prior to a big lift to trigger adrenaline-fueled super strength. Emotion can trigger superhuman performance.

### Flow State

Emotion can positively impact performance in many ways. *Flow state* is a psychological

**CHIMP MODE**

*In times of high emotion or 'threat', the subCM shifts us into 'Chimp mode'. The Chimp is the emotional part of the subconscious designed to get us out of trouble. The Chimp overrides normal subconscious regulation of sensation, perception and performance to allow 'gorilla-like strength' and lowered sensitivity to pain. In times of danger or heightened arousal, the Chimp mind affords almost superhuman strength.*

phenomenon in which an athlete's emotional state is perfectly matched to the task they wish to perform. When an athlete's emotional arousal, the stress and pressure of the situation, the difficulty of the task and the skill level and ability of that athlete are perfectly matched, that athlete may enter a 'state of flow'.

'*In-flow*', athletes describe seeing 'everything big', a state of heightened awareness, everything feels right, time slows. Athletes in-flow are able to read the situation, almost feeling like they are can predict the future. '*Flow*' is almost a euphoric state in which atheletes perform at their absolute peak. We can be in-flow in sport, but also in any other activity – reading a book, painting, talking to a partner or loved one. You know you are *in-flow* because you lose sense of time. Moments can last for ever and hours can rush by as we become absorbed in what we are doing.

A trainer should try to shift clients into *flow state* by selecting activities, tasks and challenges that match their ability and facilitate a positive *mind-set* and positive emotional responses. Whether fun, exciting or exhilarating, training should trigger a positive emotional response.

## Phobia

Emotion can both positively impact or hamper performance. There tends to be an '*inverted-U*' relationship between emotion and performance. Too little emotion and we are left unmotivated, but too much and we become over-aroused, sometimes experiencing negative emotional responses like fear, apprehension or panic. Emotion can *galvanize or paralyze* performance.

Too much pressure can cause individuals to freeze. One theory of '*choking*' describes how stress and pressure can cause an athlete to stop and consciously consider actions. Rather than relying on *instinctive* and *intuitive reaction*, the athlete enters into a *conscious mode of coordination*, slowing decision-making and disrupting performance.

Prolonged emotional distress can make an athlete withdraw from the activity in question. Severe negative emotional reactions can be so powerful they spark an irrational fear, or what we refer to as a *phobia*. Phobias trigger powerful adverse emotional reactions, even under mild exposure to an emotional situation or events.

All competitors have to cope with emotional stress and pressure. Those better able to manage emotion, those with a higher emotional IQ, tend to perform better, especially under pressure. These athletes are often referred to as 'big game players'. Trainers and coaches can enhance performance by improving an athletes emotional intelligence. A coach might discuss negative emotional reactions, unhelpful thoughts, attitudes and beliefs, providing emotional coping strategies.

## Emotion and Learning

Emotion is a powerful driver for learning. Information attached to emotional events is quickly committed to memory. For prehistoric man, who had to forage for food and avoid predators, this would have been a useful survival mechanism. The ability to retain information regarding which plants made you sick, where food was found and where predators lurk may be the difference between life and death. The brain is hard-wired to retain information about emotional events.

To commit information to memory, make it emotional. Make information interesting, useful and relevant and we make it more likely that the subconscious will commit it to long-term memory. By making learning experiences fun, exciting or exhilarating, we drive information from conscious, declarative memory to subconscious procedural memory. Even negative emotions like stress, fear and anxiety, accelerate the transition of information to long-term memory, which is why exam pressure is useful.

## Emotional Handbrakes and Emotional Accelerators

Emotion has a powerful impact on behavior. Whether we are climbing mountains, running a marathon or lifting heavy weights, our thoughts, beliefs and emotions have a powerful impact on how we behave. Negative emotions like fear or apprehension, *functional handbrakes*, hamper performance, whilst positive emotions like excitement and joy, *functional accelerators*, tend to support performance.

Functional handbrakes:

- *Low confidence*
- *Apprehension*
- *Anxiety*
- *Fear*

Functional accelerators:

- *Confidence*
- *Fun*
- *Exhilaration*

Functional handbrakes heighten *subconscious threat perception*, increasing *reflex protective modulation* which hampers performance. Negative emotional associations cause:

- Loss of functional performance:
  - *Weakness*
  - *Stiffness*
  - *Slowness*
  - *Imbalance and instability*
- Emotional distress:
  - *Apprehension*
  - *Anxiety*
  - *Fear*
- Pain perception:
  - *Irritation*
  - *Discomfort*
  - *Pain*

The goal of training is to change a client's emotional responses to movement, minimizing functional handbrakes like apprehension, fear and anxiety whilst at the same time building confidence. As confidence increases, performance improves.

## Emotion in Functional Training

A functional trainer can influence a client's emotional responses in numerous ways. An FT can:

- Restructure thoughts, beliefs and perceptions
- Build confidence
- Inoculate against threat
- Engage the subconscious
- Introduce play
- Apply pressure

## Restructure Thoughts, Beliefs and Perceptions

As Henry Ford once stated, 'whether you think you can or think you can't, you're right'. The subconscious mind filters and distorts perception to match our expectations. Every client's perception shifts depending on what they think and feel, shifting in response to our *thoughts*, *attitudes* and *beliefs*.

- Thoughts – the conscious process of thinking and reasoning
- Attitudes – settled ways of thinking or feeling about someone or something
- Beliefs – assumed knowledge, born of past learning and experience

Thoughts, attitudes and beliefs act as filters through which we perceive the world. Filters mean that two people can witness the same event and perceive entirely different things and subsequently react in entirely different ways. Stand at the edge of a walkway about to do a bungee jump and one person will feel their heart racing and interpret this as excitement and exhilaration, and they will jump, whilst another person will freeze with fear, worried they are going to hurt themselves or fall to their death. The second person is far more likely to freeze and refuse to jump.

Perspective can distort the significance we attach to life events. One famous study demonstrating the impact of perspective involved two groups of people walking across a shaky rope bridge. Whilst the first group was simply asked to walk across the bridge and to note how they felt, when the second group crossed the bridge, the researchers arranged an attractive member of the opposite sex to walk in the opposite direction. Whilst the first group attributed their elevated heart rate to fear of falling, the second group often attributed their racing heart to the attractive passer-by. The second group reported less apprehension about crossing the bridge. Perspective can have a powerful impact on perception and the meaning we attach to events.

Each individual's expectations are created by a *belief system* – models of how we expect the world to work. Belief systems are formed over a lifetime of experiences and the stories or interpretations we have about those expectations. Most of us have split from a partner in the past. Relationship break-ups can be painful and highly emotional. The brain has to make sense of why this negative event occurred so we can avoid it in the future. But different people's interpretation of this event might be very different. One person might assume there was a simple mismatch in terms of personality. Another person might consider they were not attractive enough. The two interpretations could have a powerful impact on future behavior.

*Self-image* is an important aspect of a person's belief system. Self-image is how we perceive ourselves, our individual tendencies and proclivities. Self-image can have a powerful impact on behavior. If you consider yourself to have a fear of heights or poor balance, this could have a powerful impact on your performance crossing the shaky rope bridge, for example. Self-image also distorts perception, as the subconscious strives to affirm your beliefs, assumptions and expectations. This is why people can wake up, look in the mirror and see two totally different body shapes from one morning to the next. Self-image has a powerful impact on how we perceive body shape.

Belief systems and self-image reinforce expectations and impact performance. The stories and internal dialogue we have with ourselves has a powerful impact on perception, action and re-action. Disordered thoughts, unconstructive attitudes and limiting beliefs fuel *subconscious negative prediction*, which in turn modulates and hampers performance. I often listen to my clients state:

- 'I could never lift that'
- 'I am not sporty'
- 'It always hurts when I …'
- 'My pain is just old age and arthritis'
- 'I always get injured no matter what I do'

A functional trainer can help reorientate and restructure a client's self-image and thoughts, beliefs and attitudes. Whilst we are not psychologists or counsellors, we can point out unconstructive dialogue and encourage clients to re-evaluate beliefs based on new evidence and positive experiences.

Tread with care. Clients can respond badly to advice and observation contrary to their own deeply held beliefs. Imagine telling a client who has suffered a knee injury, 'your knee pain is all in your head'. Imagine being told your physical reality is only a fragment of your imagination – can you imagine anything more patronizing? You do not live in your client's body and have not had their experiences, so you should be careful about passing judgment.

In the second half of this book we discuss chronic pain, injury and dysfunction, but for the time being, remember the old adage in *coaching*, 'giving advice only builds resistance to change'. Coaching is the process in which a trainer can encourage a client to reflect on their personal attitudes, beliefs and assumptions. A trainer can provide information, highlight evidence and create opportunities for new experiences, but should always remain humble and maintain a perspective that assumes the client is 'the expert on their own body'.

## Cultivating Confidence

One of the best ways to restructure a client's beliefs regarding their movement ability is to build their *confidence*. Confident individuals perceive situations as less threatening, and therefore perform better. Whilst we might describe an individual as being 'generally confident', confidence is actually task-specific. In psychology, task-specific confidence is referred to as *self-efficacy*.

Self-efficacy has a huge impact on behavior. Research suggests self-efficacy impacts how individuals approach specific tasks and situations, determining the extent to which they engage in or avoid an activity (McAuley et al., 1997). The greater a person's belief in success, the more effort they exert and the longer they will keep trying. Highly *efficacious* individuals approach more challenging tasks, expend greater effort and persist longer in the face of aversive stimuli (Onoda, 2014). If you want to motivate a client, increase their confidence.

In 1977 Bandura identified three major sources of self-efficacy. *Verbal persuasion, vicarious experience* and *mastery experience*.

- Verbal persuasion – being told you can perform a task
- Vicarious experience – watching the success of others performing a task
- Mastery experience – the past success or failure at that task

Verbal encouragement is most beneficial when it comes from a 'significant other', someone we either associate with (i.e. of a similar ability) or a respected professional. Vicarious experience derives from watching someone else perform a similar task and is most beneficial when the other individual is of a similar background or ability – someone we can relate to. Performance accomplishment, or prior success, is the most powerful source of self-efficacy. *It* is most impactful when the task, environment, situation and circumstance reflects that which we will experience in future performance.

## Threat Inoculation

*Apprehension* is a sure sign a client is perceiving a situation as *threatening*. We have all experienced that strange sensation in the gut that suggests something is not quite right and that we should take care. Sometimes this voice is worth listening to, other times it should be ignored. In training, tasks that trigger a sense of apprehension tend to be:

- Varied
- New or novel
- Related to negative experience
- Comined with emotional stress

Never 'throw people in at the deep end'. If training is 'threatening', the subconscious triggers a range of *protective reflexes* designed to *modulate performance* to avoid harm. Start with an exercise that is too difficult and, more often than not, protective reflexes will activate to restrict mobility and reduce power. As *sense of threat* heightens, the likelihood of success diminishes. It is far better to start at a low intensity and progress quickly as confidence improves.

The challenge lies in selecting tasks that challenge the client whilst also ensuring success. Too easy, and a task lacks a sense of challenge. Success is taken for granted and does little to build confidence. Overly challenging tasks and the sense of threat increases while the chance of success decreases. Failed attempts erode confidence, reducing future performance.

The best tasks or challenges are perceived by the client as 'challenging' but are pitched at a level that the trainer is confident the client will succeed at. The client should ideally perceive an 80% chance of success, enough that they focus attention and can concentrate on what they have to do. At the same time, the trainer should be confident of that client's success.

## Graded Exposure

The principle of *graded exposure* suggests that exercise should be progressed slowly and systematically. Challenge or sense of threat should build progressively, whilst effort is made to avoid negative outcomes. My advice is to progress exercise as and when a client feels comfortable, or at least reasonably comfortable, challenging a client to progress forwards step by step.

Confidence is built on a foundation of success. With each triumph, confidence grows, as does the client's faith in both the trainer and their approach. With each success, the trainer should evaluate whether to progress the exercise. The goal is to progressively expose clients to increasingly threatening tasks and skills, whilst minimizing the negative impact of failure. Failure is ok as long as it enthuses the client to try again and try harder.

With each success, a trainer can smugly say nothing as the client states, 'you knew I could do that, didn't you?' The client should start to realize the trainer has a keen insight into their ability and should start to trust their decisions. Each success is an opportunity for the client to reflect on assumptions regarding their ability. Opportunities to consider, 'if I could achieve that, what else could I achieve?' With each positive experience, the client builds a database of new positive experiences. As confidence improves, so does functional performance.

Confidence is 'task-specific'. To transfer to function, training has to reflect the tasks and activities we perform in real life. Imagine an elderly client wanting to get fit for walking in the countryside. Imagine she frequently loses balance on uneven terrain, losing confidence to the point where she wants to give up. Is it helpful to strengthen this client's leg muscles or ask her to balance on wobble boards? It would be far more constructive to challenge balance using obstacle courses or to practice moving over uneven ground.

To develop task-specific confidence, exercises should reflect the tasks and activities we perform on a daily basis. Training should:

- Relate to negative experiences
- Trigger mild apprehension
- Progress quickly from stress-free to challenging
- Ensure positive experience
- Regress if causing pain or instability

As confidence grows, the subconscious downgrades threat perception, reducing the neurological restraints on performance. The result is an increase in force production, flexibility and mobility. As confidence grows, so does functional performance.

## Training the Alien, Student and Chimp

Each client has a distinctive personality, mind-set and emotional state. A functional trainer should adapt training to match a client's state of mind. In the previous chapter on the subconscious mind, we used the metaphors of the Alien, Student and Chimp to describe how a client's state of mind can vary depending on their emotional state. A trainer should consider how to adapt training depending on whether a client is more Alien, Student or Chimp.

### Training the Alien

If we remember, the Alien acts like mission control – coordinating, synergizing and integrating movement. The Alien subconscious is principally concerned with maintaining certain biological priorities, primarily the need to stay safe and survive.

In many situations or circumstances the Alien subconscious scans the environment and evaluates conditions, evaluating the potential for threat. The Alien learns quickly, retaining information when it is:

- Useful and relevant
- Vital to survival

To maintain safety, the Alien regulates performance and activates motivation centers within the brain that drive behavior. Under exteme circumstances, the Alien will even trigger pain to change how we move.

The Alien is a useful metaphor to describe how the subconscious mind is far better equipped to control and coordinate movement. If we want to move with ease, speed, fluidity and power, we have to engage subconscious control. To train the Alien:

- Trust instincts and intuition
- Make exercise:
  - *Task-driven*
  - *Relevant*
  - *Varied*
  - *Emotional*
- Develop coordination using variation and complexity

All our actions and behaviors are ultimately controlled by the Alien subconscious mind, but in any given day we might be more Student- or Chimp-orientated.

## Training the Student

The Student represents the prefrontal cortex (PFC), the region of the brain associated with planning and rationality. The Student mind is essential for self-control and discipline, so it can be particularly useful to develop the PFC and encourage the student mind for clients who are looking to build positive habits, need to regulate behaviors in terms of what they eat and drink and for those clients looking to manage stress.

A client who is Student-orientated will love to think and learn and will appreciate information and explanation. For a client who appears calm and rational, who is keen to learn and who seeks detailed information:

- Instruct, but keep cues to a minimum
- Provide information and detail
- Explain context and relevance
- Provide problems to solve

## Training the Chimp

As emotion takes control, a client may shift into Chimp mode. Chimps are emotionally driven. They are being dominated by the emotional centers of the brain – the limbic system. As such, they have less rational patterns of thought and are prone to more reactive rather than proactive behaviors.

A client who arrives at training looking to have fun and play games may be in Chimp mode. Chimps love to play, have fun, socialize and interact. Chimps are prone to becoming over-excited and even competitive. A client in Chimp mode is unlikely to want to learn and will not be interested in detail. To train a happy Chimp:

- Laugh
- Socialize
- Have fun
- Play games
- Compete (where appropriate)

Clients who arrive at training with negative emotion, who are tired, angry or frustrated, are in a more negative Chimp mode. A lack of emotional control is making them feel angry, irrational and illogical. A client who is experiencing an increased sense of threat will often enter a negative Chimp mode, making them defensive, irritable and prone to withdrawal. For this client, training should help release some of this negative emotion and reduce stress, at which point the client may be better able to rationalize the conditions generating the sense of stress and pressure.

Exercise is a great way to relieve stress and can be extremely effective in drawing a client out of a Chimp-driven, negative mindset. For an 'angry Chimp', striking games like boxing can be a great way to relieve frustration. Exercise is a great way to *feed the Chimp*. To train an 'angry Chimp'.

- Play games
- Get rid of aggression

For a client that is fatigued, relaxed steady-state cardiovascular exercise is a great way to reduce emotional stress and shift a client back into Student mode. While a client warms-up, talk – have a chat and listen. Allow the client to offload. Do not give advice, just listen. Trainers are not counsellors, but sometimes listening is all it takes to reduce emotional stress. As you listen you might pick up clues as to what exercise would be of most benefit that day.

- Try long steady-state cardio
- Have a chat
- Give control and choice
- Remove threat and make safe
- Meditate and breathe
- Use mindful movement

Functional movement is a great tool to maintain emotional balance and deal with the stresses and strains of life.

## Client Types

All clients have psychological predispositions, but *mindset* can vary day to day or from moment to moment. Selecting a training program suited to a client's psychological state is extremely important. There may be occasions when your plan has to be screwed-up and thrown out the window, adjusted to suit how the client feels on that day.

There are many ways to analyze a client's psychological profile, but a trainer does not have the time or qualification to put every client through a pre-session psychological screen prior to every training session. Trainers are not cousellors, but it is important to have some basic behavioral strategies to help your client have a positive training experience. We have provided some suggestions of psychological profiles that you might recognize.

### The Newbie

A beginner may feel nervous and unsure of their surroundings. Anything too challenging or painful will shift them into Chimp mode, making them feel defensive and resistant to learning and new ideas:

- Spend time building rapport, make a joke, encourage your client to relax
- Reassure them and make them feel secure
- Explain what will happen today
- Use familiar equipment
- Pick some easy wins, exercise you know they will succeed in
- Highlight success to help build confidence

**EXERCISE AND BREATHE**

*Exercise, especially long, steady-state (LSS) cardiovascular exercise and meditation or mindfulness, both increase activity in the prefrontal cortex. Both these activities appear beneficial for rational thought and impulse control.*

- Start with low-intensity cardio to activate their Student mind
- Teach something new, but keep it brief

## The Stress Bunny

Life can be hard. Some clients exercise to relax and de-stress. For this client:

- 'Feed the Chimp' – have some fun, play games
- Hit – the Chimp loves aggressive games to release stress, striking boxing pads for example
- Don't teach
- Listen actively
- Avoid stressful goals
- Do not be overly structured

## Exhausted

Many clients have lives that leave them feeling exhausted, stressed, emotionally drained, sometimes even anxious and depressed. These are all symptoms of being Chimp-driven for too long. For these clients:

- Introduce meditation, mindful relaxation and breathing exercises
- Practice active relaxation techniques focused on releasing muscular tension
- Encourage recovery through rest, relaxation, sleep, hydration and good nutrition
- Avoid too much high-intensity exercise

## The Thinker

These clients have a Student mind. They love details, information, plans and learning – the more detailed the better.

- Teach new skills, but remember, not too many teaching points at once
- Provide structured plans
- Set goals and targets
- Provide a pathway

## The Gossip

People love social interaction to relieve stress. Gossiping is a very powerful form of social interaction and an effective strategy for forming social bonds. Have a friendly, harmless gossip as your client warms-up – Chimps love to gossip:

- Don't be afraid to have a chat while doing some cardio
- Play games in training
- Gossips enjoy less conventional exercise and variation
- Structure is less important

## The Athlete

The athlete is in good physical and mental condition and has no problem with more challenging goals and competitive games.

- Set challenging goals
- Build competition progressively
- Play competitive games

## Hurt

Pain is highly stressful and pain shifts us into Chimp mode. The subCM views pain and injury as a real threat to survival and avoids further injury at any cost. We discuss pain and injury in the second section of this book, but for the FT with a client who is in pain, remember, pain is a reaction to threat:

- Provide reassurance and safety
- Explain that movement will not make pain worse but will ease symptoms
- Avoid movements that aggravate or trigger pain
- Give the client control – choice reduces stress and threat
- Gentle, slow, low-load movements are less threatening

Imagine trying to teach an exhausted client lots of new, high-intensity exercises. When you have finished that client will likely feel worse than when they arrived. If we want clients to have positive experiences, we cannot afford to get exercise programming wrong. We have to adapt training according to a client's emotional state and mindset.

## Create Competition

For a client in a positive emotional state, functional accelerators can dramatically improve performance. Driving performance using *pressure* and *stress* through competitive games can yield dramatic results.

*Competition* can be created in various ways and should be provided at an appropriate level, matched to the ability and state of mind of the client. We have provided the following categories of competition:

- Mirrored
- Self-referenced
- Controlled competition
- Companion competition
- Adversarial competition

### Mirrored

In *mirrored competition* the client reproduces the performance of a friendly opponent, a trainer or coach for example. A trainer can then adapt difficulty to suit the skill level of that client. An example might be a friendly 'knock-up' in tennis or passing the ball to one another in football. The advantage of mirrored competition, is that an FT can control difficulty to optimize success, whilst also ensuring the task is challenging.

### Self-referenced

In *self-referenced competition*, the client competes against a previous personal best or 'PB'. This is a fantastic way to introduce competition because the client knows they are capable, having achieved that target in the past. Self-referenced goals galvanize effort and provide a great sense of satisfaction if surpassed.

### Controlled Competition

In *controlled competition* the client competes against a trainer or coach. In this scenario, there is a definite sense of competing to win, but the coach or trainer can moderate task difficulty in line with the ability of the client.

### Companion Competition

In *companion competition* the client or athlete competes against a friendly opponent in a safe and controlled environment. In this situation, both athletes are competing to win, but the stress and pressure is lower because the clent is familiar with the opponent.

### Adversarial Competition

In *adversarial competition* the client competes against a genuine opponent. Clearly this is the most threatening and stressful situation. Other factors impact the level of stress, including the nature of the opponent, the environment and the circumstances. The FT can manipulate the level of competition to match the ability and the emotional state of the client. As confidence grows, the level of the opponent and the importance of outcome is increased.

Competition galvanizes effort by increasing emotional content and providing immediate feedback on performance outcomes. Emotion shifts the client into a Chimp-orientated mindset. Chimps tend to revert to deeply ingrained patterns of movement and instinctual behavioral responses. Deep-rooted habitual patterns supersede recent learning, therefore competition is not ideal if the goal is to teach new patterns of movement and alter form and technique.

The Chimp strives to achieve goals irrespective of a rational sense of self-preservation and our

**'BEER STRENGTH'**

*Altered mental states, such as those we see when people are on drugs or alcohol, can decrease neurological inhibitors of strength. Ask any police officer how strong people can be in altered mental states such as these.*

subconscious tends to over-ride protective mechanisms that modulate force production, speed and range of motion. Decreased modulation allows increased performance, but also increased likelihood of injury.

Competition should only be introduced to clients with a sufficient level of experience who have sufficient physical conditioning to cope with increased stress. The effects of competition are to:

- Galvanize effort and motivation
- Promote instinctual behavioral responses
- Hinder recent learning
- Over-ride protective modulation designed to prevent injury
- Increase performance through elevated strength, speed and power

## Train Through Play

Another fantastic strategy to increase the emotional content of exercise is to introduce *play*. 'Play', in contrast to 'work', is traditionally defined as any activity that is 'essentially unimportant, trivial and lacking in any serious purpose' (Whitebread, 2012) – action without purpose. Far from being trivial and unimportant, play is an essential part of development. Playful behavior is hugely positive for the brain and a fundamental strategy for learning (Dewar, 2014).

All animals engage in play, especially when their educational needs are highest. The more intelligent the animal, the more they play. Chimps, dolphins and dogs play more than snakes, turtles and insects. Intelligent animals deprived of normal play do not develop into well-adjusted adults. Research has demonstrated that rats deprived of play grow up with aggressive tendencies and poor social skills. The same may be true of humans.

Children learn through play. They experiment with the world, explore rules and interact playfully with the environment around them. Children frequently play in a way that simulates adult life (Lancy, 2008). It is possible that certain 'play patterns' are ingrained within the subconscious, specifically those critical for survival. Cats play at bringing down prey, children play-fight, run and chase, throw spears, gather tokens like daisy chains. Hunter-gatherers intuitively play games and develop skills that would have supported survival in prehistoric times.

The benefits of these play periods are evidenced by improved focus and attention (see Pellegrini and Holmes, 2006). School children pay more attention after a break in which they are free to play without direction from adults. The 'hole in the wall experiment' reported by Mitra et al. (2005) is an amazing example of how curious exploration and play can support learning. A prominent Indian physicist was curious what would happen when he placed a computer with high-speed internet access into a concrete wall in one of the poorest slums of India. The computer attracted the most attention from street kids aged 6–12, who had never seen a computer before and were curious about what it was. Within days, and with no instruction whatsoever, the children were playing games and surfing the internet. In short, they developed what most adults consider computer literacy through play and exploration. Would these kids learn as quickly in a conventional classroom?

Play is pivotal for child development and is a fantastic way for even adults to learn. Play is also a fantastic way to exercise. I once watched a video of a marine soldier placed into a playroom with a group of children filled with toys and balloons. He was asked to 'do everything they do'. If they ran and jumped, so did he, if they rolled and crawled, so did he. The marine said it was one of the hardest 40-minute workouts of his life.

Play engages subconscious forms of coordination and encourages *instinctive* and *intuitive* movement. We don't consider how to move when we play, we just move. Play is fantastic for motivation because it is intrinsically:

- Rewarding
- Exploratory
- Varied
- Emotional
- Social

## Rewarding

The majority of play is *voluntary* and *intrinsically rewarding*. This means that we are motivated to play just because it is enjoyable and fun. We feel great satisfaction when we win. Play inspires feelings of happiness and joy. Most people happily engage in play for long periods and are far more likely to enter *flow state*, the psychological condition in which we become totally immersed in what we are doing and lose 'sense of time'.

## Exploratory

During play, the brain spontaneously engages in a wide variety of creative and almost random patterns. When performance outcomes are apparent, each pattern or *movement strategy* is evaluated instinctively and intuitively. Unsuccesful stratagies are discarded, whilst successful ones persist.

Game-play encourages critical thinking and problem solving. Rather than being guided or instructed, individuals can be left to discover what works best for them, a strategy known as '*experiential learning*'. Play is the most effective approach for intuitive learning – far more powerful than being given information ahead of time.

## Varied

Play allows individuals to explore and improvise. Rather than applying the learning of others in a specific form and technique, play allows clients to formulate their own strategies that are original and applicable to the individual.

Play encourages a wide range of different strategies, applied in the context of a game with goals and guidelines. A trainer or coach can even manipulate game rules to achieve a specific learning outcome, manipulating goals, tools, obstacles and targets to encourage the certain outcome. A football coach may create a small pitch crowded with players, making the rule that you can only use one touch of the ball, to create a game that encourages fast passage of play, for example.

## Emotional

Sport is tremendously popular in modern life. Sport is much loved because of the feelings and emotions it inspires. Sport is fun and enjoyable, it creates pressure and stress; can make people combative, aggressive, angry, anxious and fearful. Sport can truly create a rollercoaster of emotion. This is why we love to play. Can we introduce emotion into training to make it equally as engaging?

## Social

The advantage of play over other forms of exercise is that it brings people together. When we play games or take part in sport, we interact and socialize, and this has a whole range of mental health benefits and is a great way to relieve the stress of modern life.

Play drives movement that is complex, reactive and unscripted, not only developing health and fitness but also supporting learning, helping build relationships and improving mental health. Why on earth would we exercise in a gym, walking on treadmills or cycling stationary bikes, when we can walk in the countryside, play with kids, have fun and play games?

Fortunately, there are advantages to structured exercise, but a functional trainer should introduce play into a functional exercise program. A functional trainer can structure movement games and incorporate simple goals and rules to drive complex movement. Environmental drivers like obstacles, tools and targets can be used to enrich training environments and make exercise fun.

Play patterns such as run, jump, throw, catch, grapple, evade, gather, strike and hit are terms that can be used to create a whole range of new and innovative exercises. We can construct obstacles to make an assault course, interact with balls or frisbees to throw, hoops to jump through, hurdles to jump over, cones to turn over and targets to hit. The possibilities are endless.

We can add a social element using team games. The Chimp mind loves us to socialize and have fun with others. Just remember some of the games we used to play as children –'tag', 'bulldog', 'stick in the mud' (maybe leave 'kiss-chase'!) Whilst we could play variations of these, there is nothing stopping us creating our own games and calling them something fun.

I like to develop a game of movement. Everyone has to move around while avoiding touching each other. I then add in words that instruct a certain action or movement task:

- Ground – everyone touch the ground
- High five – jump and clap hands
- Freeze – hold position
- Turn – change direction 180 degrees
- Crawl – walk on all fours

Play creates fantastic opportunities and adds intrinsic value to exercise, making movement fun.

**PLAY**

Try designing an exercise that uses the play patterns:

1. Catch
2. Throw
3. Strike
4. Avoid

## Bringing It Together

Emotion transforms performance, changes behavior and enhances learning. An FT should be aware of functional accelerators (positive emotional responses) and functional handbrakes (negative emotional responses) that impact on functional performance.

The goal of training is for the client to enter flow state, a point where pressure and stress are perfectly matched to ability. An FT should have a positive impact on a client's emotional state by:

- Restructuring thoughts and perceptions
- Cultivating confidence
- Helping inoculate against threat
- Engaging the subconscious
- Introducing play
- Applying pressure

In the next chapter, we look at exercise and program design, applying STRIVE principles.

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# 5 FUNCTIONAL EXERCISE DESIGN

- The Functional Web
- Movement Coaching
- Monitor Effort
- Evaluate Movement Strategy
- Provide Feedback
- Prescribe Exercise Progression
- Tweak Movement Strategy
- Build Intelligent Variation
- Manage Emotion
- Regress the Task

Conventional training is designed to trigger physiological adaptation – to build muscle and expand the lungs. To improve performance, a more effective approach is to focus on the *neurological* and *behavioral* factors that influence movement, pain and performance. STRIVE training is designed to engage the brain as well as the body.

Performance is less dependent on muscle mass and more dependent on the ability of those muscles to coordainate. By developing *task-specific coordination*, we improve a client's ability to organize movement, synergize muscle and integrate the various systems of the body.

Simple, slow and controlled exercise is not the most effective approach to improving coordination. Functional training should be complex and varied, driving three-dimensional motion, triggering instinctive and intuitive reactions to external tools, obstacles and targets. In this section, we apply *STRIVE principles* to functional exercise design, starting with an introduction of the *functional web*.

## THE FUNCTIONAL WEB

The functional web (see Figure 5.1) is a tool that acts as a framework to create functional exercise. The functional web is used to combine *movement drivers* to construct a myriad of interesting movement drills. The web is only a starting point. Trainers can build on this concept, developing their own 'web' and introducing their own ideas, movement patterns and terminology – the only limit is the imagination. Think of a functional exercise as combining a range of drivers, including:

- Environment – tools, obstacles and targets
- Task – primary, secondary, travel and play
- Pathway – direction of motion
- Emotion – fun, pressure, competition or play
- Environmental
    - Tools
        - Resistance
            - *Dumbell – Barbell – Medicine ball – ViPR – Rip trainer – Cable – Bands – Suspension strap – Bungee – Other*
        - Grip
            - *Underhand – Overhand – Wide grip – Narrow grip – End-hold*
        - Attachment
            - *Hand – Waist – Knee*
    - Obstacles
        - Step – Hurdle – Swiss ball – BOSU
    - Targets
        - Marker – Cone – Pad – Other
- Task
    - Primary
        - Lift – Sit – Bend – Step – Twist – Shift – Push – Pull – Reach – Carry – Crawl – Step up – Get up
    - Secondary
        - Added by the trainer as specifically relevant to the client
    - Play
        - Run – Jump – Hop – Skip – Throw – Catch – Avoid – Gather – Follow – Climb – Grapple

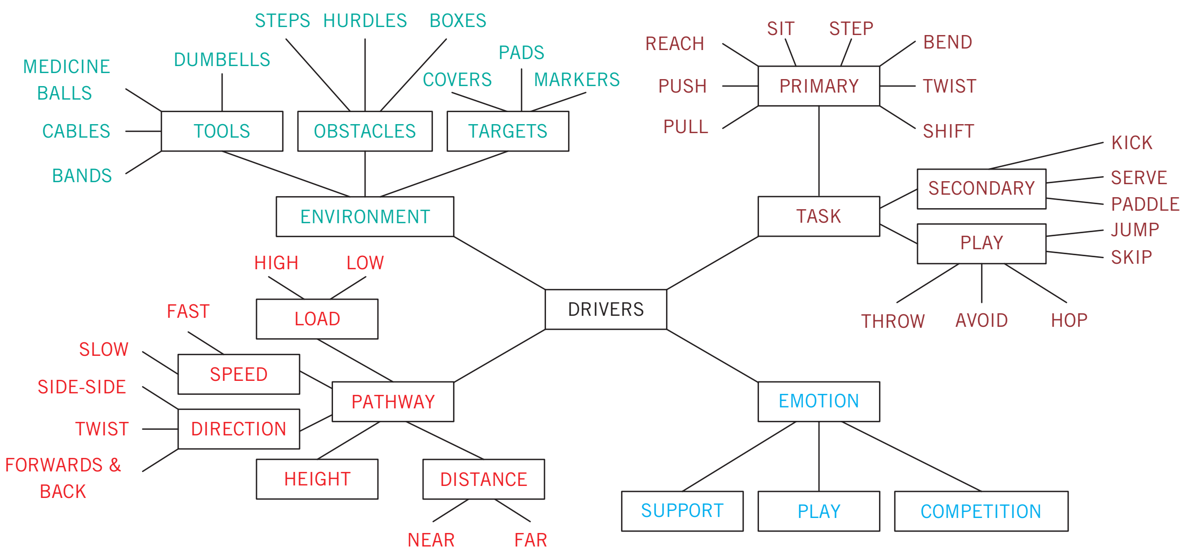


**Figure 5.1** Functional Web.

- Language drivers
  - Change the intent of the movement
- Pathway
  - Footprint
    - Start and end position:
    - Level – Split – int/rot – ext/rot – Narrow – Wide – Dorsi-flexed – Plantar-flexed – 45-degree angle – Cross-step
  - Handprint
    - Start and end position
  - Direction
    - Forwards or back – side-to-side – twisting
  - Resistance and intensity:
    - High load – Low load – Long duration – Short duration
  - Speed
    - Fast – Slow
  - Height
    - Ground – Ankle – Knee – Hip – Stomach – Chest – Shoulder – Head – Overhead
  - Distance
    - Near – Far – Into the distance
- Complexity
- Motion
    - Static – Dynamic
  - Unilateral – Bilateral
  - In-sync – Out-of-sync
- Combinations
- Sequence
  - Develop
- Matrix
- Emotion
  - Competition

## Functional Exercise Design

In conventional training, exercises are abstract – fabricated based on biomechanical principles with a pre-prescribed form and technique, and designed to load specific muscles in a manner that bears little resemblance to anything we do in daily life.

In STRIVE training, we select a number of movement drivers – useful and relevant movement 'tasks'. Rather than performing a 'Barbell Squat', a functional trainer would ask a client to simply sit or step. Movement is loaded using a range of tools. The tools used should load movement in a varied manner, becoming progressively more awkward and unusual whilst also reflecting those objects a client interacts with on a daily basis.

To inject variation and complexity, a trainer should prescribe a number of movement '*tweaks*' – small but significant adjustments to drive a movement pattern that is novel, new, awkward and unusual. The client is provided parameters, rules of the game if you like, but instructions and teaching points are kept to a minimum.

Clients should be encouraged to explore movement solutions and move instinctively and intuitively, finding what works for them and their most efficient movement strategy. In summary, to design a STRIVE exercise, a funtional trainer would:

1. Select a movement tool
2. Select a movement task
3. Prescribe movement tweaks

In conventional training, exercises are typically progressed based on load, sets and reps. Rigid adherence to strict form and technique makes training inflexible and monotonous. In STRIVE, exercises are more complex and varied, and the client is provided the freedom to *react* and *adapt* in a way that works for them, matched to their individual structure and ability. Exercises can be progressed with these additional steps:

1. Combine drivers
2. Build variation
3. Inject emotion

Let's look at each of these steps a little closer.

## Step 1: Select a Functional Tool

*Tools* resist and load movement. Each tool 'drives' movement in a different manner. A dumbbell might trigger a different movement reaction compared to a band or barbell, for example. To increase *transfer*, the tools used in training should reflect those a client interacts with on a daily basis. A trainer might integrate a football into drills to condition a footballer, or a tennis player might hold a racket as they step, bend and reach, for example.

Neurological adaptations are often associated with both the specific tasks and environments, but also the specific tools we use within training. By integrating familer tools, obstacles and targets, a trainer creates '*contextual similarity*', and therefore increases the likelihood that training gains transfer into function.

Gains in performance achieved within exercises using abstract tools, with little relevance in the real world, are unlikely to transfer to function. I may be able to lift a 100kg barbell, but this may not be reflected in my ability to lift bales of hay, for example.

The danger is that gains in 'abstract' strength create a false sense of ability. My conscious brain assumes I can lift 100kg, but both my body and subconscious mind have not been conditioned to lift the same load in complex, awkward or unusual ways. In many cases, the gap between training and function exposes us to injury because the amount we can lift in complex tasks and environments, with feet uneven, spine twisted and weight unbalanced, is far less than lifting a barbell in a safe and secure gym.

Whilst most of the equipment we see in conventional gyms is designed to be comfortable and convenient to lift, the loads we lift in function are frequently awkward and unusual. A mother has to lift a baby, we lift bags out of the car, load boxes onto shelves and so on. Rarely are loads as comfortable or convenient as a dumbbell with purpose-built handles and grips.

If the goal of training is to train in a way that transfers to function, training loads and tools should be also awkward and unusual. Try using off-set grips, asymmetrical loads, varied hand-holds, use unusual objects like boulders, atlas stones, sand-bags and water filled balloons. You will get odd looks, but how often do we lift a barbell in daily life?

## Step 2: Select a Functional Task

The next step is to select a functional *movement task* – a *primary*, *secondary*, *pain* or *travel pattern*. We never 'Leg-Curl', 'Lat-Raise' or 'Burpee' in real life, so why learn these tasks in the gym? We sit, lift, bend, twist, push and pull day in day out. These are fundamental *primary movement patterns* that should form the foundation of a functional training program.

### STRIVE Exercise Design

Try designing a functional exercise using these steps:

1. Select a *primary pattern*, e.g. sit
2. Select a *tool* (e.g. Medicine ball)
3. Combine two *primary patterns* together, e.g. sit to twist

*Secondary movement patterns* make a program specific to the individual by introducing tasks that are specific to their daily life – that client's work, sport or play. Avoid jargon and discard newfangled exercises. Instead, use a client's familiar language. Familiar language engages movement templates already ingrained within that client's subconscious. For example:

- Kayaker – *Rip trainer 'paddle'*
- Tennis player – *Cable 'forehand'*

### Bespoke Training

Try designing a series of exercises for specific populations, creating exercises that reflect the tasks, skills and activities they rely on.

- gardener
- tennis player
- shelf stacker

*Travel patterns* can be particularly effective in developing endurance and cardiovascular fitness. Movement patterns like a walk, run, skip, hop, jump and crawl can be used both in warm-ups and to develop 'fitness'. Travel patterns are particularly relevant for sport. A functional trainer would try to introduce familier travel patterns for sports performance, considering how that sport might require an athlete to sprint, change direction or accelerate in different directions and past different obstacles. Travel patterns can be combined with more conventional exercises to build complexity. Try a jump-squat or side-skip to reach.

*Pain patterns* are relevant to *functional rehabilitation programs* for clients recovering from injury. How to develop functional rehabilitation exercises is covered in the second half of this book.

## Step 3: Provide Tweaks

Tweaks are modifications to a movement pattern designed to inject variation and complexity, and therein increase the novely and coordinational challenge of that exercise.

A trainer always wants to build complexity and challenge progressively, starting with easy and progressing from there. A sound strategy, especially for novices, is to allow the client control over *resistance*, *speed* and *distance of motion*. Explain to the client, 'you can select the weight that feels right for you and progress as soon as you feel ready'. Explain that 'when you feel able, try to move (or reach) a little further (or faster) and if you still feel comfortable, we can then make the exercise more challenging in the next set'.

After each set, ask 'how did the resistance feel? Do you think we could add more resistance or move further or faster?' A client who has control over intensity by choosing load, speed and distance gains a sense of control. A sense of control reduces stress and anxiety. A sense of control reduces *subconscious threat perception*, supports motivation and enhances learning.

A trainer should set goals and boundaries for each movement drill. Too much freedom can feel confusing and many clients will feel at a loss without cues for form and technique. I might explain, 'I want you to maintain a split stance and reach and touch the ground holding a dumbbell.' The client might ask what position their spine should be in or at what point to breathe, but I will just explain, 'just reach as far as you can, smoothly in a way that feels comfortable for you'.

Too many cues and teaching points disrupt performance. *Internal drivers* should be used sparingly because they encourage an *internal focus of attention*. Internal drivers shift attention inwards, onto the client's sense of effort, stress, strain and motion. A shift towards an internal focus encourages a conscious mode of coordination, which reduces speed, fluidity and power.

'*Tweaks*' are short, concise instructions designed to transform a task, creating novelty, variation and complexity. A trainer can tweak the grip on a tool (wide grip, narrow grip etc.), tweak the start and finishing footprint (level stance, split stance), the handprint (reach, push or pull), the direction of movement and so on. Rather than instructions, tweaks are more like '*rules of the game*'. One example for tweaking a dumbbell sit to stand could be:

Tweak handprint by holding dumbbells overhead
Tweak stance by having split feet
Tweak speed by moving slowly down and fast up

Tweaks inject variety and complexity, increasing the demands for coordination. Each tweak alters the demands on movement. An overhead holding position challenges spine and shoulder mobility, a split stance challenges ankle mobility, slower motion increases time under tension, stressing endurance. Trainers should tweak movement to trigger the reaction they want and to stress the physiological systems and neurological skills they wish to cultivate.

## Step 4: Combine Drivers

*External drivers* encourage a *subconscious coordination*. Instinctive and intuitive reactions to tools, obstacles or targets increase performance with respect to speed, fluidity and power. If the client is given the functional task to sit, provide:

- A step to sit on
- A pad to reach towards with the hand at the same time

As a client '*sits and reaches*', move the target and let the client experience the impact this has. Change the position of the hand to create different movement challenges.

## Step 5: Build Variation

By building drivers and tweaking movement, a functional trainer can create a myriad of functional movement challenges, the only limit being the imagination. Try this:

1. Perform a dumbbell overhead reach
2. Now tweak the movement by:
   a. *Changing stance*
   b. *Add a step left or right as you reach*
   c. *Change the direction of reach (side to side, forwards and back)*

Practice building intelligent variation:

1. Take a tool (e.g. dumbbell) and a movement task (e.g. sit) and build intelligent variation by tweaking:
   a. *Footprint – try the exercise in different foot positions*
   b. *Handprint – hold the tool in different ways. Don't be afraid of making the holding position challenging or awkward*
   c. *Direction – try moving in different directions, adding sideways, backwards, twisting movements*
   d. *Height – alter the height of movement, reaching or stepping in different directions or at different heights*
   e. *Speed – try performing the movements super slow or as fast as possible*
   f. *Try adding 'freezes' or 'pulses'*

## Step 6: Inject Emotion

An FT can introduce *emotion* by providing a context, highlighting where and when a movement pattern is useful and relevant in real life. The

### INTELLIGENT VARIATION

*Powerlifting is a sport with three simple lifts – the squat, deadlift and bench press. One of the most successful powerlifting coaches in the world trains his athletes using constant variety. 'As soon as your body thinks it has the right answer, you need to ask it a different question,' says Louie Simmons, Olympic Lifting Coach (2008). Successful coaches understand the importance of variation in movement.*

trainer can then set challenging goals, build an element of play and provide competition.

Goals can be *self-referenced*, asking the client to achieve personal bests, or set in relation to a partner, friend or competitor. A functional trainer can create movement games, providing rules, targets and goals, making exercise fun. A simple example would be 'limbo-dancing' under a bar to challenge flexibility.

Visualization can be a powerful way to inject emotion and highlight how exercises are relevant. Ask a client to imagine themselves in a competitive game situation. Ask a footballer to imagine competing for a header as they 'jump', for example.

## MOVEMENT COACHING

Functional exercises should support performance and enhance learning and motivation. A functional trainer or movement coach should present exercise appropriately, applying the following steps:

1. Introduce task
2. Monitor effort
3. Evaluate the movement strategy
4. Provide feedback
5. Manage emotion
6. Progress or regress

Let's look at each of these stages of exercise presentation.

### Introduce the Task

A functional trainer should start by setting the client a movement task, providing a tool and tweaks. At this stage, it is important to highlight the:

- Task relevance
- Performance outcome criteria

A client should be clear about why an exercise *is relevant to their daily life. Relevance supports transfer* into function. A '*get-up*' is relevant to an elderly client, for example. Being able to get up from a lying position is important, especially as elderly clients lose strength and mobility. So much so that the ability to get up is directly associated with life expectancy. Clients should be able to 'get up' from different postures and positions without relying on support from the environment, likes chairs and benches.

In conventional training, exercises have a pre-prescribed form and technique, and are progressed based on weight lifted, sets and reps. In functional training, strict form and technique is avoided. Clients are encouraged to move instinctively and intuitively, allowing greater freedom to move. This freedom means that performance criteria and outcome measures can also be more varied.

- Performance criteria – subjective measures of performance, i.e. those that lack a measurable scale
- Outcome measures – objective measures of performance, i.e. those with a measurable scale

Objective measures of performance are still required to facilitate objective outcome feedback. A range of outcomes measures can be used and and could include *time under tension*, *distance* or *speed of motion*. As well as an objective measure, a trainer should also give *subjective feedback* on quality, stability and ease of motion.

- The task – side step and reach
- Tool – dumbbell
- Target – touch marker
- Tweaks – support foot stays fixed to the ground and moving foot returns back to cone
- Outcomes – how many repetitions can you perform in 45 seconds?

### Monitor Effort

It is important to gauge how hard a client is working – their exercise *intensity*. You cannot always tell just from the way a client looks how hard they are working. More objective measures are needed to monitor intensity. One option is to

**Figure 5.2** Dumbbell Side-Step and Reach to Target.

**APPLICATION – RATE OF PERCEIVED EXERTION (RPE)**

*Can you give me a score out of 10 for how hard you are working, 10 being maximal, you will have to stop soon, and 0 being at rest – 4 is comfortable, 6 is working hard, 7 working very hard, 9 you will have to stop soon and 10 you have reached your limit. Responses to this scale will tend to vary and can be highly individualized, so an FT has to gain a sense of what each score means to each individual client.*

ask for verbal feedback on perceived work intensity by asing for a score between 1 and 10 – what is referred to as a *Verbal Analogue Scale (VAS)*, also known in exercise as a *Rating of Perceived Exertion (RPE)*.

*Heart rate (HR)* is another useful objective measure of cardiovascular work intensity. Convention states that an estimated *maximum HR* can be calculated based on 220 minus age. Target work intensity can be calculated based on a percentage of estimated maximal HR. Client's working above 85% of their estimated maximal HR tend to be working anaerobically.

There can be significant variation in individual HR responses to exercise. Some client's HR response can be higher or lower, despite no difference in perceived work intensity. HR can be matched to RPE for a specific exercise to give an individualized measure of work intensity.

The *Talk test* is another useful indicator of cardiovascular load. If a client struggles to maintain conversation as they exercise, they have likely exceeded 85% of maximum heart rate. Ask yourself, can the client hold a comfortable conversation as they exercise?

*Verbal feedback* is another useful indicator of work intensity. Clients can tell you how hard they are working, how long before they need rest, how many more reps they think they can do or whether they feel fatigue, instability or pain. How a client looks, quality of movement and stability are all useful subjective measures of work intensity.

Use a combination of all the above and progress gradually, especially when working with new clients as you learn their individualized responses to load. It is best for work intensities to start low and progress quickly, rather than start too hard and regress.

## Evaluate Movement Strategy

Different clients approach tasks differently. Everyone will lift, bend, sit, push and pull, run, jump or throw in a slightly different way, and this is totally fine. Their choice of movement strategy is unique to them. Some movement strategies are more effective than others. Without prior instruction, a trainer *should observe instinctive and intuitive strategies*, reflecting on a client's:

- Choice of strategy
- Accuracy and precision
- Quality of motion
- Body position, posture
- Alignment and symmetry
- Distance and range of motion
- Balance, coordination and stability
- Speed and power

In conventional training, instructors correct form and technique, whereas in functional training, we observe a client's quality of movement without prior instruction, a process referred to as *observational analysis*. Rather than being planned or scripted, movement strategies should be allowed to 'emerge' depending on an individual's *structure*, *function* and *emotion* – how a client feels towards a specific task, situation and circumstance. A trainer has to decide to what extent a client's movement strategy is:

- Functional
- Dysfunctional
- Overloaded

Functional movement strategies are matched to the demands of the task, the environment, and individual *functional capacity* or movement ability, wasting little energy or effort. They are accurate and precise, producing what we refer to as *low outcome variability*. Whilst consistent and stable, functional movement strategies are flexibile enough to allow opportunity for *adaption*, affording the ability to *react* to unexpected variations, what we refer to as *high process variability*.

Clients exhibiting functional movement strategies typically feel confident and self-assured, with little sense of apprehension or fear that a task is threatening or hazardous. Functional movements 'flow' and tend to appear:

- Relaxed and adaptable
- Easy and efficient
- Self-assured and confident

In contrast, *dysfunctional movement strategies* hinder performance. Dysfunctional strategies are not well matched to either the task or a client's ability. Just like a novice cricketer closing their eyes just before catching the ball, dysfunctional strategies undermine performance.

Dysfunctional movement tends to be either too rigid, reducing ability to *react* and *adapt*, or too variable, appearing haphazard and chaotic. If a client is dysfunctional, the subCM will often vary movement, searching for more effective solutions and making it appear disorderd and chaotic. This often manifests as instability, imbalance and waving of arms and legs, muscle tremor and shake.

Dysfunctional strategies tend to expend more energy and effort, demand more attention and concentration, and often cause premature fatigue. Clients with dysfunctional postures and positions quickly fatigue, causing them to fidget and shift, searching for opportunities to off-load muscles, share load with other muscles, rest and recover.

A client with a dysfunctional movement strategy is usually aware of their lack of skill and will often feel apprehensive towards the task. Apprehension is associated with an increased subconscious sense of threat and modulation of performance. The subCM sacrifices speed, fluidity and power for safety and security.

Signs of dysfunctional movement strategy include:

- Rigidity and stiffness
- Instability and imbalance
- Fidgeting
- Need to change posture or position
- Discomfort
- Loss of movement variability
- High fatigueability and low endurance
- Loss of functional capacity
- Loss of functional performance

With overloaded movement strategy, the client is often unable to complete the task in hand. The difficulty of the task exceeds their functional capacity – they become *overloaded*, lose *form* and *technique*, and in conventional terminology, reach the point of 'failure'. Signs and symptoms of an overloaded strategy include:

- Seeking additional environmental support
- Frequently needing to change position and posture
- Deteriorating functional capacity
- Excessive effort, discomfort and irritability
- Emotional disturbance and deterioration in mood

- Apprehension, irritation or pain
- Sudden and dramatic change in posture or alignment

The FT should observe a client performing a functional task and evaluate to what extent that client is functional, dysfunctional or overloaded. With a functional strategy a trainer should:

- Provide feedback
- Progress the task

With a dysfunctional strategy an FT should:

- Provide feedback
- Tweak strategy
- Build intelligent variation
- Manage emotion

With an overloaded strategy an FT should:

- Regress the exercise (i.e. reduce challenge or intensity)

Let's look at each of these processes in more depth.

## Provide Feedback

The subCM responds far better to *outcome* rather than *process feedback*. A trainer should provide accurate outcome feedback in relation to task performance and outcome criteria, tracking and recording performance in order to set future goals. Highlighting 'personal bests' (PBs) and achievements is highly motivating. Positive *outcome feedback* is rewarding, motivating and builds confidence. When providing feedback:

- Gain client feedback – 'how did that feel?'
- Provide positive subjective reinforcement – 'great effort'
- Provide constructive outcome related feedback – 'you reached 20cm further than the last time you performed this exercise'

## Prescribe Exercise Progression

For clients achieving a task comfortably, with ease and efficiency and with accuracy and precison, increase exercise intensity and challenge. A functional task can be progressed by tweaking:

- Resistance – load or type of load
- Volume – number of repetitions or time working

(Note – These two methods are typical in conventional training and may not be the most beneficial forms of progression to improve movement ability.)

- Speed – the quickness of movement
- Range – the distance of movement
- Stability – the surface or base of support
- Complexity – a number of 'tweaks', components and variables

It is advisible to start with easy resistance, giving your client control over speed and distance of movement and systematically progressing from:

- Slow to fast
- Near to far
- Less complex to more complex
- Less load to more load
- Less intensity to more intensity

## Tweak Movement Strategy

There may be instances when you 'feel' the client displays a dysfunctional movement strategy, a movement that appears inefficient or that unnecessarily increases biomechanical stress and strain. In conventional terminology, we might describe the client as having poor form and technique. For example, a client might:

- Lift with a flexed spine
- Overpronate and collapse through the lower extremity on loading
- Hike up the shoulder girdle on reaching overhead

Should we correct these client's form and technique? The answer is tricky but should probably be 'as little as possible'. A trainer should not try to 'educate' clients on correct form and technique because:

- Human movement is incredibly complex – *task variation* means there is no single ideal form and technique. Rigid form and technique can only be applied over a limited number of scenarios.
- Educating clients on form and technique frequently undermines confidence.
- *Individual variation* means that what works for one person may not work for another – we all have *structural* and *functional variations* that impact our movement ability and may make perfect form less optimal.
- All clients *compensate* for intrinsic variations in structure and function and limitations in mobility, flexibility, instability and imbalance.
- A client's form should not be regarded as 'incorrect' because it diverges from our pre-conceived notion of ideal form and technique. An unusual movement strategy may be optimal for that client based on their structure and function.
- Teaching points and instructions shift us into a conscious mode of coordination, reducing performance in terms of fluidity, speed and power.
- Corrections frequently fail to transfer into function where clients rely on instinctive and intuitive patterns of coordination.

The goal is not to teach correct form and technique but to encourage clients to explore alternative movement strategies and find strategies better suited to either the task or their individual structure or functional capacity. Rigid form and technique may enhance performance but only within very narrow parameters. In contrast, functional movement strategies can be applied over a range of different situations and circumstances, supporting a client's ability to *adapt* to different tasks and *compensate* for individual deficits and deficiencies in ability.

- Adaptation – the ability to alter movement in reaction to task and environmental variation
- Compensation – the ability to alter movement in reaction to intrinsic deficits in functional capacity or movement ability

Rather than forcing a client into a rigid notion of 'ideal' or giving advice on what you think is best, provide suggestions and alternatives:

1. Encourage exploration
2. Propose alternative strategies
3. Provide outcome feedback
4. Encourage reflection

The FT can apply biomechanical principles to suggest 'tweaks' in strategy, but internal drivers should be used sparingly to avoid an overly internal focus of attention. Rather than correcting movement, suggest tweaks to be explored and encourage an external focus of attention – a focus on what they are doing rather than how they are doing it. Take climbing for example. When learning to scale a climbing wall, a coach cannot tell you the exact route to take. Each person's size, strength, height, flexibility, mobility and ability all vary. A coach can suggest different strategies, like pushing with the legs rather than pulling with the arms, or keeping the hips close to the wall, but a coach should not give precise instructions like precisely where to place the foot, because this hinders learning by stifling exploration.

Functional movement strategies are suited to the individual and are flexible enough to apply over a wide range of different situations and circumstances. Given sufficient time, variation, exploration and feedback, functional movement strategies should simply emerge. An FT should reinforce functional strategies by providing positive feedback when outcomes improve. Functional movement strategies for common functional tasks might include:

- Lifting
  - *Get close*
    - Get as close to a weight as possible before lifting
    - Due to leverage, a resistance is heavier the further away from you it is
  - *Widen your base*
    - Have a wide stable base of support for stability
  - *Don't collapse, stay open*
    - Feet or knees collapsing in and back hyper-extending predisposes instability
    - Push knees outwards and engage hips to support knees and spine
  - *Do not round the spine*
    - On heavy lifting, excessive lumbar extension can expose soft tissues to biomechanical stress and strain
    - Maintain a soft extension of the lumbar spine on heavy lifting
  - *Engage the abdomen*
    - A protruding stomach will decrease intra-abdominal pressure, undermining stability
    - Do not let the stomach protrude on heavy lifting
  - *Coordinate breathing*
    - Stability can be assisted by building intra-abdominal pressure
    - Prior to lifting: breathe in, pull stomach in, then hold and breathe out through pursed lips on lift
  - *Lift the chest and then drive the hips*
    - Lift the chest first and then drive the hips forwards to complete a heavy lift
- Reaching
  - *Lift the chest*
    - On reaching, the chest should lift, triggering the thoracic spine to extend, and the shoulder girdle should drop away
    - This allows space under the acromion for the head of the shoulder to move, improving range of motion and reducing impingement
  - *Relax the shoulder back and down*
    - Avoid stress in the neck by not hiking the shoulder upwards
  - *Relax the neck*
    - The neck should stay relaxed, preventing tension and avoiding shoulder hiking
- Pulling
  - *Stay loose*
    - Keep joints loose and do not lock out to keep the emphasis on muscles
  - *Drop hips*
    - Drop the hips back to lower the center of gravity and optimize stability
  - *Lift chest*
    - Keep the chest lifted to maintain optimal thoracic, shoulder and shoulder girdle mechanics
  - *Relax shoulders back and down*
    - Do not gather tension or stress around the upper shoulders, neck or jaw
- Turning
    - *Turn shoulders prior to the hips*
    - This maintains power in the hips

- *Lift chest*
  - Spinal extension maintains optimal thoracic function and allows fluid rotation
- Running
  - *Short, quick stride*
    - Quick leg turnover speed or cadence is essential for speed
    - It is a mistake to 'stride out' because this predisposes an early 'heel strike' in which the heel lands ahead of our center of gravity
    - Early heel strike causes increased ground contact time and deceleration
  - *Keep tall*
    - Flexion at the hips decreases efficiency and power
    - Remain upright with a slight lean forwards
  - *Fast arms*
    - Arm turnover speed influences leg turnover speed
    - Maintain elbows at 90 degrees and drive arms quickly
  - *Hot feet*
    - Try and reduce ground contact time
    - Imagine the ground being hot
  - *Heel kick*
    - The knee should bend well such that the heel is pulled towards the hip as the leg recovers
    - A long leg and lack of knee bend on recovery increases the leg lever and slows leg turn over
- Jumping
  - *Fast drop*
    - Drop fast into a counter-movement prior to a jump
    - The more load we generate eccentrically, the more force we have available to transform into concentric explosive force
    - A rapid eccentric countermovement contributes to eccentric loading
  - *Use the arms*
    - Rapid swing of the arms into the countermovement contributes to eccentric pre-loading
- Throwing
  - *Arm at 90 degrees*
    - Cock the elbow to 90 degrees to achieve good throwing mechanics
  - *Turn the shoulder*
    - Use the upper body to create a powerful countermovement
  - *Point*
    - The opposite arm can generate force in throwing
    - Cock the lead arm and pull it back on throwing
  - *Use the wrist*
    - A large amount of force is generated from cocking the wrist
    - Do not try and maintain a straight wrist

## Build Intelligent Variation

Functional performance relies on the ability to adapt and react. The world is complex and varied, and therefore movement strategies have to be equally complex. Correct form is impossible to predict because every person is different and different tasks and skills require a subtle blend of both stable and flexible elements.

The stable elements of a movement strategy represent elements of form and technique that will generally make movement easier and more efficient, whilst the flexible elements of a movement strategy allow an individual to adapt to unexpected variations and disturbances. Take bowling a cricket ball, for example, bowling technique has to be consistent but also adaptable, to adjust to different batsmen, varying wickets, weather conditions and so on.

The optimal balance between stable and flexible elements within a movement strategy is impossible to predict or teach. The subtle balance between each just has to be learnt over time, practice and experience. To present a 'correct' model interferes with learning by reducing exploration (Wulf and Prinz, 2001). Clients have to be afforded time to practice so that appropriate strategies can emerge.

In the case of a dysfunctional movement strategy, rather than correcting technique it may be more appropriate to introduce intelligent variation, to strategically vary posture, position, direction and speed of movement within the context of the same fundamental movement task. By introducing 'intelligent variation', a client can broaden their experience and develop coordination and skill. As coordination and experience develop, improved movement strategies may emerge. By encouraging a broad spectrum of movement experiences coupled with objective outcome feedback, a client should naturally discover easier and more efficient ways of moving.

The *Biological Priority of Ease* means that given enough time, variation and feedback, the subCM will intuitively gravitate towards what is *easy* and *efficient*. By encouraging the client to experience varied movement, they are afforded the opportunity to experiment.

Say, for example, a client demonstrates an unstable lunge pattern, losing stability as they stride forwards. One approach would be to instruct the client to push their knee out, squeeze the core or activate their glutes to create stability. But are these strategies useful in function, in the environment where we never really reflect and correct what we do or how we move? In reality, too much instruction hampers learning. Better to ask the client to practice lunging in lots of different positions, in different directions and at different speeds. As coordination and skill improves, more functional movement strategies should emerge and stability should improve.

## Manage Emotion

Unconstructive emotions are a key cause of dysfunctional movement. Unhelpful thoughts, attitudes and beliefs trigger:

- Subconscious negative prediction
- Protective neurological reflexes
- Unhelpful behavioral responses

Protective neurological reflexes trigger weakness, stiffness, rigidity and sensitivity to load and stretch. As clients become more apprehensive and fearful, attention shifts internally, reducing fluidity, speed and power. Negative expectation can even cause clients to reduce effort and withdraw from participation.

Addressing unhelpful thoughts, attitudes and beliefs can have a powerful impact on functional performance. A functional trainer should support and encourage, impart positive experience, especially positive experiences of similar clients. Programs should reinforce positive experience, and these experiences can then be used to provide the basis for the client to re-evaluate their own beliefs and expectations regarding:

- How strong they are
- How flexible they are
- How structurally sound they are
- How injury prone they are
- How capable they are

## Regress the Task

If a client is 'overloaded', i.e. they are not able to perform a task, the exercise needs to be regressed by:

- Modifying position – e.g. widening the base of support
- Tweaking environment – e.g. providing support
- Reducing load
- Modifying speed – e.g. moving slower or making use of momentum

Exercises should pose a challenge but maintain a high likelihood of success. Too easy and a client may reduce effort. Success within 'easy' tasks is unlikely to have a significant positive impact on perceived ability. Too challenging and a client may fail, negatively impacting confidence. Regressing exercise intensity is not ideal because it becomes apparent you misjudged a client's ability. It is always best to start slow and progress quickly.

## Bringing It Together

The goal of functional training is not to burn calories or build muscle but to develop a client's functional capacity and movement ability – their coordination, balance, stability, flexibility, strength and power in the context of useful and relevant functional tasks.

The functional web is a fantastic tool to combine movement drivers, creating complex patterns of movement, occurring in two dimensions, in different directions, at different speeds and distances, manipulating awkward and unusual tools in relation to external goals obstacles and targets.

In movement coaching the role of the coach is to:

- Design a functional drill
- Prescribe tasks, tools, obstacles and targets
- Tweak movement to trigger the desired movement reaction

As the client works the FT will:

- Monitor effort
- Evaluate movement strategy
- Provide positive outcome feedback

Where appropriate the FT will then:

- Progress or regress difficulty
- Build intelligent variation
- Provide emotional support

In the next chapter we incorporate functional exercises in a functional program design.

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# 6 FUNCTIONAL PROGRAM DESIGN

- Fundamental Principles of Training
- Client Appraisal
- Functional Evaluation
- Functional Program Design
- Pre-Session Appraisal (PSA)
- Functional Platform

Life is complex and varied. To reflect function, training has to be equally complex and varied. The challenge lies in placing exercises inside the structure of a systematic, progressive 'plan'. *Functional exercises* have to be placed into a *functional training program*. Each client varies in terms of their lifestyle, goals and ability, and therefore each and every functional program should also vary.

In this chapter we discuss the fundamental principles of *exercise program design*, discussing how to analyze a client's goals, assess their function and then build a unique functional program containing bespoke exercises with relevant progressions, goals and targets. The final stage involves placing that program into the context of a long-term *periodized plan* in which variables systematically cycle in order to maintain training gains.

## FUNDAMENTAL PRINCIPLES OF TRAINING

Any functional program is based on a number of fundamental principles. These are usually taught from day one, right at the start of any instructor's health and fitness education. These principles are:

- Overload
- Progression
- Recovery
- Variation
- Periodization
- Individualization

### Overload

Training is designed to create a physiological and neurological *overload* – a stimulus greater than we are accustomed to. Conventional exercise is generally designed to overload specific physiological characteristics, usually one at a time. For example, an instructor might prescribe specific elements of a program to target a client's strength, endurance or flexibility.

Within function, biomotor abilities like strength, flexibility and endurance do not take place in isolation, they combine and interact. Functional exercise is designed to reflect real life movement, where performance parameters like flexibility, balance, stability, strength and endurance blend together rather than occurring apart. Training should nearly always reflect function.

Training is *catabolic*. Overloaded tissues suffer micro-trauma and breakdown. Only when training is coupled with sufficient rest and recuperation does the body switch to an *anabolic* repair phase in which tissues start to regenerate. With sufficient time, rest and recovery, tissues repair – and beyond pre-training level. The process in which physiological tissues surpass previous *functional capacity* is known as *super-compensation*. Tissues that experience a physiological stress and subsequently adapt following a period of recovery are said to gone through a *positive adaptive response*.

Training supported by sufficient recovery, under normal physiological and hormonal conditions, leads to physiological and neurological adaptation, and subsequent increased functional capacity. Many clients fail to adapt either due to 1) a failure to create sufficient overload, 2) failure to allow sufficient recovery or 3) a failure to support recovery and repair with appropriate physiological conditions, i.e. suitable hormonal or nutritional conditions.

As the saying goes, 'what doesn't challenge you, doesn't change you'. In conventional training, instructors overload specific muscle groups, over numerous repetitions and using heavy loads. In functional training, the focus shifts away from the physiological tissues and onto neurological adaptation. Rather than emphasizing a physiological overload, the nervous system is placed under stress by moving at different speeds and distances, and challenges coordination by asking a client to maintain balance, accuracy and precision all at the same time. In functional training, overload is neurological as well as physiological.

### Progression

Without an incremental training stress, gains in performance eventually *plateau*. If a training stimulus does not change as the movement ability of the client improves, training gains start to slow. Plateau is a gradual reduction in training gains over time. It usually occurs within a four- to eight-week period when exposed to a stable, unchanging training stimulus. To maintain overload as capacity increases, trainers have to progress training stimulus, increasing the physiological or neurological load.

## Recovery

*Recovery* is essential for *super-compensation* (see Figure 6.1). Many clients work hard but fail to adapt due to insufficient recovery. Exposure to progressively increasing training stress, without sufficient rest and recovery, means tissues experience traumatic breakdown without time to repair. As overoad increases, we see a cycle of *negative adaptation*, characterized by a deterioration in performance.

### Super-compensation, Plateau and Negative Adaptation

Continued exposure to a training stress that exceeds a client's ability to cope eventually causes physical and even mental deterioration. *Burnout* is a condition in which long-term exposure to an excessive training stress, which exceeds an individual's ability to cope, undermines performance. Burnout is usually coupled with a sense of exhaustion, lack of energy, reduced enthusiasm and loss of motivation.

*Recovery* can be *active* or *complete*. *Active recovery* involves training at intensities lower than usual or by varying training stimulus to allow recovery of physiological systems. For example, some athletes might unwind by playing different games – cricketers might play touch rugby. *Complete recovery* is the complete cessation of training. Complete recovery generally results in rapid *regression* – the deterioration of functional capacity.

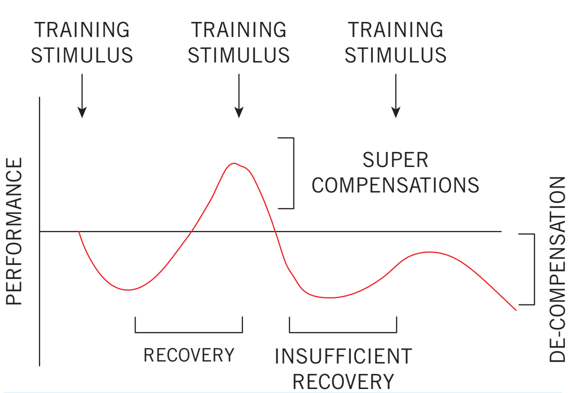


**Figure 6.1** Super-compensation, Plateau and Negative Adaptation.

## Variation

In the early stages of training, improvements in performance are often rapid. Exercise has to be progressed quickly to maintain overload and prevent plateau. The challenge lies in the fact that we cannot continue to progress training in the same way. If the nature of the training stimulus remains the same, a client eventually reaches the limits of their adaptive capability.

Imagine asking a client to lift a bar. A trainer should increase the weight on the bar as strength improves. But very soon, as neurological adaptation reaches its limit, the weight of the bar reaches its maximum. At this point, strength plateaus and the benefits of training diminish. Continuing to increase the weight on the bar at this stage increases the risk of injury.

As training gains plateau, further gains can only be achieved if the training stimulus is *varied*. A trainer needs to change the training stimulus so that neurological adaptation can continue. Many training programs cause plateau because they fail to provide sufficient training variation. Optimal neurological development requires a varied training stimulus.

## Periodization

*Periodization* is the systematic cycling of training variables to ensure sufficient overload, progression, recovery and variation, the goal being to avoid a training plateau. In a *periodized program*, exercise variables are cyclically varied, usually every four- to eight-weeks. A periodized program also programs in periods of planned rest to ensure sufficient recovery. The benefits of effective periodization include:

- Avoidance of plateau in gains by ensuring progression as well as variation
- Avoidance of over-training via planned regular rest periods
- Avoidance of over-use injuries caused by repetitive movements or doing the same exercises for long periods of time

## Individualization

Despite what we are told, we all react differently to training. *Individualization* states that we are all physiologically, neurologically and emotionally different, and therefore, what works for one, does not always work for another. Each person is different, so functional training programs should also vary. Training programs should be individualized and personalized to match the individual.

## Specificity and Similarity

The principles of *similarity* and *specificity* were covered in depth in Chapter 1, and state that training should be *similar* and *specific* to the tasks and skills we rely on within function. To create effective transfer, training should be physiologically, biomechanically, contextually and emotionally similar to function.

A functional program has to account for each of these fundamental training principles. It can be challenging to balance the conflicting demands of similarity and specificity alongside those of variation, periodization and individualization. To build a functional training program, where should a functional trainer start?

## CLIENT APPRAISAL

Building individualized programs matched to the needs and requirements of a specific client requires that a trainer takes a *person-centered* approach. A trainer needs to understand the individual goals, objectives and experiences of each and every client. Every new client should start training with a *client appraisal*, an informal sit-down chat in which trainer and client discuss their goals and clarify the client–trainer relationship.

*Rapport* is the essential foundation of any positive working relationship. A trainer should always start a new training relationship by building a basic level of rapport with the client. The client needs to feel comfortable and at ease. The client appraisal is an excellent opportunity for the FT to build rapport.

The client appraisal should take place in a comfortable setting. If you haven't already, introduce yourself, offer a drink, start with some casual 'chit-chat' and build common ground on trivial topics such as where the client lives, any shared friends or associates, how they heard about your services. Next, outline the process – what will happen today and what do you hope to achieve:

> *Today is just a relaxed chat to find out a bit more about you and your goals, and a chance for yout to find out a bit more about how functional training works. Feel free to ask any questions as we go along.*

The FT then has the opportunity to discuss the client's goals, motivations, beliefs and perceptions alongside their daily environment at work, rest and play. The FT needs to gain information about a client's:

1. Goals
2. Activities of daily living
3. Painful movements and injury history
4. Attitudes, perceptions and beliefs regarding exercise

I suggest the consultation process should involve the following stages. The FT might cover the following areas:

### Goals

- What are the client's goals?
- What is it they want to achieve?
- How would they monitor their success?
- How would they know they had achieved their goals?

### Activities of Daily Living

- What do they do on a daily basis? What are their hobbies and interests, and what sports do they do?
- What daily activities do they find challenging or difficult? What do they want to improve?

### Painful Movements and Injury History

- Are they experiencing any pain or injury and in what context? (Pain patterns – more relevant for functional rehabilitation)
- What makes their pain worse?

### Attitudes, Perceptions and Beliefs

- Has the client trained before?
- Have they worked with a trainer before?
- What was their experience?
- What types of training did they enjoy?
- What factors have stopped them achieving their goals in the past?

It can be useful to have a form that reinforces this structure. A funtional trainer needs a clear vision of where a client is and where they want to go. To create a clear vision, a trainer needs to empathize with the client in terms of how they feel and their goals. Do not forget, we all perceive the world differently and have different perspectives. A trainer needs to appreciate a client's perspective.

An FT needs to understand how the client wishes to structure training. In discussing options, a trainer can guide a client's thinking and structure a plan that is most likely to achieve the result the client wants. For example, it might be unrealistic to expect dramatic results from just one training session per month. It is ok to have different approaches and ideas in this matter, but it is essential that the trainer and client agree on an approach.

A good starting point is to give the client an idea of what packages are available and what structure might work best for them. Have a clear idea how many sessions a client might need and how long you will work with them. I normally frame this discussion by explaining, '*in your case, how I normally work is …*' or '*what I would recommend is …*' or '*what most people do is …*'. But we need to ascertain:

- What support the client is looking for at this stage
- How many sessions they require
- How frequently they want to meet

We recommend seeing a client on a weekly basis whilst forming new habits. I like to work with a client at a regular slot each week to support habit-forming behavior. Ask:

- What times are suitable to them
- When they want to start
- If we should book their first appointment and do the paperwork today

It is normal to pre-book coaching sessions and to have some sort of contract for the client to complete that includes a PAR-Q (Pre-Activity Readiness Questionnaire) and an agreement for conditions regarding remuneration, such as a contract or agreement. At this stage it is vital that an FT explains how functional training works. We might explain that:

> *Functional exercises improve not just how our body looks but also how well it works. Exercises are designed to improve the activities we perform on a daily basis, like bending, lifting, twisting, reaching, pushing and pulling.*

It is essential that an FT explains that functional exercises may be very different to what a client has experienced in the past:

> *Whilst most conventional exercises take place in one direction, real life occurs in lots of different directions, therefore functional exercise is designed to make us move in lots of directions and in lots of different ways. Functional exercises can often appear unusual and may be very different from what you may have been used to.*

It is essential that we measure outcomes of training as objectively as possible to evaluate progress, provide constructive feedback and highlight success. I usually explain what I want the client to learn and how the client will know they are improving:

> *We can measure performance not just by how much weight we can lift but rather how well your body moves in terms of coordination, balance and precision. We will identify a number of relevant movement patterns and create some objective measures from which we can measure progress.*

## FUNCTIONAL EVALUATION

From the client appraisal you can form an idea of the client's *relevant movement patterns*. These movement patterns might form the basis of a *functional evaluation*. Say, for example, the client expresses an interest in playing football, getting fit for runing, and explains that they occasionally experience back pain on bending and lifting. It makes sense that an objective functional evaluation would include football-specific agility drills, a running task (e.g. 800m run time), and a bend and lift. It really is that straightforward.

The first session should generally be a client functional evaluation. The FT might explain the purpose of the session and reassure the client they are not being assessed or graded.

> *Today is a relaxed session. We are just going to watch you move and try to identify what your body does well and what movements you find more challenging. We will gauge your level of fitness and see in what areas there is the greatest room for improvement.*

This is not an opportunity to tell the client what they are doing wrong or highlight biomechanical faults or biomechanical dysfunction. From a sales perspective, it can be advantageous to create a 'need' in the form of a biomechanical fault, a tilted pelvis or weak serratus for example, from which we can prescribe a 'corrective exercise plan', but this is not a functional approach.

A functional trainer should always build a client's confidence and reduce apprehension. It is important to highlight areas of strength and draw positive observations, downplaying the significance of dysfunctional movement patterns. The FT should appreciate that anything that undermines confidence also undermines performance.

In a standard biomechanical assessment, as a trainer we often stand a client up, assess postural alignment and ask the client to perform a series of pre-prescribed '*movement screens*'. The client is aware that they are being assessed so they move in an artificial manner, performing movements that have little functional relevance and do not reflect how they really move in the real world.

In a functional evaluation, trainers perform an *observational analysis*, in which client's perform relevant movement tasks or skills in an instinctive and intuitive manner, ideally within that client's natural environment. A functional trainer wants to observe a client's *subconscious movement strategies*; how they naturally sit, stand and lie, how they bend, lift, twist and so on. In observational analysis, the goal is to observe a client's instinctive movement strategies:

- For relevant tasks and activities
- In a natural environment
- Without being aware an assessment is taking place

In terms of what to observe:

- A functional trainer should observe basic 'functions', like walking, lifting, pushing, pulling
- A physical therapist should observe painful or problematic movements or tasks
- A coach should observe sport performance and relevant sport skills

Oberving instinctive and intuitive patterns of movement can be difficult. A client is nearly always aware they are being assessed, and therefore nearly always adapts behavior. To see natural movement behaviors, we might ask the client to record videos of them at home, at work or during sport, or visit clients in their natural environment.

In the client appraisal, we should have identified some key movement patterns to evaluate as part of a functional evaluation, but most client evaluations should include a variety of:

1. Primary patterns
2. Secondary patterns
3. Travel patterns
4. Pain patterns

Primary patterns form the basis for more complex movement and so a selection of primary movements should be evaluated alongside a collection of secondary tasks and skills, which are of specific relevance to the client. We might observe:

- A swimmer's stroke in the water
- A boxer throwing a punch

An FT might not be able to provide specific feedback on a sport-specific skill – specific coaching is best left to a qualified coach – but a functional trainer can identify movement patterns that are less easy, efficient, accurate or effective. A trainer can identify asymmetries in strength, stability, flexibility and mobility from one movement pattern to the next, of from one side of the body to another. The goal of training will be to build symmetry. A trainer might focus on movement patterns that are less fluid or patterns that trigger apprehension or pain – patterns that are clearly less functional.

Below are some examples of movement patterns we might include in a functional evaluation and what movement strategies we might look for.

## Primary Patterns

- Sit pattern
  - Imagine you are siting into a chair. Sit the hips all the way to the ground, keeping your heels down
  - Is there rigidity or instability at the ankles, knees or hips?
  - Does the person look for or need support?
- Step pattern
  - Step forwards and lower the back knee towards the ground
  - Is there asymmetry of hip motion?
  - Is the client able to remain upright and not lean forward?
  - Is there instability at the ankle or hip?
- Lift
  - Lift a resistance
  - What lifting strategy does the client employ?
- Reach
  - Reach forwards with both arms loaded with a band or cable from a split stance
  - Is there balance in strength with one side compared to the other?
  - Is the motion at the shoulder and shoulder blade balanced and even?
  - Are there any compensatory patterns like a shoulder hike or winging scapula?
- Push
  - From a four-point stance, lower chest to the ground and push back up again
  - Under load is the spine stable?
  - Is the shoulder stable or do we see scapular winging?
- Pull
  - Pull arms towards you with resistance, usually a cable or band
  - Do we see full range of motion or compensation at the waist?
  - Does the client extend through their spine as they lift or round into a flexed posture?
  - Does the client's shoulder draw back or protract forwards, closing the shoulder down?
- Neck rotation
  - Turn head left and right keeping shoulder still
  - Is there compensatory movement in the shoulders, i.e. hiking
  - Is rotation balanced left to right?

- Deep breath
  - Take a nice deep breath in and out
  - Do the lower ribs lift and mid-ribs expand outwards?
  - Does the sternum tilt or elevate upwards?

## Travel Patterns

- Walk/run
  - Walk and then run at a comfortable pace
  - Is the lower extremity symmetrical?
  - Is there even loading and unloading through the lower extremity?
- Crawl
  - Can the client maintain position on all fours?
  - Is there asymmetry or arching through the spine?

From a functional evaluation, a functional trainer can construct a program, highlighting movement patterns in need of work.

# FUNCTIONAL PROGRAM DESIGN

A *functional program* is a single session or workout containing many of the same elements as a conventional workout. We recommend that a functional program contain the following elements:

- General warm-up
- Dynamic stretch
- Movement preparation
- Main program
- Cool-down

## General Warm-Up

The physiological systems (heart, lungs, muscles, fascia) and nervous system all function better when warm. A workout should start with a *'travel pattern'* to raise body temperature and create a gradual increase in work intensity. In conventional training, a short period of work on a piece of cardiovascular equipment is often recommended. In a functional program, we might program brief periods of 'traveling', maybe starting with a short walk, progressing to a brief run, skip or crawl, or maybe some low-intensity jumping and hopping.

## Dynamic Stretch

A *dynamic stretch* involves controlled movement through a full range of motion at low intensity. A *dynamic stretch* is a continuation of the general warm-up, designed to develop range of motion, mobilize fascia, activate the nervous system and prepare the client for more challenging movement (see Figures 6.2–6.4).

**Figure 6.2** Long Step and Overhead Reach.

**Figure 6.3** Lateral Step Reach Overhead.

**Figure 6.4** Step and Toe Touch.

## General Pre-Stretch

- A long step and overhead reach
- Lateral step and reach overhead
- Step and toe touch

## Movement Preparation

*Movement preparation* is designed to address specific areas of instability, weakness, rigidity or immobility, i.e. functional rehabilitation exercises. These exercises can be performed after a pre-stretch or integrated into a client's main program, to be performed between sets. Movement preparation can include:

- Mobilization
- Activation
- Inhibition
- Myofascial release

Functional rehabilitation is covered in Chapter 7.

## Main Program

The *main program* involves exercises to improve functional performance. These should be specific and relevant to the client's needs, and will generally include:

- Primary movements
- Secondary movements
- Travel patterns
- Play patterns
- Pain patterns

A *functional session plan* needs to adhere to basic principles of program design.

- Balancing movement patterns – not over-using any one pattern of movement
- Balancing antagonistic movements – equivalent amounts of push to pull, bend to extend
- Balancing planes of motion – introducing a mixture of sagittal, frontal and transverse movements
- Balancing volume – not creating excessive levels of fatigue in any one area or system of the body
- Ensuring overload – the client is doing more than they normally would
- Ensuring progression – there must be a graded increase in exercise challenge to maintain overload
- Rest and recovery – there must be sufficient time for recovery between exercises and exercise sessions

## Cool-down

The cool-down involves a period of 'travel' at a low intensity to enhance recovery, promoting venous return and removal of waste products such as lactic acid.

## PRE-SESSION APPRAISAL (PSA)

Prior to any functional training session, it is useful to screen a client's current condition and emotional state of mind. A pre-session appraisal (PSA) is a brief five-minute relaxed chat to establish the client's physical and emotional state on that day. The PSA should determine:

- How the client's week has been
- Progress towards the client's health, fitness and behavioral goals
- The client's response to the last session (e.g. 'how did you feel after last time?')
- The client's current emotional state ('how are you feeling today?')
- Sources of pain or discomfort (e.g. 'how is the body feeling, any niggles, aches or pains?')
- Preference for today's training (e.g. 'what would you like to work on today?')
- Preference for areas or exercises to avoid
- Key goals they would like to achieve in the session
- Educational topics they would like to cover in the session

A PSA is an essential part of a *session plan* because it provides an opportunity for the FT to adapt a client's session to their physical and emotional state. Whilst an FT should plan each and every session, they should also be able to adapt that session based on the client's PSA. The PSA can be performed before the start of the session or it can be done during their general warm-up.

# FUNCTIONAL PLATFORM

Sessions have to be placed within the broader context of a *periodized plan*. *Periodization* is the systematic cycling of exercise variables, with periods of planned rest, to maintain training gains. Periodization and systematic cycling of exercise variables is essential to maintain physiological and neurological adaptation. There are numerous models of periodization. A periodized training program is typically structured into:

- Microcycles – a functional program
- Mesocycles – a weekly schedule
- Macrocycles – a monthly or yearly plan

## Weekly Schedule

The weekly schedule outlines the structure of the client's weekly plan and details how many sessions they will perform, what movement patterns will be emphasized on each day and when the client will rest and recover from exercise. The weekly schedule accounts for factors like:

- How much time the client has available
- How many times they would like to train
- Other commitments (e.g. work, children, hobbies)
- The level of recovery they need

## Long-Term Plan

The client's *long-term plan* includes information regarding how weekly sessions will vary month on month and how exercise variables and training focuses will change. Long-term plans should consider:

- Competitive seasons vs. non-competitive seasons
- Competitive events
- Expected peaks in performance
- Rest periods and holidays
- Training phases

A periodized plan should include details of *training phases*. Exercise variables challenging distinctive performance parameters should be systematically cycled to maintain training gains. A periodized program prescribes training phases identifying specific exercise variables to emphasize endurance, strength, speed or power.

### Endurance

*Endurance* is the ability to sustain a prolonged stressful effort or maintain work over an extended period of time. Endurance training is typified by increased number of repetitions, increased time under tension (the amount of time we are producing force) and increasing distance of travel.

### Strength

*Strength* is the ability to exert or withstand force, stress or pressure. The aim of conventional strength training is to increase *maximal force production*. Goals within strength phases tend to focus on increasing loads lifted. Strength training or high-load training is a fantastic way to improve *intra-muscular coordination*.

### Speed and Power

In *power* training, the aim is to develop explosive movement, the ability to produce force within a shorter space of time, or to move with speed. Power training is typified by the need to move quickly under varying levels of load or to travel over distance as quickly as possible. Within power phases, the emphasis is on the use of biomechanical forces like speed, momentum, ground reaction force, reactive strength and plyometric forms of force production. Speed and power phases tend to include more explosive movements like jumping, hopping and throwing.

As well as detailing the nature of work, a periodized model should also plan for recovery. Any training program has to achieve a subtle balance between activity, exercise, play and rest. *Pacing* is the art of balancing:

- Activity – light to moderate movement (e.g. walking, gardening, housework)
- Exercise – intense or stressful movement (e.g. intense training)
- Play – motion with emotion (e.g. sport, hobbies)
- Recovery – resting, eating, relaxing, sleeping, meditating

## Active Recovery

Active recovery is a period of reduced intensity exercise, allowing *super-compensation* and to avoid staleness or *burnout*. We should *actively rest*:

- Following competition or high-intensity training – one to five days in duration
- Following each microcycle – one day in duration
- Between mesocycles – two to five days in duration
- Between macrocycles – five days to three months recovery

Athletes or competitive sports people may have longer periods of active rest before starting their pre-season, known as an off-season. The nature of exercise should allow for active recovery – for mental as well as physical recovery. Swimming, basketball or other activities could be integrated into a phase of active recovery for a sprinter, for example. Some activity or light training should always be integrated into recovery phases to prevent regression and loss of training gains.

## BRINGING IT TOGETHER

A functional trainer should create a program based on a client's individualized long-term plan, called a *functional platform*. This platform outlines the client's:

- Phases of training – endurance, strength or power
- Details their weekly plan
- Details periods of rest and recovery

The client's functional platform is constructed from information taken from their client appraisal and functional evaluation.

Each session will be modified based on a client's pre-session appraisal, allowing the FT to account for a client's emotional and physical state on that day. Each functional training session will be constructed to include:

- A general warm-up
- A dynamic stretch
- Movement preparation
- The main program
- A cool-down

The main program will include a blend of primary, secondary, travel, play and pain patterns, with specific emphasis on patterns that appear dysfunctional or overloaded.

This chapter concludes functional training. You should now understand and be able to apply the main STRIVE principles: Subconscious control, Task-orientated training, Reactive movement, Intelligent variation and Emotion. You should be able to apply these principles to create functional exercises and be able to place exercises into the context of a functional training program, individualized and specific to your client.

In the next chapter, we look at the application of neuroscience and STRIVE principles to clients with pain and injury.

# 7 FUNCTIONAL REHABILITATION

Most clients start training with aches or pains, or present with a history of injury or systemic disease that restricts movement and hampers performance. In this chapter, we apply neuroscience to the management and prevention of pain and injury.

Be clear, *functional rehabilitation* is quite distinct in both its aims and objectives. Functional training is not physiotherapy. A functional trainer (FT) is not qualified to 'diagnose' musculoskeletal conditions or prescribe specific injury advice. An FT is not able to detect a 'slipped disc' or diagnose 'sacroiliac dysfunction'.

Whilst a trainer can contemplate potential causes of pain and injury, he or she is not a qualified medical professional. As and when appropriate, a functional trainer should always seek professional medical support and act in a professional manner. A functional trainer should not:

- Misrepresent the level of their professional qualification
- Misrepresent the scope of practical practice
- Make misleading claims
- Denigrate other medical or health professionals
- Contradict the recommendations of another medical professional

In functional rehabilitation, the goal is not to diagnose or 'treat' conditions but to prescribe functional movement as a vehicle to support healing, promote recovery and reduce risk of future injury. Functional rehabilitation is not designed to address specific injuries or disease processes but to enhance the ease and efficiency of movement.

Any client experiencing pain or injury is likely to have altered function – limitations in flexibility, mobility, strength, stability and power that hamper their ability to function in daily life. Rehabilitation programs highlighted in this book are not designed to treat symptoms but to restore '*function*' and *movement ability*. Reduced pain is not the goal but is a by-product of restored movement.

Altered thoughts, attitudes and beliefs regarding movement are commonplace after episodes of pain or injury. Negative thoughts, attitudes and beliefs are often fundamental to lost performance, and frequently impact a client's behavior and how they act in future. Functional rehabilitation is a vehicle to improve not just a client's physical condition, but their neurological and psychological state.

Functional rehabilitation is a flexible and collaborative approach designed to restore movement ability, build confidence and restore functional patterns of coordination. As part of the training process a client should experience:

- Improved thoughts, beliefs and attitudes regarding movement
- Improved coordination
- Improved movement strategies
- Improved performance parameters, i.e. task-specific strength, flexibility, mobility, stability and balance
- Improved functional capacity, i.e. the ability to lift, bend, twist, walk, run and so on

- Improved functional performance, i.e. the ability to perform at work, in sport or during play

Unlike approaches designed to resolve symptoms, a functional approach is designed to improve the ease and efficiency of movement. This suggests that rehabilitation can continue long past the point at which ‘symptoms’ have resolved. Even though difficult to prove, functional rehabilitation embraces the notion that training can reduce the risk of injury.

To summarize the aims of each of the following sections in this chapter:

- In ‘Injury and Repair’, we summarize the physiology of injury and the processes taking place as the body heals. To gain a greater insight, we highlight some of the more common injuries and consider how a functional trainer might support recovery through movement.
- In ‘Pain’, we look at the neuro-physiology of *pain*, how it starts and why it sometimes persists long past the point of healing. We see pain does not originate within tissues but is a perception constructed within the brain, designed to signal ‘threat’ and change behavior.
- In ‘Pain Rehabilitation’, we discuss pain management and how to apply functional movement to facilitate recovery from persistent pain.
- In ‘Functional Biomechanics’, we evaluate the complex topic of injury prevention and corrective exercise in the light of emerging neuroscience research, including biomechanical approaches to posture, form and technique, and injury prevention.
- In ‘Regional Interventions’, we apply functional rehabilitation to different regions of the body.

The intricacies of pain and injury are complex. This text is only a mere introduction to a small portion of the many concepts surrounding pain and injury prevention. To expand upon each topic and discuss specific cases please go to the STRIVE Movement website, where you can find further discussion and resources: www.strivemovement.com.

# INJURY AND REPAIR

- Introduction to Injury
- Traumatic Injury
- Stages of Soft Tissue Repair
- Supporting Soft Tissue Repair
- Injury Evaluation
- Supporting Healing in the Inflammatory Phase
- Supporting the Repair Phase
- Supporting the Remodeling Phase
- Introduction to Injury Prevention

Most clients present with pain or injury. Whilst a functional trainer is not qualified to diagnose musculoskeletal conditions, functional training can be extremely beneficial in restoring 'function'. An appreciation of common musculoskeletal conditions is essential if we want to train clients impacted by current or previous episodes of pain or injury.

In this section, we introduce the physiology of musculoskeletal injury and the stages of *soft tissue repair*. We discuss how functional training can support recovery and facilitate a return to 'normal' function at each stage.

## Introduction to Injury

Client frequently experience aches, pains or strains. A basic understanding of the various processes relating to each stage of injury and soft tissue repair is essential in functional rehabilitation. It is essential that exercise does not aggravate or exacerbate any issues a client presents with.

To start to understand injury and the stages of injury, we can first classify injuries using the following categories:

- Structure – the specific tissue injured
- Severity – the degree of injury
- Mechanism – the mode and mechanism of injury
- Chronicity – duration or time from point of injury
- Stage of repair – the stage of healing

### Structure

*Structure* relates to the specific tissue damaged. Distinct tissues tend to have a characteristic symptom profile, which helps clinicians establish a patient's complaint. A functional trainer might be aware of a client's symptom profile if they suffer an injury during or prior to training.

- Strain – damage to muscle fibers, characterized by:
  - Sudden onset relating to a specific traumatic event or action
  - Sharp pain on stretch or contraction of muscle tissue
- Sprain – damage to connective tissue, characterized by:
  - Sudden onset, usually involving over-stretch
  - Sharp pain on stretch
  - Lack of pain on local muscular contraction in mid-range
- Fracture – damage to bone, characterized by:
  - Acute trauma or impact
  - Severe pain on palpation
  - Severe pain on loading
- Neuropathy – injury to or irritation of nerve tissue, characterized by:
  - Lancinating pain (like a jolt of electricity) radiating along the path of the nerve
  - Possible associated weakness
  - Altered sensation (e.g. burning, numbness or pins and needles)
- Joint impingement – compressive or irritation of a joint, characterized by:
  - Restricted range of motion at a joint
  - Pain in the inner range of joint motion (i.e. as the joint closes)
- Subluxation or dislocation – partial or total separation of joint surfaces, characterized by:
  - Traumatic incident

- Severe pain
- Deformity
- Weakness

## Severity

Injuries can be graded based on their severity. For example, a muscle sprain and connective tissue sprain can be graded on a scale of I–III.

- Grade I – partial tear with moderate pain and minor loss of function. Individual experiences pain but can continue to perform the task or activity they are engaged in.
- Grade II – partial tear with severe pain and significant loss of function. Individual has to stop the task or activity they are engaged in.
- Grade III – complete rupture, complete loss of function and absence of pain.

## Mechanism

An FT needs to appreciate the 'mechanism of injury' (MOI), in other words, how the injury happened. A trainer should investigate where the client was when the accident happened, what environment they were in, and what the situation and circumstance was. The answer to these questions may provide clues as to how the injury occurred and what tissues, if any, have been damaged. Most musculoskeletal injuries are either:

- Acute – sudden onset resulting from sudden force
- Chronic – slow onset due to some pattern of overuse or repetitive strain

If a symptom profile is more complex and less recognizable, pain may not relate to traumatic injury, but rather a more 'sinister' *systemic condition*. Symptoms indicating non-musculoskeletal pain might include:

- Multiple sites of pain
- Unremitting pain
- Pain not associated with movement
- Diffuse pain
- Night pain

These symptoms represent '*red flags*' and indicate a need for immediate medical referral. Other non-traumatic causes of pain include:

- Osteoarthritic pain (related to age- and use-related degeneration)
- Visceral pain
- Psychosomatic pain

*Osteoarthritis* is a type of joint disease with age- and use-related degeneration. Pain can arise due to use-related damage to joint structure, cartilage and bone. Symptoms of osteoarthritic pain can include:

- Pain within joint spaces
- Pain aggravated with prolonged use, loading or weight bearing
- Dull pain progressing to sharp on movement or loading
- Swelling on occasion
- Instability in early stages
- Stiffness in later stages

*Visceral pain* originates from disease or dysfunction of visceral organs (stomach, kidney or heart etc.). Symptoms of visceral pain can include:

- Diffuse and ill-defined pain
- Coupled with systemic symptoms
- Unrelated to movement. Often unremitting

*Psychosomatic* pain relates to emotional distress. Its symptoms can include:

- Client is suffering emotional distress, anxiety or depressive symptoms
- Pain can be relieved using relaxation strategies
- In the case of stress-related psychosomatic pain (whilst not recommended), pain will often be relieved by having a glass of alcohol

Whilst an FT should not diagnose or prescribe, he or she is well placed to prescribe functional movement to manage a client's condition, in conjuncture with a qualified medical professional. A trainer can encourage appropriate behavioral change, encouraging a client to minimize activities that might aggravate or exacerbate an injury. When required, an FT will refer, encouraging a client to seek qualified medical attention.

### Chronicity

*Acute* injuries can be classified based on the time of injury. Injuries should pass through reasonable predictable patterns of healing and repair. *Chronicity* refers to the *stage of repair* tissues are within.

- Acute – the first three days following the point of injury
- Sub-Acute – 72 hours to 21 days from the point of injury
- Chronic – 21 days to two years from the point of injury

If an injury is not resolving within a reasonable time scale, a trainer might consider whether there is 1) some degree of unresolved structural damage, 2) a reason for poor tissue healing (e.g. inadequate nutrition or underlying systemic disease) or 3) patterns of behavior that are aggravating or maintaining injury and preventing repair.

## Traumatic Injury

Many clients experience 'soft tissue injury', a muscle strain or fascial sprain. The causes of injury can be complex, but we can consider *acute soft tissue injury* to arise from one, or a combination of the following four potential sources:

- Overload
- Confusion
- Overuse
- Underuse

### Overload

Overload injury occurs when tissues are exposed to forces exceeding the ability of tissues to cope. For example, a kick to the leg can damage blood vessels, bruising muscle and causing swelling. A missed step can twist an ankle, damaging ligaments. A client might tear a hamstring running, after accelerating from a standing start. These would all be examples of *overload injury*.

Overload is unusual in healthy tissue. Under normal circumstances, the body is well adapted to cope with the demands of functional movement. Muscles, ligaments and bones are well adapted to absorb forces when loaded in a 'normal', functional manner. It can take great force to rip, tear or fracture healthy tissue or bone.

**PERPETUAL MOVEMENT**

*To maintain homeostasis our internal physiology is always moving:*

- *The heart beats 120,000 times a day to ensure arterial perfusion*
- *The diaphragm moves 24,000 times per day to not only maintain movement of oxygen but also assist in venous return and lymphatic drainage*
- *Continual intestinal waves of peristaltic motion support digestion*
- *Muscle contraction stimulates lymphatic fluid flow that prevents swelling and congestion and removes inflammatory fluid*

Overload tends to occur either when clients are exposed to forces that are 1) greater than normal, 2) applied in an unusual direction or an unexpected manner or 3) applied to tissues suffering underlying dysfunction or loss of health, undermining their ability to absorb load.

Acute traumatic injury is common in competitive sport, where increased force, speed, load and unexpected collisions increase risk of overload. In healthy individuals, acute injury usually requires forces that are either:

- Extremely large
- Unexpected
- Unusual

## Confusion

You may have experienced that feeling of missing a step, walking into a pot-hole, being tackled by an opponent without seeing them coming. In these instances '*confusion*' has caused tissues to be loaded in an unusual or unexpected manner.

Confusion increases the chances of injury. Unexpected loading undermines the motor system's ability to prepare for load and reduces the ability of an individual to *adapt* and *react*. Confusion reduces readiness and undermines the ability of the body to stabilize, absorb and redistribute load. An absense of preparatory stabilization undermines customary adaptive responses to stabilize the body, creating a situation in which stabilizing systems are ill-prepared to absorb load, making injury far more likely. As boxers say, 'it is the punch you don't see that knocks you out'.

The key to avoiding confusion is to predict problems before they occur, to recognize situations that are potentially hazardous. Athletes spend years developing an intuitive understanding of their sport, becoming risk aware and conscious of threat.

## Overuse

*Overuse* is the gradual breakdown of tissue over time. Overuse usually arises as a result of prolonged exposure to repetitive and unvaried loading, even at light to moderate loads. Repeating the same task over and over slowly fatigues tissues, overloads tissue resilience and overloads the ability of tissues to cope. Micro-trauma caused by unrelenting overuse can eventually cause pain and injury, a process referred to as *repetitive strain injury (RSI)*.

Overuse is common in situations in which an individual is required to perform the same task over and over, in a highly repetitive pattern, absent of variation. It occurs frequently in the workplace or in sport. RSI is common from repetitive typing or sitting. We often see overuse injuries in sport. Baseball pitchers suffer elbow injuries as a result of repetitive throwing, boxers experience early onset Alzheimer's from repeated punches and runners experience issues because they tend to run the same direction around a track.

The key to preventing overuse injuries is to avoid overly repetitive behaviors or rigid movement patterns (i.e. create movement variation) and to introduce 'intelligent variation'. Performing tasks in different ways allows tissues to rest and recover whilst others work.

## Underuse

Movement is essential for health and a lack of use can be a major source of pain and dysfunction. Just like a balanced diet, the body needs a healthy balance of movement. Varied movement is essential for physical and mental well-being and a lack of movement is a major source of pain and dysfunction. Along with poor diet, a decline in daily movement is a fundamental factor in the modern-day epidemic in obesity-driven illness, health disorders, arthritic conditions and chronic pain.

Becoming more active and introducing exercise and play into your daily routine is essential for

**MOVEMENT HEALS**

*In the past, patients with back pain were prescribed bed rest, whiplash was treated with long periods of time in neck braces and patients stayed in hospital for long periods after surgery. To recover from surgeries and significant injury, patients are now not advised to rest but to move as soon as possible. After surgeries, knee joints are passively mobilized, after hip replacements patients are walking almost the next day. To facilitate healing, joints are mobilized and bones are loaded to stimulate repair. Time spent in casts is reducing. Even modern medicine is starting to appreciate the benefit of movement for healing and tissue repair.*

maintaining health and preventing pain or injury from *underuse*.

## Stages of Soft Tissue Repair

There are various physiological processes associated with each stage of *soft tissue repair*. By understanding these processes, a functional trainer can prescribe a movement and rehabilitation program to best support recovery. The body has three distinct phases of healing following injury:

- Inflammatory phase
- Repair phase
- Remodeling phase

By determining the point at which injury occurred, a trainer can make an educated guess as to which phase of repair a client may be in, and therefore what appropriate action should be taken.

### Inflammatory Phase

Following acute injury, damaged blood vessels seep blood into local tissue, creating swelling. If the injury has split skin, the area is open to the air and vulnerable to infection. Damaged tissues are weak and vulnerable to further injury if loaded. In this early stage of injury, the body's priority is to:

- Prevent infection
- Control bleeding
- Avoid further injury

*Inflammation* is the body's primary response to insult and injury, and the first stage of soft tissue repair. Damage to tissues triggers the release of pro-inflammatory mediators such as prostaglandins, serotonins, protons, bradykinin, leukotrienes, amines, nerve growth factor and cytokines. These neurotransmitters trigger:

- Clotting
- Brief initial vasoconstriction
- Subsequent rapid vasodilation

*Clotting* and vasoconstriction prevent further blood loss and close the wound. A clot seals unprotected tissue, preventing infection. Subsequent vasodilation causes a rush of blood to the local area. Blood carries immune cells, including macrophages and phagocytes that kill bacteria, debride damaged tissue and release chemical factors, such as growth hormones that stimulate repair. Characteristics of *inflammation* include:

- Dolor – pain
- Calor – heat
- Rubor – redness
- Tumor – swelling

Another acronym, 'PRISH', is also used to identify the cardinal signs of inflammation, which are pain, redness, immobility (loss of function), swelling and heat. Vasodilation and subsequent increased blood flow cause swelling, which in turn leads to local stiffness. Stiffness is initially helpful because it restricts movememt, preventing an exacerbation of injury due to uncontrolled movement on unstable and vulnerable tissues. Swelling not only causes a considerable loss of mobility but also inhibits local muscles, resulting in weakness and instability.

Whilst inflammation is an adaptive response to injury, it is usually an *over-response*. Left uncontrolled, excessive levels of inflammation create local swelling, creating pockets of pressure that prevent the inflow of fresh blood to the area, which in turn slows the healing process. Blood flow is essential for tissue nutrition and healing. To facilitate healing, efforts should be made to *moderate* the inflammatory response, removing excess swelling and encouraging healthy blood flow.

The PRICE protocol is a popular protocol for moderating the inflammatory response and anti-inflammtory medications are frequently prescribed following acute injury to manage inflammation and reduce pain.

## Repair Phase

The sub-acute phase of soft tissue repair is characterized by '*repair*' and is therefore often referred to as the 'repair phase'. During this *repair phase*, damaged tissue is restored and regeneration occurs. The repair phase is characterized by:

- Scar tissue formation
- Angiogenesis

Scar tissue formation is the next stage of healing and involves *fibroblasts* acting to produce and lay down collagen filaments. Immature scar tissue is deposited in a random or *haphazard* manner, and therefore injured tissue still lacks strength or resilience compared to the healthy tissue it replaces. The fragility of scar tissue makes the risk of re-injury in the repair phase high.

Scar tissue reaches in different directions, binding with neighboring fascia and muscle sheaths, causing stiffness, poor movement and loss of localized function. Excessive or improperly formed scar tissue slows the healing process. Scar tissue is highly sensitive to touch and triggers pain on movement. Replacing scar tissue with healthy functioning tissue is an important stage of recovery, often negleted.

Loading stimulates fibroblastic action, stimulating the conversion of *haphazard scar tissue* into healthy functional soft tissue. Repair and regeneration of scar tissue is supported by gentle loading. Loads have to be low to avoid re-injury and are best applied along functional lines. Loaded movement should be moderated in the repair phase to avoid overload of vulnerable tissue. By loading tissues in a manner similar and specific to how they will be used in daily life, scar tissue is remodelled along functional lines of stress.

As new scar tissues form, capillaries sprout to replace damaged ones. New blood vessels bring a fresh supply of nutrient rich blood. The process of revascularization is referred to as *angiogenesis*. Endurance exercise at a low intensity supports angiogenesis and stimulates blood flow.

### APPLICATION – PRICE PROTECTION – REST ICE – COMPRESSION – ELEVATION

*The PRICE protocol should be our initial response to inflammation resulting from acute injury. Ice, compression and elevation are strategies used to prevent excessive fluid accumulation by encouraging vasoconstriction (using cold) and encouraging venous return.*

## Remodeling Phase

Remodeling is the final phase of soft tissue repair. In the early *remodeling phase*, cross-bridges form and collagen fibers shorten, tightening scar tissue and making it progressively more reliant to stress. As scars tighten, they pull on and deform surrounding tissue, creating stiffness and tension. Loss of mobility is a side-effect and functional exercises should be prescribed in the remodeling phase of soft tissue repair to restore mobility.

Scar tissue is also sensitive, triggering pain when stimulated by movement. Pain inhibits the action of local muscles, making the area prone to weakness and instability. In this early stage of healing, scar tissue is rigid, brittle and susceptible to re-injury. As tissues remodel, exercise should be prescribed to activate local muscle tissue as well as remodel and remove scar tissue.

As remodeling continues, collagen fibers aggregate, orientate and organize themselves along lines of mechanical stress, a process that relies on the mechanical stimulation provided by movement. Scar tissue not stimulated by movement fails to be broken down, leaving bulky remnants, left unabsorbed and preventing a return to normal function.

Without adequate mechanical stimulation, scar tissue is not broken down or reabsorbed to be replaced with healthy tissue. To *remodel*, scar tissue has to be exposed to stress and strain. Stress is ideally applied along functional lines of movement, so that tissues adapt in a way that will be beneficial when the client returns to function.

In conventional rehabilitation, exercises are prescribed to isolate specific injured tissues without consideration for how those tissues will be loaded within function. For example, a client may strain a hamstring. A conventional approach to treating this injury may be to load the hamstring using a Leg-Curl machine. The client would sit and pull the heel towards the backside against a resistance. The Leg-Curl loads the hamstring, stimulating repair, but in a manner that fails to reflect how tissues will absorb load during function. Scar tissues stimulated this way may not repair in a manner relevant to function, increasing the risk of re-injury.

To prevent injury, scar tissue should be remodelled in a manner reflecting patterns of loading experienced 'within function'. Next, we discuss how functional training can support the various stages of soft tissue repair.

## Supporting Soft Tissue Repair

Functional exercise can be a highly effective tool in supporting repair following acute soft tissue injury. Always bear in mind, a functional trainer should always consider referring to a qualified medical professional for specialist advice before the onset of a functional rehabilitation program. The decision to refer will depend upon the attitude of the client, the nature of the injury and the severity of that injury. Functional training is an effective tool in supporting recovery from mild injuries, aches, sprains and strains, but a qualified medical professional should always be consulted when injury and loss of function is more severe.

Any client presenting with 'red flag' signs or symptoms should be immediately referred for further investigation. '*Red flags*' are signs and symptoms of 'sinister' pathological processes, including:

- Unremitting pain
- Pain unrelated to movement
- Night pain
- Rapid or unexplained weight loss
- Fever or temperature
- Recent severe trauma
- New structural deformity
- Lancinating pain referral down the leg
- Pain coughing or bearing down
- Pain coupled with loss of sensation in the 'saddle' area of the lower extremity
- Abdominal pain
- Change in bladder or bowel habits
- Unremitting thoracic pain

A trainer should refer if a client is concerned or apprehensive about their condition, if the client's condition is not improving or is worsening. Refer a client with:

- Red flag signs and symptoms
- Concern or apprehension
- Deteriorating condition

A trainer should always act in a professional and appropriate manner and maintain a good working relationship with other medical professionals and other trainers. Once a client has been cleared for exercise, functional training can run alongside mainstream medical intervention.

## Injury Evaluation

An FT is not qualified to 'diagnose' conditions and is rarely asked to coordinate rehabilitation in the early stages of major, acute injury. Functional training is of most benefit in the mid to late stages of rehabilitation, in the *repair* and *remodeling* phases of healing and in *chronic pain* conditions.

The first step in any functional rehabilitation program is to assess a client's condition and movement ability. This takes place within a client appraisal and functional evaluation in much the same way as with normal, healthy clients. The goal is to identify deficit and dysfunction relating to a client's pain or injury, and identify potential causes and predisposing and maintaining factors for these deficits.

To design a functional rehabilitation program a trainer is likely to need details of a client's pain and injury, including:

### Location

- Is the client currently experiencing pain or dysfunction?
- What are the key areas of concern?
- Has the client experienced pain or injury in the past?

### Quality

- If pain is the main concern, what does your pain feel like?
- On a score of zero to ten, ten being the worst pain you can imagine, how painful is it?
- Does pain radiate or travel? (E.g. down the leg, into the arm)
- If the client is experiencing dysfunction, what does that feel like? (E.g. stiffness, difficulty moving, difficulty performing certain activities)

### Cause

- How did the pain start?
- Did the pain start with a particular event or injury?
- What were you doing?
- Where were you?
- How did you feel at that time?
- Did the injury make you stop what you were doing?

### Pain Patterns

- What movements cause you pain?
- What movements cause you apprehension or concern?
- What movements do you find difficult? (I.e. stiffness or loss of range)
- What activities are you doing when you experience pain?
- What makes pain worse?
- What relieves your pain?

### Mechanism

- Did the problem start with a specific event?
- What exactly happened?

### Chronicity

- When did it occur?
- How long has the pain been a problem?
- How has the pain changed in this time?
- Is this the first episode?
- Have you had similar problems in the past?

## Context

- When do you experience pain?
- Is it any particular time in the day?
- What are you doing when you experience pain?
- Does pain or dysfunction prevent you from doing anything or cause difficulty with any specific activities?

## Cause

- Why do you think the problem started?
- Do you think anything predisposed this problem?
- Were there any changes in your activity, habits or behaviors around the time of the onset of the pain/problem?

## Emotion

- How does this problem make you feel?
- What is the problem stopping you from doing?
- How has your life changed?
- How positive are you about the pain resolving?

## Patterns of Daily Activity

- What do you do for work?
- What are your hobbies, sports …?

## Goals

- What are your goals for training?
- What do you want to achieve?

Note, the word 'pain' is interchangeable with any other of the client's symptoms. A client might complain of aching, stiffness, numbness, tightness and so on. The goal is to establish a clear vision of the client's injury and their perspective on the impact of that injury. A trainer should clearly understand the client's experience relating to injury and the significance they attach to those experiences.

Always allow a client to 'tell their story'. Do not be overly leading. By leading the client, a trainer may miss important information and superimpose their own expectations. Always ask open, non-leading questions to allow a client to give an accurate portrayal of their experience as it relates to injury. From this discussion, a trainer can ascertain:

- The nature of pain or injury
- The site of pain or injury
- The stage of soft tissue repair of injury
- Possible causes of pain or injury
- The impact of that pain or injury
- Potential predisposing and maintaining factors

The goal of a functional rehabilitation program is to design a bespoke program of movement aimed at restoring a client's function. From what we know of pain, we can say that many of a client's functional restrictions, aches, pains and dysfunctions relate to how they *feel* about their injury and subsequent condition. In many cases, pain and dysfunction recede as confidence in movement expands.

Reducing pain is a side effect, not a focus of functional rehabilitation. In the case of actual soft tissue injury, functional rehabilitation should reduce apprehension about pain and injury, support soft tissue repair and help restore movement ability. The first steps in a functional rehabilitation program for acute soft tissue injury include:

- Removing the cause of injury
- Supporting soft tissue repair
    - *In the acute or inflammatory phase*
    - *In the sub-acute or repair phase*
    - *In the chronic or remodeling phase*

## Remove Causes of Injury

The first step in any functional rehabilitation program is to eliminate any potential cause of injury. In the inflammatory phase, damaged tissue is weak and vulnerable to overload. Premature return to function can aggravate and exacerbate tissue damage, delaying the healing process. Injuries often re-occur due to an untimely return to function. 'Re-injury' is often worse than the initial insult.

Most injuries arise from either overload or overuse, or a combination of both. A trainer should encourage a client to either cease or at least moderate behaviors that might exacerbate injury or hamper recovery. For example, a client experiencing back pain after lifting a heavy box might limit how much 'lifting' they do in the period immediately following their injury.

As part of a client appraisal, an FT should also identify potential sources of overuse and repetitive stress. If pain is aggravated by sitting for extended periods of time, a trainer might encourage that client to take regular breaks to get up and move around. For any client experiencing injury, it is prudent to avoid tasks, activities and behaviors that 1) triggered the initial injury or 2) reproduce pain and create a sense of apprehension.

If a client is experiencing shoulder pain whilst decorating, a trainer might advise a client on how to moderate patterns of use, introducing variety into a work schedule to reduce stress and allow recovery. 'Pacing' is a useful concept to discuss with clients. Pacing involves balancing patterns of work, activity, exercise and rest to avoid overuse or underuse.

Once a client has reduced the potential for re-injury, a functional rehabilitation program can then take place to support the various stages of soft tissue repair.

## Supporting Healing in the Inflammatory Phase

In the inflammatory phase of healing, clots form to prevent blood loss and reduce the risk of infection. Local blood vessels dilate, increasing blood flow that brings nutrients for healing and immune cells that attack damaged or foreign tissue.

Whilst essential in the early stages of healing, the inflammatory response tends to be an *over-reaction*. Local vasodilation leads to a pooling of fluid local to the site of injury, creating *swelling*. Excess swelling can hamper the healing process by preventing adequate flow of blood to the area and by restricting movement of local joints. Efforts should be made to moderate the inflammatory response. The PRICE protocol is a classic approach for avoiding excessive inflammation and swelling.

- Protection – avoid further injury
- Rest – avoid further injury
- Ice – vasoconstriction and pain gating
- Compression – assist venous return
- Elevation – assist venous return and lymphatic drainage

Clients should 1) apply splints, braces, strappings, supports and bandages to '*protect*' the site of injury; 2) '*rest*' from tasks and activities that exacerbate pain or swelling; 3) apply a '*cold*'

### CRYOTHERAPY – COLD APPLICATION PROTOCOL

*In the acute phase cold can be used to stimulate local vasoconstriction (i.e. constriction of blood vessels, reducing blood flow). Ice can be applied using a cold pack, a bag of peas or ice wrapped so as not to cause damage to tissue. Although protocols vary, we suggest applying comfortable cold for roughly three minutes, three times, with enough time between applications to allow the area to reheat. Athletes will often plunge into an ice bath immediately post performance to support recovery. Excessive exercise causes a form of micro-trauma to muscles and other soft tissue that is similar to injury.*

compresses to encourage local vasoconstriction; 4) apply '*compression*' using a Tubigrip dressing or strapping, for example, to moderate swelling and assist venous return; and 5) elevate the site of injury above the level of the heart (at rest) to encourage venous return.

## Managing Pain in the Inflammatory Phase

Whilst commonly regarded as a negative consequence of injury, *pain* is actually reasonably beneficial in the inflammatory phase. Pain signifies when movement, tasks and activites place damaged tissue under stress and strain, potentially exacerbating and aggravating tissue damage.

By adapting movement to avoid pain, we 'off-load' damaged tissue, preventing further tissue injury. Pain triggers 'antalgic' patterns of movement, variations in movement strategy designed to avoid pain. In functional rehabilitation, these are known as a client's '*pain patterns*'.

A limp is a form of antalgic gait. A client might limp after spraining an ankle, causing damage to ligaments and local swelling. In the early stages of injury, antalgic movement patterns like a limp are useful becasaue they trigger changes in movement to reduce loading compromised tissue.

Rather than instructing a client to walk 'normally' in the early stages of rehabilitation, a functional trainer should encourage antalgic patterns of movement and explain that in the inflammatory phase of healing:

- 'Pain is a normal reaction to injury'
- 'Antalgic movement patterns are fine'
- 'Keep moving, but without exacerbating pain and swelling'
- 'Increased pain or swelling is a sign you have done too much'

Pain is not pleasant. Movement should be moderated to avoid exacerbating pain or swelling. Most clients will ask, 'what can I do? Can I still exercise?' My advice is generally 'if it hurts … don't do it.' Moderate behaviors that avoid intensifying pain or exacerbating swelling.

To manage pain in the inflammatory phase, one strategy is to apply a 'pleasant' sensory stimulus to the local area. Cold, gentle mobilization, mild stretch and gentle massage can all be carefully applied to the injury site to generate a mild sensory stimulus that competes with pain sensations traveling through sensory nerves to the brain, creating a sense of relief. The phenomenon in which mild thermal or mechanical stimuli act to reduce pain sensation is referred to as '*pain gating*'. (Note that heat vasodilates blood vessels. As such, heat may exacerbate swelling in the inflammatory phase and so may not be appropriate. Better to apply cold in the early stages of injury).

## Boosting Circulation in the Inflammatory Phase

In the inflammatory phase, various neurotransmitters are released at the site of injury, triggering vasodilation and increased local blood flow. As blood pressure at the injury site increases, plasma leaks from blood vessels into the interstium, leading to swelling. Swelling exacerbates the pain and stiffness associated with injury and hampers the healing process by preventing healthy fluid flow. Steps should be taken to moderate the inflammatory resonse and reduce swelling.

The lymphatic system is responsible for returning fluid from the interstitium back to the blood stream. The lymphatics act like a secondary circulation, returning fluid back to the venous circulation. Unlike the cardiovascular system, the lymphatic system lacks an active pump. There is no heart to pump fluid through the lymphatic circulation, therefore the lymphatics rely on mechanical stimulation from several sources, including:

- Movement
- Muscle contraction
- Mobilization
- Diaphragmatic action
- Breathing
- Walking
- Massage

A functional trainer can apply this information to create a functional rehabilitation program that encourages lymphatic flow, reduces swelling and accelerates healing in the inflammatory phase.

### Movement and Muscle Contraction

Movement stimulates the venous and lymphatic circulatory systems. The lymphatic system works 40 times more efficiently when we move. The contraction of muscles is particularly helpful in pushing fluid through vessels. As long as movement is painfree, contracting muscles pump fluid through the body. Moderate functional movement is one of the most effective methods for reducing swelling and managing inflammation.

### Mobilization

The gentle rhythmic movement of joints creates a pumping effect that stimulates fluid flow. Gentle, unloaded mobilization of local joints can be very useful in assisting lymphatic flow. Mobilization involves taking joints smoothly through a full, pain-free range of motion. Mobilization can be either passive, i.e. performed by the trainer with the client relaxed, or active, with the client gently mobilizing joints in a safe and secure manner.

### Diaphragmatic Action

The body has various fascial diaphragms and domes located within it. The plantar fascia forms a diaphragm on the sole of the foot, the pelvic diaphragm and thoracic diaphragm move when we breathe and the fascia found at the base of the neck create what is known as the thoracic inlet, for example. Fascial domes expand and contract with movement, stimulating changes in pressure within fascial cavities that pump fluid around the body and support lymphatic drainage. Exercise that stimulates fascial domes supports recovery by clearing inflammatory fluid and reducing swelling.

- Walking stimulates the medial arch and plantar fascia
- Loaded movement stimulates the pelvic diaphragm
- Breathing activates the thoracic diaphragm
- Movements of the head, neck and shoulders stimulate the thoracic inlet

Dysfunctional movement, stiffness, rigidity, lack of local strength or stability all undermine fascial function and therefore the function of fascial domes. A functional trainer should assist healing and support repair by prescribing exercises to stimulate and restore diaphragmatic function. A

#### SOLEUS, THE SECOND HEART

*The soleus passes very close to many blood and lymphatic vessels in the deep calf. Contraction of the soleus and other deep compartment muscles during walking provides rhythmic contractions that help pump fluid back to the heart from the feet. Lack of movement in these muscles, like during a long flight, often results in swelling around the ankles.*

**Figure 7.1** Pelvic Tilt.

**Figure 7.2** Knee Swings.

**Figure 7.3** Shoulder Rolls.

**Figure 7.4** Head Turns.

functional trainer might ask a client to massage the base of the foot with a ball to mobilize the plantar fascia, assess the quality of a client's breathing or prescribe exercises to mobilize the neck and shoulders, for example.

## Breathing

Breathing is one of the most powerful mechanisms for driving fluid flow. During breathing, the thoracic diaphragm (the primary breathing muscle) contracts and expands. On inhalation, the thoracic diaphragm pulls downwards, expanding the lungs and creating a pressure gradient that draws oxygen from the atmosphere into the lungs. Changes in cavity pressure also drive lymphatic flow and assist fluid drainage.

Encouraging functional breathing exercises are an excellent strategy for reducing inflammation and supporting fluid return. 'Mindful' breathing, learning to engage the thoracic diaphragm, mobilizing the ribs and many other techniques are useful in improving fluid flow. Just encouraging some mild cardiovascular work is useful in assisting recovery.

### Walking

Functional movements that stress the cardiorespiratory system, like stepping, walking and running, can create a 40-fold increase in lymphatic flow. This is one of the fundamental reasons why movement is essential for healing. Walking is a fantastic example of a travel pattern that is a great way to support healing.

Walking is a cyclical whole-body movement that stimulates each and every fascial diaphragm of the body. Walking rhythmically loads the arch of the foot, contracts the calf muscles, drives rotatational movement through the pelvis, activates the pelvic diaphragm, intensifies breathing and drives rotational movements of the neck and shoulders. Walking is the simplest and most effective movement for enouraging lymphatic flow and is not only physically restorative, but also great for mental health and relaxation. Walking is one of the most powerful tools a client can employ to support soft tissue repair. As soon as they weight bear without pain, a client should start walking.

### Pharmacological Intervention

General practitioners often prescribe medication to manage pain and reduce inflammation. Over-the-counter 'non-steroidal anti-inflammatory medications' (NSAIDs), such as Ibuprofen, can be taken to manage the inflammatory response. Whilst not their scope of practice to prescribe medication, a functional trainer can recommend a client seek medical advice, either from a pharmacist or GP regarding medication to manage pain and inflammation.

Medication should be a short-term intervention to manage sysmptoms and support a return to normal function. Whilst effective, medications tend to have side effects that impact health. Taken over extended periods, Ibuprofen irritates the stomach lining, causing digestive symptoms, for example.

### Massage

*Lymphatic drainage massage* is intended to push fluid through soft tissue, assisting venous return. Massage strokes are directed from tissues, back towards the heart, literally pushing fluid through the body. Massage is a useful tool to support recovery by improving lymphatic circulation.

## Supporting the Repair Phase

In the *repair phase*, fibroblasts deposit collagen to form a scar tissue. Collagen is deposited in a haphazard manner, giving it poor structural integrity and making it susceptible to re-injury. In the repair phase, functional movement can be used to rehabilitate and strengthen scar tissue.

Mild tensile stress applied through scar tissue re-orientates collagen fibers and promotes healing. To support repair, scar tissue should be exposed to mechanical stress. Stress is best applied in a manner that reflects how tissues are loaded within function. This way, collagen re-organizes along useful and relevant lines of stress, and in a manner that prepares tissues for a return to function.

The simplest strategy for supporting repair is to expose clients to low-intensity functional movement. For a 1-week old hamstring strain, for example, a conventional approach would be to prescribe a 'Leg-Curl', but it would be far better to squat, bend or reach at low intensities, loading the hamstring whilst avoiding aggravating pain or swelling.

Functional movement is a fantastic tool in supporting the rehabilitation of immature scar tissue. In the repair phase, loads should be moderated to avoid re-injury. Training should provide a *graded exposure*, slowly and systematically increasing load in line with what the client feels is safe and secure. As healing progresses and function is restored, loads are progressively increased. An exacerbation of pain or swelling indicates intensity has been increased too quickly and exercise should be regressed.

## Managing Pain in the Repair Phase

In the repair phase, pain recedes, but tissues are still vulnerable to re-injury. One of the key challenges at this point is to ensure that a client does not return to normal function too quickly. A lack of pain means a client has no warning that loading is too much. Immature scar tissue still lacks resilience to load and risk of re-injury is high, especially if return to function is too quick. A gradual 'graded' return to function reduces risk of re-injury. A functional trainer needs a clear idea of how long tisues take to re-strengthen so that they can manage a client's expectations.

A functional trainer should 'moderate' a client's behavior, managing their thoughts, attitudes and beliefs regarding injury to support a successful return to function. Most clients experience apprehension on returning to function and may even develop a fear of movement.

Fear of movement often causes people to withdraw from exercise completely, restricting movement to a degree that actually hampers recovery. These clients have to be reassured and encouraged to move. Research indicates that negative beliefs regarding pain and injury increase the likelihood of pain persisting beyond the repair phase. Clients are more likely to suffer *persistent pain* if they show signs of:

- Catastrophization – an increased pain perception
- Perception of negative outcomes – belief injuries will not heal
- Negative beliefs on pain and injury – believe pain relates to damage

Steps should be taken to reduce the likelihood of persistent pain. The FT should highlight that:

- Pain resolves
- Tissues heal
- Movement supports healing

Athletes or clients more accustomed to pain and discomfort are often eager to return to sport and down-play symptoms and under-estimate recovery times. For these clients, movement behaviors have to be moderated and alternative activities prescribed that avoid risking re-injury. A clear and agreed set of goals and signposts for progression of movement and exercise is essential. Throughout any 'repair' process, a trainer has to manage a client's thoughts, attitudes and beliefs, identifying when expectations become unrealistic or when behaviors do not facilitate recovery.

## Supporting the Remodeling Phase

In the *remodeling phase*, scar tissue is mature and robust. Pain should have subsided and tissues healed. At this stage, scar tissue is 'remodelled' – massaged by movement and broken down to be replaced with healthy functioning tissue. Remodelling of mature scar tissue can continue over weeks, months or even years, as tissues are slowly restored to their original state.

The effective remodelling of scar tissue relies on tissues being stressed. Mechancial stress is best applied along lines of stress that reflect how those tissues will be loaded within functional movement. The best way to reproduce these 'functional' stresses is to perform functional movements but at levels that do not compromise weakened tissues. In the remodelling phase, there should be no need for specific rehabilitation exercises, only a graded return to 'normal' function.

In the remodelling phase of soft tissue repair, tissues have all but healed and pain should have resolved. Research tells us one in five people continue to experience pain, what we refer to as 'persistent pain'. Persistent pain is complex and is covered in greater depth in the following section.

Throughout a client's recovery from acute injury, functional movement is an invaluable tool to support soft tissue repair. The graded exposure to normal movement also helps build a client's confidence, which is critical for avoiding persistent pain. Functional movement should be prescribed at every stage of a client's recovery, to optimize tissue repair and avoid physiological and neurological complications of injury. Functional trainers should encourage a graded return to normal patterns of movement whilst avoiding exacerbating pain and swelling and, wherever possible, without risking re-injury.

Consider a client suffering a 'Grade-I Back Strain'. In the acute phase, functional mobilization of the lower back will reduce pain and swelling. A trainer might recommend supports and strappings to off-load lumbar muscles and ligaments.

Alongside prescribed analgesia, a functional trainer can recommend a program of sensory stimulation to help manage pain (cold, heat, stretch, massage, movement etc.) and design a program of functional movement to systematically re-introduce *pain patterns*. In this case, a trainer might slowly re-introduce twisting, reaching, bending and lifting movements into a client's program, matching loads, speeds and directions of movement to avoid pain and swelling and to match the client's stage of repair. Movement behaviors would be moderated as tissues repair and confidence builds.

In the early stages, a trainer would apply principles of *intelligent variation* to design exercises that do not trigger pain or apprehension. Pain patterns can be adapted in terms of *movement strategy*, including tweaks in posture and position, load, speed and distance to avoid pain and to ensure the client feels safe and secure.

Throughout the rehabilitation process, a trainer should manage a client's beliefs and expectations as they build confidence. Functional rehabilitation is discussed in greater depth later on. As rehabilitation continues, exercise intensity can be increased, building in speed, variation and complexity of movement to support the healthy repair and remodelling of scar tissue. In the later stages, loads can be increased so that a client experiences the full restoration of movement ability.

## Introduction to Injury Prevention

Injury prevention is a huge topic, covered in greater depth later in this chapter. To start, we might consider injuries arising from one (or a combination) of four main factors:

- Overload – forces exceeding the ability of tissues to cope
- Confusion – unexpected or atypical loading
- Overuse – chronic repetitive loading over time
- Underuse – chronic lack of use

To avoid injury, we should avoid each of these four factors. This can be achieved using the following strategies.

- Adapting tasks
- Modifying environments
- Building capacity
- Restoring variation
- Developing adaptability
- Improving reactions

### Adapting Tasks

The typical gym is safe and easy to use. Conventional training takes place in a slow and controlled manner, under maneagable loads. *Overload*, *confusion*, *overuse* and *underuse* is obviously rare because conventional exercises are pre-planned and pre-meditated, and therefore these things are all easily avoided. In function, events are less controlled and pre-meditated, and therefore injury prevention is far less straightforward.

In real life, movement is generally unpredictable. When we play games, tidy the garden, clear the house or go to work, the tasks we perform are nearly always complex and varied. The emotional drive to 'get things done' means we often tackle far more than is sensible. We end up performing repetitive tasks under awkward and unusual loads.

One self-employed mechanic I knew based himself in a workshop at home, working under cars and replacing gear boxes all by himself. The work can be repetitive, the loads extreme and postures and positions unusual. The lifts this mechanic had to perform are never replicated in conventional training. For this client, the risk of overload, overuse and confusion are high.

A key strategy for preventing injury is to manage the tasks and behaviors clients take on. Identifying and adapting patterns of behavior that can cause overload, confusion, overuse and underuse is an important strategy for avoiding injury.

Appropriate *pacing*, creating a healthy balance between work, activity, exercise, rest and recovery, coupled with varied patterns of use, can reduce the risk of overuse injury. Whilst many clients understand that training sessions should last 40–60 minutes, they think little of spending hours gardening. Many of us:

- Sit for too long
- Drive long distances
- Use PCs or laptops
- Carry heavy bags
- Carry children
- Play sports
- Lift repetitively, e.g. during gardening

## PACING

*A trainer can help a client set realistic goals and 'pace' behavior to balance work, activity, exercise, rest and recovery. Work is the activity we perform to earn a living. Just like exercise and activity, work expends energy and effort. At times we forget, just like exercise, our body needs recovery from work, which should be considered when planning an exercise program.*

*Activity is low-intensity exercise, below an intensity sufficient to make us breathless. A recent guideline suggests we should be active for what is roughly equivalent to 10,000 steps per day, but the more enjoyable activity is the better. Activity could include light gym training, walking, gardening, housework, dancing or singing.*

*Exercise is movement at such an intensity that it causes us to be out of breath, making it difficult to hold a conversation. Exercise is highly beneficial for health and well-being. Small doses of exercise can have a huge benefit. Thirty minutes of intense exercise two to three times a week can be sufficient to help maintain good health.*

*Rest and recovery is time away from exercise. Recovery strategies support sleep, hydration, diet, manage stress and so on. Sufficient rest and recovery are essential to avoid overuse. Details of when and how a client should rest and recover should be contained within a client's functional training program. Remember, we don't get stronger when we work but when we recover.*

A trainer can identify repetitive behaviors contributing to pattens of overuse or repetitive stress. A trainer can then help a client set goals, moderating activity and introducing variety into daily routines.

One of the key factors contributing to repetitive stress is chronic underuse. The human body is designed to move and prehistoric man would have walked between 5 and 9 miles each day to find food. Many of the body's recuperative and restorative processes rely on the mechanical stimulation of movement. In modern society, the majority of people have chronically low levels of physical activity, leading to underuse – a potential cause of many of modern societies prevalent health-related diseases and disorders.

There are many strategies a trainer can recommend to increase activity. Setting an alarm to get up from a workstation, taking a walk, using a standing desk, walking at lunchtime – the possibilities are endless. A functional trainer can provide clients with strategies to increase daily activity. A trainer could:

- Encourage regular walks
- Provide simple mobilization routines to perform at work
- Encourage a variety of resting positions and postures
- Change environment to encourage movement, (e.g. sit on a swiss-ball rather than a rigid chair)

## Modifying Environments

A trainer can minimize overload, confusion, overuse or underuse by asking the client to modify the *environment* in which they move. The surfaces we walk on, objects we lean against or obstacles in the way – environments drive movement behavior.

*Ergonomics* is the practice of modifying a client's environment to reduce risk of injury. This is most common in the workplace. Clients can switch chairs, reposition work stations or purchase ergonomic keyboards. Older clients might need additional support, walking sticks, kneeling mats in the garden or grip mats in the bathroom. Adapting the environment can dramatically reduce the risk of overload or overuse injury.

## Building Capacity

Building movement ability is one strategy that can make it less likely that a client experiences injury. But rather than developing 'general' fitness, training is most effective when it is *specific* and *relevant*. Whilst we could build non-specific strength and stamina, it is far better to develop the ability to perform useful tasks and skills.

If a client has to lift heavy boxes at work, for example, it makes sense to train to lift boxes. Training should be similar and specific and develop a client's:

- Pain patterns
- Primary movement patterns
- Secondary movements patterns
- Travel patterns

## Restoring Variation

Conventional thinking suggests injuries arise from poor form and technique – that faulty patterns of movement expose tissues to excessive biomechanical stress, and therefore predispose injury. Biomechanical approaches to injury prevention focus on correcting form and technique, effectively reducing variety of movement. Clients are taught how to lift or bend to avoid stress. They are taught to squat with knees over toes to prevent knee pain for example.

In a biomechanical model, 'variation' is identified as an error. According to neuroscience, the opposite is true. Research suggests groups suffering pain or injury exhibit more rigid patterns of motion compared with healthy individuals (Pollard et al., 2005). Injury is associated with less, rather than more variation. Just look at some of the research:

- People with low back pain alter muscle coordination patterns, decreasing variability in the timing of anticipatory postural adjustments (Jacobs et al., 2009).
- Loss of ankle stability after injury reduces movement variability during single leg jump-landing compared to healthy controls (Hopkins et al., 2012).
- Lateral ankle sprain results in alterations in the activation and recruitment pattern of muscles, reducing the number of motor strategies available to the individual and making them less able to respond to movement challenges (Hopkins et al., 2012).
- Achilles tendon injury cause 'distinctive and consistent pattern of loading' compared to uninjured control groups who displayed markedly different patterns of loading.
- Injured runners display decreased hip-knee and knee-ankle variability in the injured limb compared to the uninjured limb.

Clients suffering pain or injury tend to lose 'variability'. Behavioral rigidity is a side-effect of pain and injury, and one factor contributing to future re-injury. A lack of variability is associated with reduced *adaptability*, *redundancy* and *recovery*. As Stergiou et al. (2011) recognized, one of the key stages of functional rehabiliation is to restore *movement variability*.

Functional rehabilitating should encorperate a client's pain patterns, performed in lots of different postures and positions, in different directions, at varied distances and speeds, in a variety of challenging situations and circumstances (at intensities that do not trigger pain).

## Developing Adaptability

Being 'adaptable' means having the ability to modify movement in response to different tasks, skills and activities in awkward and unusual situations and circumstances, as well as having the ability to arrive at a number of different solutions to the same movement problem – a quality we refer to as '*redundancy*'.

*Adaptability* and *redundancy* are key factors in preventing injury. The main challenge we face in function is not extreme load but moderate loads, lifted in awkward and unusual ways. The level of complexity and variation inherent within functional movement means that adaptability is an essential element of injury prevention. To develop adaptability, training should be:

- Complex
- Novel
- Awkward
- Unusual

Exercises should be progressed not through increasingly high loads, which invariably reduces the variation in lifting, but through increased complexity and variation, progressively challenging a client's ability to adapt.

## Improving Reactions

Under normal circumstances, subconscious modulation and common sense mean we avoid lifting extreme loads. Tissues are also uniquely adapted to absorb the stress and strain of most common functional movements. These factors mean that, under normal conditions, overload injury is unusual.

Overload is far more common when loads are applied in an awkward and unusual manner, in a way we are not expecting. Tissues are not adapted to absorb loads in unsual directions and loads applied in an unexpected manner frequently circumvent preparatory mechanisms designed to create stability.

The knee, for example, is adapted to absorb huge axial loads, like those created when we run and jump, but it is poorly adapted to absorb rotational forces and valgus or varus strain, like a blow from the side of the knee. Loads applied rapidly and without warning, in unusual directions, often cause injury.

The ability to instantly and spontaneously adapt and react to unexpected and unusual forces is critical for avoiding overload injury. The question is, how do we develop a client's ability to react and adapt, developing spontaneous reactions to unexpected danger? The first step is to develop a client's *task-specific knowledge*, so that they get better at predicting problems before they occur. A footballer can start to sense when an opponent is going to make a last-ditch lunge tackle. They anticipate and learn to quickly jump out the way. The unfortunate truth is that these players are sometimes called up for 'diving', which given this analysis may be unfair.

Improving a cient's ability to anticipate, react and adapt is critical for injury prevention. A functional rehabilitation program should incorporate situations in which the client has to react to unusual, awkward and unexpected loads, adapt to unstable and shifting tools, obstacles and targets (see Figure 7.5).

**Figure 7.5** Adapting and Reacting – wobble board balance as an FT provides a reasonable level of disturbance

## Bringing It Together

Functional trainers should have a basic appreciation of common musculoskeletal injuries, be able to recognize those injuries, refer a client to a qualified medical professional where necessary, adapt training to accomodate injury and design a basic program of functional rehabilitation to facilitate the repair process and avoid the potential for further injury.

- An FT should be able to classify a client's injury based on the structure damaged, the severity, chronicity and stage of soft tissue repair that injury is at.
- The FT should be able to adapt training according to the stage of soft tissue repair and be able to explain how functional training can complement mainstream medicine and support a rehabilitation and repair process.
- In supporting injury prevention, an FT trainer should collaborate with a client to avoid overload, confusion, overuse and underuse. To achieve this goal, an FT will design behavioral changes and programs to:
    - Adapt the tasks a client is performing
    - Modify the environments in which a client moves
    - Build a client's capacity to perform challenging daily tasks and activities
    - Restore lost movement variability
    - Support a client's ability to adapt and react to unexpected changes in the environment

In the next section, we look at pain – what it is and how it evolves.

# PAIN

- Explain Pain
- Neuroscience of Pain
- Nociception
- Pain Perception
- Persistent Pain
- The Impact of Pain

In the previous section we discussed injury – how injuries occur and the characteristic symptom profiles of tissue damage. In this section we discuss *pain* – what it is, where it comes from and why we suffer from it.

Pain is generally perceived as a sign and symptom of injury. Most people assume that sensory nerves send pain signals to the brain, indiating when tissues are damaged. We see that pain is not produced within muscle, ligament, tendon or bone and is not transmitted via pain nerves to the brain telling us of damage. Pain is created within the *functional mind*.

Pain is a subconscious instrument designed to trigger a change in behavior to avoid hurt or harm. Pain is triggered when the subconscious perceives some sort of 'threat', the anticipation of danger. Pain protects us from harm but rarely reflects the actual state of tissues.

Functional trainers supporting rehabilitation from pain and injury need to understand that pain is regulated by the brain. Pain is triggered by the subconscious mind in response to threat.

## Explain Pain

Ever since the dawn of time, people have tried to understand pain – what it is and where it comes from. One of the first theories was that of Homer in the eighth century BC who described pain as 'arrows shot by Gods'. Aristotle (384–322 BC) thought pain was caused by evil spirits or gods entering the body after injury. Whether derived from the gods, flows from fields of energy, the moon or the stars, all cultures and societies develop ideas about what pain is.

In modern society, pain is associated with injury. The average person believes that injured tissues stimulate nerve endings that send signals to the brain, informing us of damage. The notion that 'hurt and harm are one and the same' originates from the Ancient Greeks. These sentiments were then echoed by the French philosopher René Descartes who proposed the *Cartesian model*.

The Cartesian model, in which nerves send signals to the brain telling us about damage, influence modern approaches to pain to this day. Many people suffering pain visit the local physician expecting a diagnosis, a summary of what is 'damaged', what muscle, tendon, ligament or bone is injured. Until recently, modern medicine validated this perspective.

A patient presenting to a modern clinic suffering pain is frequently referred for a scan, X-ray or MRI to identify the tissue causing the patient's pain. Patients are prescribed painkillers to alleviate symptoms and exercises to help stretch or strengthen the relevant soft tissue. In some cases, when scans reveal significant deformity, a patient is referred for surgery to remove the offending tissue lesion.

The Cartesian model is a simple perspective and one that makes sense. But when we look at the evidence, things get a little more squirly. Research proves the relationship between pain and tissue condition is far from straightforward. Surgeons scan patients to identify pain generating structures, disc lesions, osteoarthritic degeneration and bone spurs, but scan asymptomatic individuals and we see that in people past a certain age, osteoarthritic degeneration is commonplace. One in five people appear to have herniated discs but suffer no pain whatsoever. Wear and tear in later life is completely normal. When surgeons scan patients, can they be sure structural variations are the cause of the patient's pain?

Many people suffer pain without any discernable cause. Back pain and headache are some of the the most common reasons why people visit a doctor. In most cases, physicians are unable to identify any clear cause. Non-specific musculoskeletal pain is one of the greatest burdens on society. One in five people suffer from non-specific pain syndromes like:

- Back pain
- Neck pain
- Headache
- Migraine
- Myalgia

Patients with non-specific pain are frequently labeled with vague diagnoses such as 'lumbago' or 'myofascial pain'. Pain is often associated with psychosomatic conditions, emotional disorders and mental ill-health, stress or depression. These patients are often discharged with little or no treatment – prescribed medication and told, 'you will get better with time'. Physicians are trying to treat pain without truly understanding what it is or where it comes from.

Pain does not reflect the state of tissues. 'Hurt' does not reflect harm. A two-inch incision does not hurt twice as much as a one-inch incision. Pain can vary day-to-day and moment-to-moment without any discernable change in the state of tissues. A person can experience pain without injury or injury without pain. There is a clear lack of correlation between the state of tissues and how we feel

*Phantom limb pain* epitomizes the clear mismatch between pain and injury. Amputees, people who have lost an entire limb following trauma, often suffer pain in their missing appendage. Despite lacking a physical limb to cause pain, amputees often experience pain in the area that their limb would have been. How can this be? Phantom limb pain clearly shows that pain does not reflect the state of tissues (Flor et al., 2006).

Pain literature is full of interesting stories illustrating how pain and injury diverge. Tales of surfers oblivious to losing a limb, after feeling nothing more than a bump on the leg, yet later finding they have suffered a shark attack. Fighters continuing despite horrific injuries, broken hands or fractured jaws. Adrenaline seems to have made them impervious to pain. Pain is clearly complex and to this day scientists struggle to 'explain pain'.

## Neuroscience of Pain

Is pain 'sensed', 'perceived' or 'felt', or all three? Is pain a *sensation*, a *perception* or an *emotion*? Aristotle proposed that pain is not a sensation, but an 'emotion' – a state of feeling, originating not from within tissues but from inside the head, an experience that is altered by what we think and feel.

In the last 30 years, scientists have developed amazing new tools with which to investigate the brain. New tools such as *functional Magnetic Resonance Imaging (fMRI)* and *Computer Tomography (CT)* have meant that rather than prodding the surface of the brain, scientists can monitor the electrical signals and flow of fluid within the brain in healthy, functioning adults as they think and move. Scientists now understand more about pain and how it works than ever before.

There is no such thing as a 'pain receptors' – no 'pain nerves' sending signals to the brain telling us when we are injured. The only nerve resembling a pain receptor is the *nociceptor.* Nociceptors are sensory neurons that detect *abnormal deviations in local tissue condition*. Nociceptors are *high threshold receptors*, quiet and inactive under normal conditions. Nociceptors are only activated under higher levels of stimulus, when local tissue conditions change dramatically. Nociceptors normally lay dormant, only firing when exposed to abnormal changes within tissues, hence their nickname, the 'silent receptor'.

Nociceptors have *free nerve endings* embedded within tissue, which monitor changes in varied stimuli, like chemical conditions (e.g. acidity), mechanical stress and temperature. Nociceptors are sentive to:

- Abnormal tissue temperature
- Decreased blood flow (causes chemical stimulation due to hydrogen ions) (Meyer et al., 2006)
- Muscle spasm
- Local lactic acid accumulation

Nociceptors are not 'pain' receptors. Nociceptors detect unusually large chemical, mechanical or temperature disturbances and send impulses to the brain, indicting unusually large fluctuations within tissue conditions. Nociceptors also monitor more than one stimulus. If the environment within tissues changes in more than one way, an accumulation of lactic acid and an increase in temperature, for example, then signals combine or *summate*, increasing the chance that nociceptors activate and send signals informing the brain of an abnormal change in condition.

When the brain receives nociceptive feedback, indicating a change in tissue temperature, acidity, stress or strain, this feedback is evaluated alongside a host of other information to determine whether there is a problem. Nociceptive information is interpreted alongside a host of other sensory information, including where we are, what we are doing and how we feel.

Only under certain conditions will the brain interpret nociceptive feedback as an indication of potential 'threat'. Only in certain circumstances will the subconscious mind think we might suffer hurt or harm. Only then will the brain trigger pain. Only in certain conditions does the brain consider changes to local tissue condition to be threatening and only when abnormal conditions are interpreted as being 'threatening' might the brain decide to trigger *pain sensation*.

Pain is not created within tissue. Pain is a subconscious response to a range of conditions that indicate that the brain feels we are under some sort of threat. Pain emerges in reaction to a raised subconscious evaluation of threat. Pain is an output of the brain – a subconscious mechanism designed to draw *attention* and change *behavior*. Nociceptors are not pain receptors, they are 'threat' receptors. Remember, nociceptors:

- Provide feedback regarding the state of tissues
- Are not pain receptors
- Could be considered 'threat receptors'

## Nociception

To understand how pain works, we need to understand the process of *nociception*. There are four stages of nociception (McCaffery and Pasero, 1999):

1. *Transduction*
2. *Transmission*
3. *Modulation*
4. *Perception*

### Transduction

Transduction is the detection of noxious stimuli by *nociceptive free nerve endings*. *Nociceptors* respond to:

- Mechanical stress or strain – e.g. pressure, swelling, incision, tumor growth
- Thermal change – e.g. burn, scald
- Chemical change – e.g. toxic substance, ischemia, infection

A sufficiently large stimulus excites the free nerve ending of the *nociceptor*. A sensory stimulus that

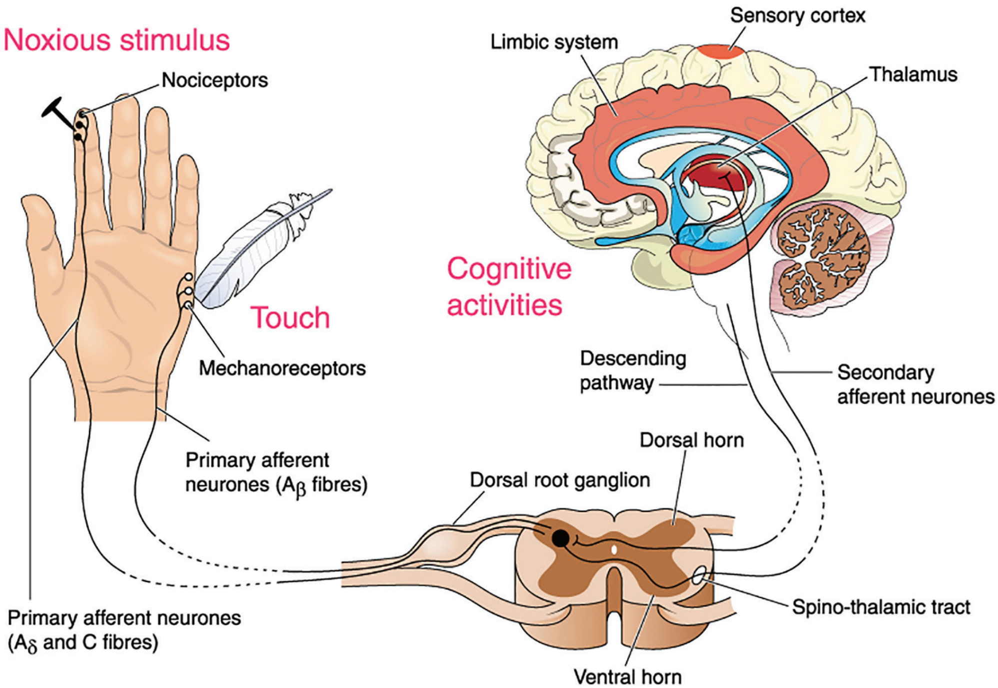


**Figure 7.6** Nociception.

is significant enough reaches the *nociceptive threshold* and triggers nociceptive feedback.

## Transmission

*Transmission* is the process by which an electrical signal passes through a sensory nerve. Electrical signals pass through the dorsal horn of the spinothalamic tract of the spinal cord and enter the brain via the brain stem and thalamus before spreading throughout the brain.

There is no specific 'pain center' within the brain. Nociceptive signals trigger neural activity throughout the *pre-motor* and *motor cortex* (the areas of the brain that control movement), the *prefrontal cortex* (the area that deals with reasoning and problem solving), the *sensory cortex* (responsible for processing sensory information), the *hypothalamus* (which deals with stress responses), the *amygdala* (the emotional part of the brain), and even the *spinal cord* (which influences nerve signals as they go to and from the periphery).

Look at the brain's activity and we see pain triggers a virtual fireworks display of activity, influencing almost every area of the brain in a distinctive patchwork of neurological signals, often referred to as a '*pain signature*' or '*pain neurotag*'.

### THE PAIN 'NEUROMATRIX'

*The neuromatrix theory offered by Ronald Melzack in 1990 theorizes that pain is an output of the brain resulting from a 'multi-dimensional experience produced by multiple influences' relating to level of perceived threat.*

## Modulation

As nociceptive signals pass through the nervous system, they are modified and adapted in a process called *modulation*. Modulation provides the nervous system an opportunity to regulate, organize and adjust nociceptive feedback. Imagine running from a saber-toothed tiger. In this situation, being paralyzed by pain is not useful. A painful limp could prevent us getting away from danger, undermining performance and hampering the ability to survive. The brain 'modulates' pain to ensure performance remains optimal and matched to the situation and circumstance.

Modulation of feedback occurs at various points throughout the nervous system, from nerve endings all the way to the cerebral cortex. Nociceptive signals are adapted:

- At nerve endings
- Within the spinal cord
- Within higher centers of the brain

Chemicals released around the free nerve ending modify the sensitivity of those nerves, a process called *neuro-modulation*. A good example is the impact that *inflammatory* chemicals have on nerve sensitivity. The '*inflammatory soup*' released in response to tissue damage and injury contains a host of chemicals that sensitize free nerve endings. These chemicals 'sensitize' nerves, lowering the threshold at which they fire.

*Sensitization* lowers the threshold of nociceptors, causing them to be activated by otherwise normal mechanical stimuli. This is known as the 'awakening phenomenon'. Sensitization of nociceptors by inflammatory mediators is why injury is usually coupled with pain. Inflammation sensitizes nerves making it more likely that we feel pain. There are various substances that sensitize nociceptors following injury, including:

- Globulin and protein kinases
- Prostaglandins
- Histamine
- Nerve growth factor (NGF)
- Substance P (SP)
- Calcitonin gene-related peptide (CGRP)
- Potassium ($K^+$)
- Serotonin (5-HT)

The inflammatory soup turns *high threshold nociceptors* into *low threshold nociceptors*. Inflammation has such a significant influence on nociception that in otherwise healthy individuals, pain is unlikely in absence of inflammation. The activation of otherwise *silent nociceptors*

### GATE CONTROL THEORY OF PAIN

*When you bang yourself, it always helps to rub the bit that hurts. In 1965, the prominent neuroscientist Professor Ronald Melzack (1990) observed this phenomenon and proposed the Gate Control Theory, which states that the activation of nerves that do not transmit pain signals, non-nociceptive fibers, compete with nociceptive signals, thus inhibiting pain.*

*Non-nociceptive signals, such as pressure or heat for example, compete with nociceptive signals, affectively 'closing the gate' on pain. If a client has an area that hurts, they can moderate pain by applying an alternative sensation like cold, heat, stretch, pressure or gentle massage. The Gate Control Theory spurred many studies in pain research and significantly advanced the scientific community's understanding of pain.*

contributes to conditions characterized by heightened pain perception, such as:

- Hyperalgesia – formerly painful stimuli become more painful
- Allodynia – formerly non-painful stimuli become painful

Nociceptive signals are modified during *transmission* or *transduction* as they pass from tissues towards the brain. These are examples of *ascending inhibition*. As well as ascending inhibition, the brain also sends signals *down* to alter nociception. This is known as *descending modulation*.

There is are many *descending* pathways that act to *modulate* pain (Ossipov et al., 2010). The brain triggers the release of various *inhibitory neurotransmitters* that block or dampen the transmission of nociceptive impulses. These neurotransmitters reduce pain perception, creating an *analgesic* effect. The body produces a host of chemical messengers that alter sensation, acting almost like the body's in-built pharmaceutical store. Examples of inhibitory neurotransmitters include:

- Endogenous opioids and endorphins
- Noradrenaline
- Dopamine
- Serotonin
- Oxytocin

*Endogenous opioids* are particularly powerful chemicals that modify pain. When the situation demands, the brain can release opioid 'pain-killers' to alter pain perception. These internal pain-killers are very useful if pain hampers our ability to perform or survive.

The brain modulates pain in times of danger. Stress, anxiety, fear, anger and excitement are all intense emotional responses associated with danger that trigger pain modulation. Soldiers wounded in battle or athletes injured in sport often report absence of pain despite severe injury. H.K. Beecher (1959), a physician who served with the US Army during the Second World War, noted a remarkable lack of pain in soldiers after combat situations. Beecher observed as many as three-quarters of badly wounded soldiers reported little or no pain, and even refused pain medication despite having compound fractures of long bones or penetrating wounds of the abdomen, thorax or cranium. Moreover individuals were clearly alert, responsive and not in shock. *Stress-induced analgesia* (SIA) is the name for the condition in which pain is usually lower in times of stress and danger.

*Sensory modulation* is another factor explaining the potential mismatch between sensation and pain. Whilst mechanical, chemical or thermal conditions affecting local tissue can be intense, nociceptive feedback can still be modulated to avoid pain perception. Modulation means we can suffer injury without feeling pain, or pain without actually sustaining injury.

## Pain Perception

In previous chapters we have discussed how the subconscious mind (subCM) 'predicts' and anticipates future events to allow strategies to be formulated ahead of time. The subCM strives to help us survive and incessantly scans the environment looking for potential threats to survival. Nociception is one source of information the subconscious uses to evaluate the potential for harm.

Nociceptive feedback is evaluated, alongside a host of other sensory feedback and historical experience, to predict the risk of danger. The subconscious analyses sensory feedback alongside contextual factors like where we are and what we are doing, emotional factors like what we think or how are feel, and historical data of similar past experience to answer the question 'are we in danger?' The reaction to nociceptive feedback can vary, depending on:

- Where we are – environmental drivers
- What we are doing – task drivers
- What we think and how we feel – emotional drivers

Only when 'threat of danger' is sufficiently high will the subconscious trigger *pain perception* – and only when pain is a useful tool to change behavior to avoid that danger. Pain is not so much sensation but a subconscious warning system. The magnitude of that warning depends on the situation and circumstance, and even the meaning we attach to that situation.

When a child falls, they look to their parent to decide how hurt they are. Children do not have an extensive database of past experience so they look to parents to decide how serious a situation is. A look of concern on a parent's face heightens subconscious *threat perception* and the child feels pain. Ironically, the more fuss you make, the more pain a child is likely to experience and the more likely they are to cry.

When threatened, the subconscious triggers a range of phsyiological and psychological reactions. These reactions support behaviors to prevent hurt or harm. Motivational centers within the brain trigger apprehension, anxiety and even fear. Pain is the most potent strategy the subconscious employs to motivate a change in behavior. Nothing modifies movement faster than pain.

Pain perception varies depending on an individual's attitude, state of mind, expectation and experience – even upbringing and culture can have an impact. Pain varies depending upon where a person is and what they are doing. Have you ever wondered why footballers who leap on top of each other after scoring a goal never seem to suffer pain or injury?

## Persistent Pain

Under normal circumstances, pain and discomfort are highly beneficial. Pain drives changes in behavior that are essential in helping avoid behaviors that could cause hurt or harm. Pain tells us to take our hand off a hot plate, to rest when tired, cool down when overheating. Without pain, staying safe would be difficult.

In the acute and sub-acute phases of injury, pain and injury are closely associated. The degree of pain in the early stage of injury is generally a fair reflection of the state of tissue. A more serious injury causes more pain. Pain is useful in these early stages, helping patients off-load damaged tissue. Pain causes a limp after an ankle sprain, for example.

As tissues heal and the threat of re-injury reduces, pain should subside and movement patterns should normalize. A typical repair phase

### SUBCONSCIOUS PERCEPTION

*The Alien subCM constantly monitors and evaluates our situation or circumstances, evaluating levels of threat. If 'threat' is high enough, the Alien triggers pain perception to encourage adaptive avoidance of any potential threat. The Alien listens to what we think and especially monitors how we feel to help base its evaluations. Imagine if the Alien was aware that you are anxious, apprehensive and fearful. Imagine it remembering a similar situation in which you became injured and had to take time off work. Would it not make sense for the Alien to trigger pain just to avoid this situation and keep us safe?*

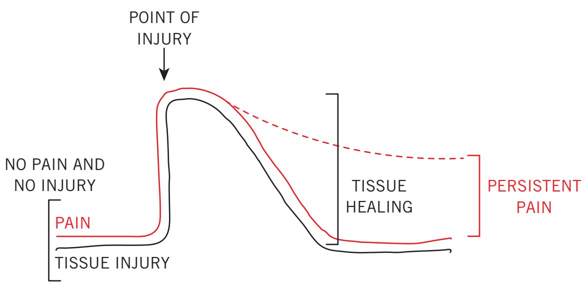


**Figure 7.7** Pain Injury Correlation.

takes 12 weeks from the point of injury, from which point, pain should then recede. Repaired tissue should not be painful, but 1 in 5 people experience pain after the point of repair.

Pain persisting longer than say 12 weeks is referred to as *persistent pain*. At this point, tissues have healed and risk of injury is low. At this point, pain serves little or no purpose. There is no tissue damage, no inflammation, no real threat to tissue, but still pain persists (see Figure 7.7).

The link between pain levels and the state of tissues become distorted. The client is experiencing 'pain without purpose'. At this point, pain is not structural, but *neurological*. Persistent pain is an error in neurological processing – a problem caused because the brain is either misinterpreting sensory information or over-estimating the potential threat. We can understand persistent pain based on two neurological processes:

- Prediction error
- Pain neurotags

## Prediction Error

As we have discussed, pain is not a signal sent from tissues via pain nerves, but it is created within the subconscious mind in response to *threat*. To evaluate levels of threat, the subconscious takes nociceptive feedback and evaluates that feedback alongside a host of other information. The brain analyzes where we are, what we are doing and how we feel to evaluate nociceptive feedback and evaluate the potential for danger.

Each situation and circumstance is analyzed and catagorized using a complex system of pattern recognition. The current situation is then compared against a database of similar past situations to create a prediction of future events. The brain asks, based on the current situation, what do I know of similar past events and the intensity of nociceptive feedback, to what extent am I under threat? The subconscious evaluates the level of threat and asks if it is wise to change our present behavior. If so, is pain a useful driver of this change in behavior? If the answer is yes, we experience pain.

Persistent pain occurs because we over-estimate threat. Imagine a child being bitten by a dog. It would be easy for the child to assume that all dogs bite. This is a form of '*prediction error*'. Pain can work in much the same way. Due to say a sequence of negative past experiences, the brain starts to predict danger where none exists, or over-estimates the potential for harm or risk of injury.

Negative emotions have a powerful impact on subconscious prediction. Events associated with high levels of emotion transition far faster to subconscious (procedural) memory, and therefore impact future decision-making. Injury associated with strong negative emotions, or injury that triggers a sequence of events we feel particularly negative about, are far more likely to impact future behavior.

When the brain evaluates the potential for threat, it also considers current levels of emotion – how you feel, your thoughts, attitudes, beliefs and expectations. Negative past experiences, damaging thoughts, unconstructive attitudes and beliefs, and negative expectations all distort threat perception, increasing the likelihood of *negative prediction*, and therefore pain perception. The impact that negative emotion, fear, apprehension or anxiety has on pain perception is well documented in the literature.

- Anxiety increases pain (Fields, 2000).
- Attention on pain amplifies pain perception, so that focusing on pain makes it feel worse (Eccleston, 1994).
- Believing pain to be an accurate indicator of the state of the tissues is associated with higher pain ratings (Moseley and Arntz, 2007).
- Expectation of pain makes symptoms worse (Wager, 2005).
- Emotional stress and anxiety increase pain perception (Arntz et al., 1994).
- Expectation of negative outcomes associated with pain and injury, known as catastrophization, has been shown to make pain worse (Sullivan et al., 2001).

The subCM strives to confirm expectation, a phenomenon called *confirmation bias*. The subCM searches for sensory information that confirms initial expectation, drawing into consciousness information that confirms beliefs, making our expectations reality. In this case, pain becomes a self-fulfilling prophecy – we expect to hurt, so we do.

Internal dialogue, known as 'self-talk', has a powerful impact on perception. The stories we tell ourselves truly influence how we perceive the world. If we view our body as being frail, structurally unsound and injured, the chances of experiencing pain and dysfunction rise rapidly. Pain becomes like a habit that has to be broken.

The *placebo effect* is a powerful illustration of how thoughts impact pain perception. It is a well documented phenomena that if a patient 'thinks' they will get better, they probably will. A water tablet acting as a placebo can significantly reduce pain if the patient thinks it will help. Research even illustrates how different color pills work better for different conditions. A red placebo pill is very good at relieving headache, for example. During dental surgery, patients expecting pain relief tend to experience less pain following placebo injection (Levine et al., 1978). Neuro-imaging shows that placebos act by inhibiting cortical and subcortical regions of the brain that control pain (Pollo et al., 2001).

Many of the benefits of musculoskeletal treatment are mediated by the patient's *expectation*. The 'non-specific benefits of treatment' are very powerful. Treatment tends to be more effective if a patient has better rapport with their therapist. Acupuncture works better if it is performed by an oriental person. Many of the benefits of treatment are mediated by a change in a patient's belief about their condition. A patient simply booking a session or being reassured that an injury is not serious can be sufficient to reduce pain.

When scientists test new medications they have to be very careful to account for the *placebo effect*. Double blinded 'randomized controlled

## PAIN TOLERANCE

- Many athletes, especially endurance athletes like cyclists, train years to build 'pain tolerance'. Athletes frequently associate 'pain' with 'work' and learn to ignore it. I have seen athletes train through incredible pain – runners literally fracturing tibial bones because they have ignored shin-splints. To top athletes, 'pain tolerance' can be a real problem in injury prevention because they simply do not know when to stop. Each person's pain tolerance varies.

trials' (RCT) are performed, in which one group is given the actual medicine and compared to another group who only 'believe' they have received medicine.

The term '*nocebo*' describes the negative impact of believing a condition will get worse (Benedetti et al., 2007a). In one study, subjects were told they were to receive a hyperalgesic (pain enhancing) drug. These subjects experienced increased pain perception, even though no such drug had actually been administered (Benedetti et al., 2003). If we expect pain, then we likely experience pain.

Many factors influence pain perception. The pamphlets we read, what we see on TV, what we are told by friends – everything feeds into our perspective and impacts how we feel. Treating persistent pain involves restructuring expectations to avoid negative prediction.

## Pain Neurotags

Every thought or movement has a distinct pattern of neuronal activity, referred to as a *neurotag*. We have neurotags for walking, bending, reaching, talking and writing, and we also have a neurotag for pain. When we learn, the brain 'links' different neurotags. For example, we associate the smell of fresh bread with feeling hungry. As Shatz (2009) states, 'cells that fire together, wire together'. Neurons that fire at the same time start to link together. Over time, when one neurotag fires, so does another.

The brain works to make life easy by 'chunking' information together and identifying patterns. *Neuronal linking*, chunking and pattern recognition are all strategies the brain uses to reduce 'computational load'. But in the case of injury, these mechanisms create a problem.

Following injury, movement triggers pain. Over time, the neurotag for movement slowly becomes linked with that of pain. The two patterns of neuronal activity connect, at which point one triggers the other. In the case of back pain, it may be that the neurotag for bending or lifting triggers pain, in spite of the fact that tissues have all but healed. In persistent pain, the specific neurotag for movement, otherwise known as a *motor program* or what we call a *movement template*, becomes intertwined with the neurotag for pain, to the point where moving causes pain.

Imagine placing a stone into your shoe. Each step hurts. It is an instintive reaction to limp, taking pressure off the foot to relieve pain and so creating an antalgic gait. If we left the stone in the shoe for months or years, that antalgic gait becomes habitual, as does the sensation of pain when we put weight through the foot. The neuronal link between walking and pain can become so ingrained that walking triggers pain, even if we were to take the stone back out of the shoe. Pain has been learnt and remains.

Imagine suffering a whiplash after a motor vehicle accident. If the crash was significant enough, causing pain and tension over a long period of time, then turning the head can remain painful even after the neck muscles have healed. In some instances, simply getting back into a car is enough to trigger neck tension and even pain. Pain becomes linked, not only to movement patterns, but to the context and situation in which that pain occurs. This is because in the brain, pain is a

### SCANS MAKE PAIN WORSE

*Having a scan and looking to see all sort of scary looking deformities (that are generally quite normal) can make pain worse and result in less favorable clinical outcomes. Having a scan is not always a good idea from a pain management perspective.*

subconscious indication of threat. If driving feels sufficiently threatening, just getting into a car may trigger a pain response.

I once had a client who had a particular fear of flying and suffered back spasms prior to every flight. Why did he have pain only prior to flying? Was it the stress he experienced? Was pain just a habituated pattern of behavior? There was certainly no underlying injury that was causing the pain that miraculously healed after the flight. It was clear that his symptoms were neurological and psychological, not physiological.

To resolve persisatent pain, rehabilitation has to address the underlying neurological processes. For the client experiencing pain when flying, recovery involved not only mobilization exercises, but a process of stress inoculation combining visualization, breathing and relaxation exercises prior to each flight to reduce pain and protective muscle spasm.

## The Impact of Pain

Pain is hugely impactful. Pain reprograms the nervous system faster than any other input. Painful movement is rarely coordinated or fluid. It is almost impossible to develop strength on a foundation of pain. Pain has a huge impact on various aspects of performance. Pain:

- Distorts perception
- Influences behavior
- Distracts attention
- Disrupts sensation
- Alters activation
- Disrupts coordination

### Pain Distorts Perception

Persistent pain distorts perception and undermines the sense of what a client feels their body is capable of. Clients suffering persistent pain tend to have negative attitudes, beliefs and expectations relating to movement ability. A client suffering persistent back pain, for example, might have an intense fear of bending and twisting. After episodes of pain, clients often have a distorted sense of threat, predicting problems in a way that seems extreme to the rest of us.

### Pain Influences Behavior

Fear and apprehension cause sufferers to avoid seemingly innocuous tasks. Pain reduces the desire to move and causes the sufferer to withdraw activity. Clients suffering persistent pain tend to restrict movement, avoid exercise and alter behavior to avoid threatening situations. Reduced activity leads to a general deterioration in health, fitness and function. As functional capacity deteriorates, persistent pain becomes more likely and deteriorating function make future injury even more likely. Pain and injury become self-fulfilling prophecies.

### Pain Distracts Attention

The subconscious shifts attention on ‘threatening’ stimuli. If we are experiencing pain, attention is drawn inwards, towards painful areas. Pain drives an internal focus of attention, which not only increases pain perception but also undermines performance with respect to speed, fluidity and power.

By drawing attention internally, pain distracts us from other, more useful sensory information. By competing for attention, limiting the ability to process external events, pain undermines decision-making and, therefore, performance. During episodes of pain, the sufferer has less attention to process important sensory information, making persistent pain sufferers prone to rash decisions. During painful episodes it is not unusual to feel clumsy, ill-coordinated and forgetful.

### Pain Disrupts Sensation

Nociceptive feedback competes with more useful proprioceptive feedback for attention within the brain. If the brain is interpreting nociceptive signals, it cannot process proprioceptive feedback regading the forces that are passing through the body. Pain therefore hampers performance and undermines the ability to coordinate movement and activate muscle. Pain degrades position sense (aka proprioception) and movement sense (aka kinesthesia), hampering functional performance.

Pain distorts *internal body maps*, interfering with the brain's ability to sense itself in space. Asked to draw a representation of their own body, an individual suffering persistent pain tends to portray painful areas as larger than they actually are. Painful areas tend to feel large, fuzzy and indistinct. Painful areas also become hypersensitive, to the point where normal mechanical stress can cause pain.

As sense of threat increases, the subCM triggers a range of other *protective reflex responses* designed to modify behavior and prevent harm, starting with increased *sensory acuity*. Heightened sensitivity of *muscle spindles* causes increased sensitivity to stretch, resulting in reflexive stiffness and rigidity. In extreme circumstances, sensitivity to stretch triggers protective muscle spasms. You might have experienced that sensation of your neck locking and not being able to turn the head. This is the resut of protective muscle spasm.

Persistent pain can increase sensitivity of GTOs to load, causing a reflexive weakness, reducing strength and power, and decreasing the ability to lift load – an effect known as *antalgic weakness*. Pain makes us weak and inflexible. It is almost impossible to build performance in the context of persistent pain.

## Pain Alters Activation

Pain affects muscle recruitment and activation, disrupting intra- and inter-muscular coordination, decreasing force production. Anecdotally, it appears some muscles are particularly prone to being *inhibited*, losing their ability to produce force, whilst others become *facilitated* and *hypertonic*.

Some researchers suggest that altered patterns of recruitment relate to muscle fiber type and are, to a certain extent, predictable. The suggestion in the popular literature is that in response to local pain, stabilizing muscles, those muscles thought to be responsible for controlling motion at joints, are prone to weakness or inhibition. This effect is referred to as antalgic inhibition. At the same time, mobilizing muscles, those that generate movement, are prone to becoming tight or 'hypertonic'. This make intuitive sense. Pain acts to reduce risk of injury by both restricting motion and reducing power production. The gluteal muscles and deep core muscles seem particularly prone to weakness in response to pain.

In reality, patterns of altered recruitment in response to pain are complex and frequently vary from person to person. There are few hard and fast rules. What is apparent is that pain hampers performance. Over time, patterns of altered recruitment become habituated and ingrained. After persistent pain, muscles become chronically inhibited and fail to support movement, a condition referred to as *sensor-motor amnesia*. In these cases, functional rehabilitation exercises need to be prescribed to address dysfunctional patterns of recruitment.

## Pain Disrupts Coordination

Pain alters patterns of coordination and triggers changes in movement strategy. Pain causes people to shift weight and avoid painful ranges of motion. Everyday 'antalgic' movement patterns include 'limping' in the case of lower limb pain, reduced spinal bending and twisting in the case of back pain, 'hiking' the shoulder on reaching and shoulder rotation to avoid neck pain.

Dysfunctional patterns of coordination associated with pain include:

- Loss of dissociation:
  - Individuals lose the ability to dissociate movement in neighboring areas
  - E.g. back pain can reduce the ability to dissociate spine and hip motion or one spinal segment from another
- Co-contraction:
  - Increased bracing of movement
  - Antagonistic muscles contract in unison causing rigidity, loss of range of motion, decreased speed and power
- Decreased variation:
  - Pain decreases movement variation and promotes more rigid patterns of movement
  - E.g. back pain will result in less variation in bending and lifting movement patterns

Over time, *antalgic movement strategies* become habituated and ingrained, making them persist long after the point at which pain subsides. Sensor-motor deficits, distorted patterns of sensation and activation, all become imbedded, resulting in a protracted deterioraton of performance.

To restore function, rehabilitation has to resolve pain and normalize sensor-motor function. Rehabilitation is not physiological but neurological. Rehabilitation strategies have to address the cognitive and behavioral deficits that result from persistent pain.

## Bringing It Together

In this section, we have learnt that:

- Pain and injury are rarely proportional
- Pain is not an indication of damage but emerges from a subconscious evaluation of 'threat'
- We do not have pain receptors. The closest thing resembling a pain receptor is the nociceptor
- Nociceptors could be regarded as 'threat receptors'
- Nociceptive signals to the brain are modulated based on what the subconscious perceives as being functional at that moment
- In persistent pain, subconscious evaluation of threat has become distorted such that normal movement becomes associated with pain. This occurs due to prediction error and pain neurotags
- Pain is influenced by a client's thoughts, beliefs and perceptions, and pain is increased by negative expectation, anxiety, emotional stress and overt attention
- Persistent pain provides little functional benefit
- Pain negatively impacts functional performance by:
  - Distorting perception
  - Influencing behavior
  - Distracting attention
  - Disrupting sensation
  - Altering patterns of activation
  - Disrupting patterns of coordination

In the next section, we evaluate how an FT can help manage a client's pain through functional exercise.

## PAIN REHABILITATION

- Manage Emotion
- Explain Pain
- Avoid Pain
- Engage Pain Patterns
- Graded Exposure
- Intelligent Variation in Rehabilitation
- Contextual Similarity
- Corrective Exercise
- Mapping Drills
- Inhibition Exercises
- Activation Exercises

Pain does not derive from within tissue. There are no 'pain nerves' informing the brain of injury. Pain emerges from a complex subconscious sense of threat, intended to change behavior and protect us from harm.

In some cases, pain persists long past the point of healing. Persistent pain arises from a distorted sense of threat – a subconscious hypervigilance that emerges as a result of negative past experience, harmful emotion and negative thoughts, attitudes and beliefs. Persistent pain (PP) is neurological not physiological.

In functional rehabilitation, the aim is not to diagnose injury or 'treat' pain, but to restore 'function', normalizing the deficits that result from long periods of pain, such as sensor-motor function. The aim is to reduce threat perception by restricting beliefs and building confidence in the body's ability. In this section we discuss how rehabilitation can address neurological problems relating to PP.

Functional training can be extremely effective in managing chronic pain. Training is a great way to help a client restructure beliefs, expectations and emotions surrounding movement. Functional rehabilitation exercises can be prescribed to address sensor-motor dysfunction and disrupt the neurological links between pain and movement. Functional movement helps downgrade PP by:

- Addressing negative emotions
- Reducing threat perception
- Dissociating movement from pain
- Addressing sensor-motor dysfunction

We will now look at the different strategies that can be used to manage PP.

### Manage Emotion

We all experience the world differently. Thoughts, attitudes, beliefs and expectations filter our experience of the world by molding and distorting perceptions. Clients suffering PP experience a range of negative emotions associated with movement. They might feel incapable of performing certain tasks, they expect pain on movement, assume increased risk of injury and often consider their body structurally and biomechanically unsound.

Clients suffering PP frequently pay too much attention to a painful area, becoming acutely aware of sensation or sense of load. Poor expectations drive *negative prediction*, increasing the likelihood of pain and descreasing performance in a self-fulfilling cycle of complications.

In functional rehabilitation, a trainer explains how exercise and a progressive program of natural movement can facilitate a return to normal function. Before starting a rehabilitation program, an FT should discuss a client's:

- Expectations and beliefs regarding their condition
- Areas of concern
- Past experiences relating to pain and injury

The FT can help encourage positive emotional responses by:

- Setting realistic goals and expectations for exercise

- Giving the client control and choice
- Providing options, alternatives, progressions and regressions

Functional rehabilitation is a collaborative procces. Training should be progressed at a speed at which the client feels comfortable and at ease. Providing the client with a sense of control over their rehabilitation program provides a sense of confidence and security that is esentiual for positive progress.

## Explain Pain

The first step in the rehabilitation of PP is to *explain pain*. Inspired by the work of Lorimer Moseley and David Butler (2003), 'explain pain' introduces the notion that pain is not caused by signals sent from tissues to the brain, telling the brain of injury, but is an error in processing, a disruption in *neurology* not *physiology*. A client should appreciate that pain does not reflect the state of tissue or level of injury or damage.

There are various approaches to explain pain. An FT might provide an information pack, an educational video, a YouTube clip or may set aside time to explain how PP develops. 'Explain pain' should help a client restructure their thoughts, beliefs and expectations regarding movement. 'Explaining pain' has been proven to significantly reduce pain and disability (Moseley, 2003).

Whilst explaining pain is a fantastic start to a rehabilitation process, an FT needs to appreciate that negative beliefs can become deeply entrenched and difficult to unravel. Clients can be resistant to new ideas, contrary to their own.

The subconscious is structured to reinforce pre-existing beliefs and expectations. When confronted with a conflicting viewpoint, it is natural to be skeptical. Contradictory viewpoints can even trigger powerful, negative emotional reactions, making a client feel threatened and apprehensive, and sometimes even angry and frustrated. Negative emotions tend to shift us into an irrational state in which sound decision-making is difficult. Imagine telling a client with knee pain that squatting is actually good for their knees. This suggestion could be difficult for the client to accept and if not handled correctly a client will withdraw effort.

There is an old adage in coaching that 'giving advice only builds resistance to change'. Advice can often feel like coercion, especially when a trainer's perceptions and ideas conflict with the clients. 'Explain pain' has to be handled very carefully and cautiously. We do not want to tell clients that:

- 'Your pain is all in your mind'
- 'Your fears are unfounded'
- 'There is no reason why you cannot perform certain exercises'

'Explain pain' is an evidence-based approach that encourages clients to re-evaluate beliefs and expectations. As a trainer, you simply want a client to reconsider their assumptions surrounding their condition and the origin of their pain. A client should appreciate that pain is a 'neurological alarm mechanism' designed to warn you of potential 'threat' – a system that can, at times, become sensitized and distorted.

## Avoid Pain

A trainer should exaplin to a client that '*movement is vital for healing*'. Movement supports the repair of tissue, de-sensitives the nervous system and, in doing so, reduces pain. The goal is to *move* as much as possible without triggering pain.

Pain triggers reflexive weakness, stiffness and undermines confidence, and therefore should be avoided. Exercises should not trigger or exacerbate symptoms. Movements that trigger pain or swelling are only likely to reinforce negative beliefs and exacerbate pain responses. The goal should be to move as much as possible whilst avoiding triggering a pain response. If a client asks ‘can I do x, y or z?’, the answer is yes, unless it hurts. ‘If it hurts, don’t do it’.

Clients are often concerned that movement or exercise may aggravate or ‘flare’ symptoms. A trainer should explain that ‘flare-ups can occur, but they are are a natural part of the healing process, a sign that you may have done too much’. If a ‘flare-up’ occurs, simply take time to recover, regress movement or exercise intensity, and then progressively re-build.

## Engage Pain Patterns

Whilst a general strength program builds non-specific strength and fitness, *transfer* into function is poor because exercises lack *neurological*, *behavioral* or *emotional* similarity. Pain is often associated with specific movement patterns, in specific situations and circumstances. It is not uncommon for a client’s pain to be unrelated to the loads they lift. People can feel pain brushing their teeth but still lift heavy weights in the gym. The specific tasks that trigger pain are referred to as the client’s ‘*pain patterns*’.

Every time a client engages a pain pattern, synaptic links within the brain trigger a pain neurotag. One of the goals of rehabilitation exercise is to disrupt the neurological link between pain and movement by activating pain patterns whilst at the same time avoiding pain. This can be tricky.

## Graded Exposure

The diffculty lies in engaging pain patterns without also triggering pain. There are a series of strategies for creating rehabilitation exercises that reflect painful tasks and activities without also triggering a client’s pain. The first strategy is to reduce exercise intensity. By performing pain patterns at a reduced load, speed or distance, we reduce sense of threat and make a pain response less likely. If a client can perform a pain pattern without also triggering pain, confidence grows, threat perception reduces and pain recedes (see Figure 7.8).

A gradual progression towards more threatening situations and circumstances is known

**Figure 7.8** Strap-Sit. A client with persistent knee pain, triggered as they ‘get-up’ from sitting, needs to engage this specific movement pattern in their rehabilitation program. Here we reduce intensity by using partial weight bearing using supportive straps. By reducing the load on the knee, we also reduce sense of threat created by the exercise.

as *graded exposure*. Exercise intensity can be adapted by tweaking:

- Load – reducing load
- Speed – slowing movement down
- Momentum – using momentum to support movement
- Strategy – adapting patterns of coordination

On occasions, even unloaded movement may trigger pain and apprehension. In this case, pain patterns might have to be performed at very low intensities. In severe cases, rehabilitation may start with passive mobilization, coupled with breathing and mindful relaxation. One strategy is for clients to simply visualize performing pain patterns without also feeling pain.

## Intelligent Variation in Rehabilitation

A functional trainer should apply principles of *intelligent variation* to prescribe rehabilitation exercises that avoid triggering a pain neurotag. On movement, the brain engages a *movement template*. These templates help the brain structure and organize movement, prescribing which muscles to activate at what time, with what force and so on. In persistent pain, templates become linked with neurotags for pain so that each time we activate a movement pattern, a client also experiences pain.

The goal of a functional rehabilitation exercise is to engage a movement template without also triggering a pain neurotag. This might be achieved by introducing sufficient variation into the movement so that the brain does not associate the movement with pain. To avoid activating a pain neurotag, a trainer should progressively and systematically vary movement pattern until movement does not hurt. To achieve sufficient levels of variation, a trainer might tweak:

- Start or finishing position
- Environment and support
- Movement strategy

### Position Tweak

Asking the client to perform a pain pattern from different postures and positions may avoid a pain response. A trainer can tweak:

- Stance – widening stance or tweaking foot position
- Posture and position – changing from standing to sitting, sitting to kneeling or to all fours
- Hand position – tweaking grip from pronated to supinated, narrow grip to wide grip

Say, for example, a client experinces pain bending and reaching towards their toes. We might ask that client to bend and reach:

1. From a wider stance
2. From bent knees
3. From a split stance
4. From sitting
5. From lying

The movement pattern should still reflect ‘reaching towards toes’, but posture and position is ‘tweaked’ or regressed until pain free. As the client gains confidence, movement is systematically progressed back to the original task.

### Environmental Tweak

The subconscious mind constantly evaluates any situation and circumstance, identifying levels of threat based on historical experience. By ‘tweaking’ the environment, we reduce *subconscious threat perception* and decrease the chance of activating a pain neurotag. A trainer could:

- Use external drivers – use external drivers, tools, obstacles and targets to draw attention away from painful areas. Game play may be a good way to distract using external stimuli.
- Change context – by training in a different environment, we might avoid a pain reaction.

**HYDROTHERAPY**

*A runner suffering knee pain may exercise effectively pain free by running in a pool. The feel of the water, the coldness, and the change in environment is an excellent way to avoid triggering a pain neurotag. The athlete can visualize being on the track to increase transfer.*

We could ask the client to perform movement in a rehabilitation studio or even in water, for example.

- Introduce sensory stimuli – sensory stimuli like music or vibration plates may be enough to distract the nervous system from pain

### Movement Strategy Tweak

A subtle change in coordination may be enough to avoid activating a pain neurotag. If reaching overhead is painful, a slight tweak in how we reach may avoid triggering pain. A trainer might tweak:

- Direction of motion – reaching to one side or another, forwards or back
- Speed of motion – moving faster or slower
- Complexity of motion – combining spine or leg motion, a weight shift etc.

The potential for variation is huge. Variation can be introduced systematically until movement is pain-free. The goal is not to encourage *compensatory* patterns but to create enough of a sense of variation to avoid triggering a pain response.

## Contextual Similarity

To transfer into function, rehabilitation exercises need to reflect not only the task that triggers pain, but also the context in which that pain occurs. The subCM associates pain with specific situations and circumstances. If a client experiences pain lifting boxes at work, rehabilitation should reflect this specific situation.

As well as incorporating similar tasks, i.e. bending and lifting, rehabilitation exercises should incorporate similar contextual cues – similar environments, tools, obstacles and targets. A trainer might ask a client to lift similar boxes or visualize similar situations and scenarios as those in which he or she lifts at work, for example. An athlete or sportsperson experiencing pain related to sport might consider the following stages of rehabilitation:

- Functional rehabilitation in the gym
- Rehabilitation incorporating specific sport tools
- Visualization of sport performance within rehabilitation
- Perform rehabilitation pitch-side
- Rehabilitaton incorperating other players
- Low intensity 'play'
- Increasingly threatening play

Rehabilitation solely in the gym is unlikely to transfer to function. A return to game play without rehabilitation that considers the context in which pain and injury occurs is likely to trigger protective reflexes and increase the chances of pain and re-injury.

## Corrective Exercise

Strength is rarely built on a foundation of pain. Any training program should always start by addressing pain. In many cases, strength improves as soon as pain is resolved. Persistent pain negatively impacts sensor-motor function.

Pain is usually associated with *protective neurological reflexes* that alter sensation, alter recruitment and undermine coordination. Pain causes some muscles to weaken, whilst facilitating others, making us rigid and stiff. Pain can have a range of negative consequences, including:

- Disrupted sensation:
  - Hyperalgesia (increased levels of pain)
  - Allodynia (pain in response to non-threatening stimuli)
  - Distorted body maps
  - Loss of positional sense
  - Loss of movement sense
- Disrupted activation:
  - Motor inhibition – reduced activation of myofascia
  - Motor facilitation – increased activation of myofascia
- Altered coordination:
  - Antalgic movement patterns – movement adapted due to pain
  - Reduced movement variability – behavioral rigidity
  - Loss of precision – reduced accuracy and efficiency
  - Loss of dissociation – inability to separate regions

In many cases, *sensor-motor dysfunction* persists long after pain resolves. Altered coordination and recruitment becomes habituated and ingrained. To correct sensor-motor dysfunction, rehabilitation exercises sometimes have to be regressed or varied to such an extent that they bear little resemblance to normal functional tasks. We refer to these rehabilitation exercises as being 'extra-function'.

*Extra-functional* exercises can be placed into one of three main categories:

- Mapping
- Inhibition
- Activation

## Mapping Drills

Pain alters sensation and distorts *internal body maps*, impacting sensory perception, affecting coordination and undermining the quality, accuracy and precision of movement. Altered sensory and disrupted internal maps alter the brain's perception of sensory feedback, in some cases causing hypersensitivity (aka allodynia) and increased pain sensation (aka hyperalgesia).

*Mapping drills* are designed to restore normal sensation and help reorganize internal body maps. The goal is to help re-educate the sensory system with regards to what tissues feel like and where they are. Mapping can be performed in many different ways, including:

- Therapeutic touch
- Position sense
- Mapping movement
- Dissociation drills
- Movement accuracy

### Theraputic Touch

A functional trainer can re-educate a client's sensory system by exposing tender painful areas to various sensory stimuli. Sensory stimuli can be applied using heat, cold or stretch, but one of the most powerful tools is touch.

**SCAR TISSUE**

*Injuries tend to leave scars. If you have ever had an operation you will notice how the scar tissue can be very sensitive to touch and can cause a great deal of pain when they are manipulated. Scar tissue can disrupt sensation and activation in areas local to them.*

*Therapeutic massage* is a powerful tool for normalizing sensation and reducing pain. Massage can be hands on or applied using tools such as foam rollers. In any case, a range of sensory stimuli can be applied to sensitive areas to normalize pain perception. Stimuli should always be comfortable, pain free and varied.

## Position Sense

Improving '*position sense*' is one of the most effective ways to develop sensory perception and build accurate internal body maps. A trainer should work on a client's ability to orientate their posture and position in relation to different functional tasks and external tools, obstacles and targets. For example, one exercise might be to maintain balance in a split stance whilst reaching towards a target behind them. The client might be asked to maintain a functional spinal posture, with chest lifted, avoiding a slumped and rounded posture.

Clients should be encouraged to gain visual feedback from mirrors as they build position and movement sense. To build internal body maps as part of a rehabilitation process, a client should build an awareness of where different body parts are as they move – the position of the hips and pelvis, the positon of knees relative to the feet, curvatures of the spine, head posture and the positon of the shoulders and ribcage.

To build accurate internal maps, clients should orientate themselves and coordinate movement from various different postures and positions – from standing, single-leg stance, sitting, kneeling, on all fours and so on. As internal maps develop, not only will coordination and performance improve, but pain should also recede.

## Mapping Movement

*Mapping* exercises are simple movements designed to develop internal body maps by developing *motion sense*. Mapping movements are generally performed in postures and positons that provide a sense of safety and stability, to avoid triggering protective neurological reflexes or pain.

'Mapping' is usually performed lying down, kneeling or from a four-point stance, to allow stable, slow and controlled motion through a full and comfortable range of motion. *An internal focus of attention* allows clients to 'mindfully' reflect and correct motion, creating ease and fluidity of motion. Mapping develops internal body maps, relaxing hypertonic muscles and enhancing coordination.

## Dissociation Drills

One sign of poor coordination is the inability to isolate motion of one body part from another. Back pain frequently interferes with the ability to '*dissociate*' movement of the spine from that of the hips, for example. Lumbo-pelvic rhythm is disrupted to the point where movements of the hips and spine occur in one single, rigid block. Clients with shoulder pain often lose the ability to dissociate movement of the arm from the shoulder

### MAPPING THE LUMBAR SPINE – CAT STRETCH

From a four-point stance, ask a client to smoothly flex and extend their spine, being mindful of segmental spinal motion. The 'Cat stretch' develops a client's lumbar spine body map, alleviating pain, relaxing paraspinal muscles and activating deep stabilizing core muscles. The Cat stretch is fantastic for low back rehabilitation.

girdle. Clients with neck pain frequently lose the ability to dissociate movement of the head and neck from the shoulder girdle.

*Dissociation exercises* involve a client isolating motion of one part of the body from another. For example, turning the head without hiking the shoulder, turning the spine without moving the hips. Dissociation exercises should be performed in different postures and positons, at different speeds and in different contexts. As movement skill develops, trainers can introduce external drivers and contextual cues. For example, a trainer might ask a client to track the movement of a target with the head and eyes, without moving the shoulders or shoulder girdle.

## Movement Accuracy

Encouraging clients to reflect and correct posture and position is useful in rehabilitation because it develops *position* and *motion sense* and builds accurate internal body maps. Keeping the hips level whilst maintaining a single-leg stance, for example, is a useful proprioceptive exercise. But trainers need to be aware, these exercises are '*extra-functional*'. They drive an *internal focus of attention*, which reduces performance with respect to speed, fluidity and power.

By asking a client to react with accuracy and precision to tools, obstacles and targets, a trainer develops the brains ability to orientate the body, refining internal body maps. An *external focus of attention* also maintains performance with regards to speed, fluidity and power. Game play can be particularly effective. By 'game-ifying' training, asking clients to handle awkward and unusual tools, accurately step onto markers, reach towards, throw at or strike targets, avoid and negotiate obstacles, a trainer develops coordination. By ensuring that exercises, tools, obstacles and targets reflect the tasks and activities we do on a daily basis, performance should transfer into a client's daily life.

## Inhibition Exercises

When the motor system identifies instability, excessive stretch or overload, or if the subconscious perceives significant threat, the brain activates various protective neurological reflexes designed to restrict movement and prevent injury. These mechanisms are particularly active after periods of pain or injury. Adaptive strategies vary from person to person, but it is not unusual for specific muscle chains to become *facilitated* and 'hypertonic', i.e. have an increased state of tone. Hypertonicity creates segmental stability, but also stiffness and rigidity.

To restore mobility, a trainer can prescribe 'inhibition'. *Inhibition* exercises are designed to relax hypertonic muscle and can be performed in various ways, including:

- Static stretch
- Direct pressure

By placing a client into a posture or positon that elongates a myofascial chain, and then holding that position for over 30 seconds, we create a stretch that acts to desensitize *muscle spindles*, 'inhibiting' the *stretch reflex* and relaxing hypertonic muscle. On holding the static stretch, a client should feel a palpable sense of ease and relaxation along with a transient increase in range of motion.

Inhibition can also be achieved using direct pressure on hypertonic muscle. Hypertonic muscles are often painful or tender to touch as muscle contraction causes an iscaemic build-up of waste products, like lactic acid, that sensitive the area. Direct pressure on muscle fibers, held for 30–60 seconds or until a sense of ease is felt, stretches muscle fibers, working in a similar way to a held stretch to decrease muscle tone. *Self-myofascial release*, or SMR as it is commonly referred to, can be applied using direct pressure from foam rollers, trigger point balls or manual pressure by a trainer (see Figure 7.9).

**Figure 7.9** Self-Myofascial Release of the Hip.

Inhibition should always be followed by the functional task it is intended to improve. For example, if a client is restricted in how far they can forward bend, a trainer might inhibit the posterior chain myofascia (calves, hamstrings, erector spinae, suboccipital muscles) and then re-test by asking the client to forward bend again.

## Activation Exercises

A heightened sense of threat facilitates Golgi tendon organs, increasing the sensitivity of local muscles to load. Elevated GTO sensitivity *inhibits* local muscles, creating a sense of weakness and instability. Folllowing episodes of persistent pain, patterns of inhibition become ingrained and habituated, so that weakness and altered recruitment persists long past the point of injury.

Certain muscles appear particularly susceptible to inhibition. The gluteal muscles of the hip and deep abdominal muscles appear particularly prone. Exercises to '*activate*' gluteal and abdominal muscles have become popular in musculoskeletal therapy to restore strength and stability to the lumbo-pelvis.

*Activation exercises* derive from principles of *post-activation potentiation* (PAP). PAP takes advantage of the fact that muscles produce greater force after a brief bout of near-maximal contraction (Robbins, 2005). Whilst pre-contraction appears to facilitate motor neuron pools, facilitating patterns of local activation and enhancing subsequent force production, a range of neurological and physiological effects are likely to contribute to PAP (Rassier and Herzog, 2002).

To activate inhibited muscle, a trainer would isolate and pre-contract that muscle. An internal focus of attention on the inhibited muscle facilitates recruitment of that muscle. Palpating the muscle in question is also effective at increasing recruitment. A trainer might ask the client to press into a muscle group as they activate that muscle.

Pre-contraction can be maximal, but there appears be benefit from sub-maximal levels. To reintegrate inhibited muscles into normal movement followng PAP, the client would immediately perform

### TRAVELL AND SIMMONS MYOFASCIAL TRIGGER POINTS

*Travell and Simmons referred to localized myofascial tension as trigger points. In theory, trigger points are palpable nodules of tension that trigger local and referred pain (i.e. pain that can be felt in distal regions of the body) on direct pressure.*

*Travell and Simmons (1998) developed charts identifying common myofascial trigger points and their referred pain patterns. Inhibition of these trigger points is thought to reduce myofascial pain, restore range of motion and improve local strength and stability. The presence of Travell and Simmons' myofascial trigger points and the ability of therapists to reliably find these points is up for debate.*

a relevant functional task and should feel an immediate improvement in functional performance. If there is no immediate benefit, an alternative strategy may be more appropriate. A 'test–intervention–re-test' strategy is always optimal when applying rehabilitation exercises.

Mapping, inhibition and activation are all 'extra-functional' exercises that can be performed prior to or between sets. In functional rehabilitation the use of extra-functional exercises prior to functional movement is referred to as '*movement preparation*'. A client can perform the same exercises daily as part of a functional rehabilitation program.

## Bringing It Together

A functional trainer can manage persistent pain by:

- Regulating emotional responses to movement
- Taking time to 'explain pain'
- Helping to manage painful activities

Training should expose clients to pain patterns whilst avoiding triggering pain, by applying:

- Graded exposure
- Intelligent variation

Exercise can be prescribed to address sensor-motor dysfunctions resulting from persistent pain, including:

- Mapping drills
- Inhibition exercises
- Activation exercises

These drills can be incorporated into a functional exercise program. Details on how to structure a rehabilitation program are presented later in this section.

In the next section, we discuss *functional biomechanics* and the role biomechanics plays in injury prevention.

### GLUTEAL AMNESIA

*The gluteus maximus is the biggest musle in the body and a powerful stabilizer of the back, pelvis, hip and knee during stepping, walking, running and jumping. Gluteal 'amnesia' leads to core and lower limb instability, causing collapse on loading. The back may arch, pelvis tilt anteriorly and knee may rotate internally and adduct on loading. One rehabilitation strategy would be to 'activate' the hip prior to functional loading to increase stability.*

## FUNCTIONAL BIOMECHANICS

- Posture and Position
- Anatomical Variation
- Form and Technique
- Movement Screens
- Corrective Exercise
- A Functional Perspective
- Positions of Ease
- The Path of Least Resistance
- Functional Evaluation
- Complex Movement

Functional exercise is a fantastic tool in managing pain, but to what extent can functional training prevent injury? Conventional approaches to injury prevention tend to have a biomechanical bias. Biomechanics implies there is a 'correct' way to perform any task or skill. Deviation from correct form and technique is thought to both hamper performance and predispose injury.

Most instructors assess posture, correct form and technique and apply various 'movement screens' to diagnose biomechanical dysfunctions, such as postural misalignments, faulty movement, weak or tight muscle.

In this section, we analyze a biomechanical approach to injury prevention and evaluate biomechanical principles in the light of emerging neuroscience. Various sciences contribute to our understanding of human movement. Anatomists dissect bodies to comprehend how various anatomical structures function. Physiologists study cells and molecules, how organs work and tissues interact. Biomechanics applies the laws of physics to human movement (Knudson, 2007).

There are several branches of biomechanics. *Kinematics* is the study of the relative movement of body segments through space. *Kinetics* investigates the forces that produce, arrest and modify motion, analyzing biomechanical forces like momentum, inertia, mechanical advantage and leverage. Ostokinematics and arthokinematics apply biomechanical principles to the movement of bones and joints.

- Kinematics – the study of human motion
- Kinetics – the study of forces that produce, arrest and modify motion
- Osteokinematics – the study of bone motion
- Arthrokinematics – the study of joint motion

Biomechanics is frequently applied to enhance performance, improve safety and prevent injury. Biomechanists analyze film footage using mathematical models to find the most effective way to perform any task or skill – calculating the best way to sit, stand, walk, run, jump and throw, how we should organize movement and activate muscle. Deviation from correct form and technique is considered *dysfunctional* – a source of inefficiency, decreased performance, stress, strain and increased risk injury.

Conventional training stems from biomechanical principles. Most conventional gym equipment is ergonomically designed to reduce biomechanical stress and strain. Instructors, coaches and therapists typically apply biomechanical models to:

- Assess posture
- Correct form and technique
- Design movement screens
- Prescribe corrective exercise

Do biomechanical models apply to real people, and to what extent are they able to predict or prevent injury? We use neuroscience to evaluate the efficacy of each of these approaches, starting with posture.

### Posture and Position

*Posture* is regarded as the '*position or attitude of the body*', or the relative position or alignment of the body in space, before and after movement. In evolutionary history, posture played an important role in man's development. Homo sapiens gained an advantage over their animal counterparts by shifting from a quadra-pedal to a bi-pedal stance.

Standing upright frees the hands to manipulate tools and reach for food, although the cost of this is the additional stress and strain of maintaining an upright position against gravity on two legs, rather than four. Upright posture places greater strain on load bearing joints like the spine, hips and knees, one reason why osteoarthritis and lower back pain are so prevalent in today's society.

In most circles, posture is regarded as an important component of health. Poor posture is commonly cited as a source of musculoskeletal pain and injury. Trainers and musculoskeletal therapists frequently assess posture, asking clients to 'stand-up straight' as they visually scan the relative alignment of boney points.

In 'good posture', body parts align and balance under gravity, reducing the effort it takes to remain upright. Misalignment is thought to increase the relative weight of body parts, intensifying the stress and strain on postural muscles and increasing the effort required to remain upright.

Imagine an office worker straining to read a computer screen. The ribcage sinks, the head shifts forwards, increasing the relative weight of the head on the shoulders and loading the muscles of the upper back and neck. This type of poor posture is thought to be a major source of back and neck pain (see Figures 7.10 and 7.11).

**Figure 7.10** Normal Head Posture.

**Figure 7.11** Forward Head Posture.

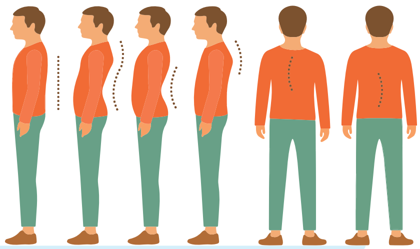

**Figure 7.12** Common Postural Deviations.

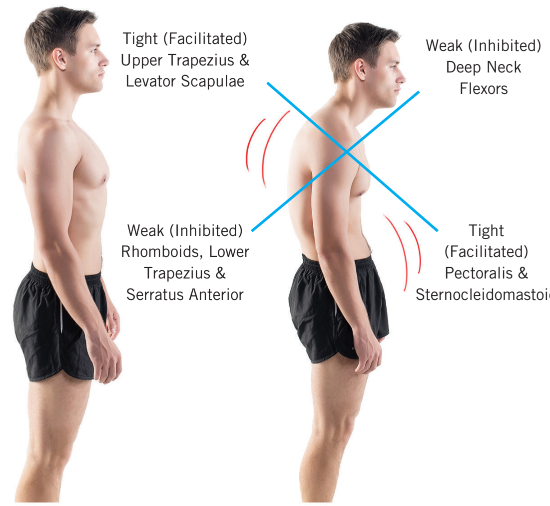


**Figure 7.13** Upper Crossed Syndrome.

Poor posture affects the entire body. If one body part deviates, other parts compensate and shift to maintain center of gravity. Compensatory patterns translate throughout the entire body. Popular texts identify common patterns of *postural distortion* (see Figure 7.12).

- Hyper-lordosis – increased lumbar curve and anterior pelvic tilt
- Hyper-kyphosis – increased thoracic curve and forward head position
- Scoliosis – frontal pane spinal curve

Muscle imbalance is cited as a common cause of postural deviation. Strong, tight muscles on one side of a joint, (the *agonist*), overpower weaker muscles on the opposite side of a joint (the *antagonists*). Instructors prescribe corrective exercises to 're-balance' opposing muscles to correct posture, reducing postural stress and preventing pain and injury. This may be an overly simplistic way of thinking about posture (see Figure 7.13).

Each and every day, people are diagnosed with a whole range of postural distortions and biomechanical dysfunctions. Overpronation, collapsed arches, genu valgum and varum knees, tilted pelvis, scoliosis, winging scapula, rounded shoulders and forward head postures, excessive curvatures of the spine, leg-length discrepancies, pelvic rotations and misaligned joints – the list of biomechanical defects infecting the population appears endless.

## POSTURAL TWEAKS

*Try this task:*

- *From standing, tilt your pelvis forward and back and find a middle position in which your belt line is level*
- *You are now in theoretical 'neutral spinal alignment'*
- *Now try and maintain neutral alignment as you walk up and down the room*
- *How successful were you?*
- *Could you do this all the time, every day?*

Patients up and down the country are prescribed orthotic inserts, ergonomic chairs to support backs, orthopedic mattresses, back supports and postural braces, all to correct poor posture and reduce biomechanical stress and strain. Clients are taught to correct posture in their daily lives – 'tilt youer pelvis', 'tuck the tailbone under', 'retract the chin' or 'set the shoulders'. How easy is it to maintain these postural corrections in daily life?

## Anatomical Variation

We assume everyone's body should be much the same, that everyone's bones and joints are similar. In reality, we are all different. Each and every person is riddled with structural variations, abnormalites and oddities. 90% of people have a leg length discrepancy, pelvis structures vary from person to person, most people have a degree of pelvic rotation meaning their hips are not square, and congenital abnormalities like additonal vertebrae or ribs are commonplace.

We are all a little asymmetrical, a little abnormal and odd. Variations in structure are actually quite normal, inherited or acquired over years of developmental stress. Everybody's structure is moulded by individual experiences, patterns of use, injury and old age. Structural variations drive posture and position.

Contrary to popular belief, there is little evidence to suggest poor posture causes pain or injury. In his article 'The fall of the postural-structural-biomechanical model in manual and physical therapies', Eyal Lederman (2010) cites an impressive array of research proving this point.

- 'There was the lack of association between postural spinal asymmetry, thoracic kyphosis and lumbar lordosis in teenagers and developing LBP [lower back pain] in adulthood' (Poussa, 2005).
- In adults, the extent of lumbar lordosis as well as the presence of scoliosis failed to show an association with back pain (Christensen and Hartvigsen, 2008).
- 'Even obvious increases in lordosis and sagittal pelvic tilt during pregnancy lack an association with back pain' (Franklin and Conner-Kerr, 1998).
- Also differences in regional lumbar spine angles or range of motion between the segments failed to show an association with the future development of LBP (Hamberg-van Reenen, 2007).
- 'The evidence suggests that for most people anatomic leg-length inequality is not clinically significant' (Knutson, 2005).

There is little evidence that physical abnormalities like posture or disc bulges consistently cause pain. And as such, evience of such abnormalities on either x-ray or Magnetic Resonance Imaging should not automatically be assumed as the cause of an individual's pain. Far from being pathogenic, *variations* in structure are relatively normal.

Many athletes have significant postural distortions and still peform at elite levels. Usain Bolt has a scoliois that appears to have little impact on performance. Despite having knees that collapse inwards, ankles that flick out and and feet that flail out, Priscah Jeptoo still won the London Marathon, collected Olympic and world championship silver medals with a 2:20 personal best time. Can we really be sure that analyzing posture gives us a useful insight into how well a client will walk, run, bend, lift, carry, throw, climb, swim or surf? If posture does not predict or reduce performance, why worry about it all?

## Form and Technique

'Form and technique' is the next cornerstone of a biomechanical approach. Biomechanical models calculate the most efficient and effective ways to perform all sorts of tasks – how to run, jump, throw and so on. Deviation from 'ideal' form is thought to hamper performance and predispose injury. Coaches use biomechanical models to train athletes, highlighting biomechanical errors in movement.

Conventional training is heavily influenced by biomechanical principles. Instructors go to great pains to correct form and technique. Many movements are branded unsafe due to the biomechanical stress and strain they generate. We are told not to:

- 'Bend' or 'lift' with a rounded spine
- 'Squat' below 90 degrees of knee flexion
- 'Lunge' with the knee passing the toe
- 'Swing' or use momentum

Whilst prohibited in most gyms, these movements are commonplace in the real world. Lift a pencil off the ground and we crouch, flex the spine and twist. Not once have I seen a client's spine or knees explode lifting this way. In South East Asia people deep squat to eat or go to the toilet. Is this damaging their spine? Children squat, bend and twist in lots of directions and all manner of interesting ways. Is this unsafe? Should we restrict how our children play?

One experiment I read about involved inserting dissected pig intervetebral discs into a machine where they were repetitively flexed and extended. Over many repetitions the discs ruptured. This experiment was cited as evidence that spines should be kept 'neutral' – we are told not to twist and bend for fear of damaging the spine.

Spines do not work in isolation. They work as an integrated unit supported by networks of muscles, ligaments, tendons and fascia. Under reasonable loads, the spinal engine is designed to bend and twist. Not only is spinal motion safe, it is also essential for vertebral health. Intervertebral discs do not have a direct blood supply. Mechancial stimulation generated by the rhythmic loading and unloading of the spine is needed to imbibe nutritious fluid into the nucleus. Movement is not only safe, it is essential for spine health.

Does poor biomechanical form and technique predispose injury? The answer is it probably depends. It depends on who you are and what you are doing, the nature of the task, the load, speed of movement, duration of movement, fatigue and so on. Should we worry about how to pick up a pencil off the ground? Probably not. Should we keep the spine in alignment to reduce mechanical stress when lifting a very heavy box? Probably. As with many things, the answers to these questions are far from straightforward.

## Movement Screens

The importance of form and technique is clearly illustrated in how instructors frequently assess clients using *movement screens*. Many instructors assess their clients using a movement screen and ascertain their risk of injury. A movement screen is a specific exercise in which poor form and technique is thought to predict risk of injury (Cook et al., 2006). Popular movement screens include the:

- Overhead squat
- Lunge
- Single leg balance support
- Press-up

Below are a short list of common deviations and biomechanical defects thought to predispose poor form and technique.

### Squat

| | | |
|---|---|---|
| • *Excessive hip flexion* | Restricted ankle joint<br>Tight calves<br>Tight hip flexors | |
| • *Pronation at the knee* | Tight adductors<br>Weak gluteal muscles<br>Tight iliotibial band<br>Weak vastus medialis muscle | |
| • *Pronation at the ankle* | Restricted ankle joint<br>Flattened medial arch | |

## Lunge

| | | |
|---|---|---|
| • *Excessive hip flexion* | Weak glute maximus<br>Tight hip flexors | |
| • *Rear foot external rotation* | Restricted hip capsule<br>Tight hip flexors | |

## Single Leg Support

| | | |
|---|---|---|
| • *Pronation at the knee* | Weak gluteal muscles, specifically weak glute medius and minimus | |
| • *Ipsilateral hip shift* | As above | |
| • *Contralateral hip drop* | As above | |

## Press-up

| | | |
|---|---|---|
| • *Scapular winging* | Weak serratus anterior | |
| • *Flexed thoracic spine* | Weak lower abdominal muscles<br>Decreased thoracic mobility | |
| • *Increased lumbar extension* | Weak lower abdominal muscles | |

Musculoskeletal therapists use more precise movement screens, or orthopedic tests, to identify specific biomechanical dysfunctions. Some texts describe in great detail what biomechanically sound movement should look like and use this as a foundation for subsequent treatment. For example, we are told on reaching overhead:

- The scapula (i.e. shoulder blade) rotating 1 degree for every 2 degrees of humeral motion
- The scapula remaining flush to the ribcage and not 'winging' (i.e. the inferior angle should not pull up)

It is common for texts to identify the order in which muscles should fire. We are told for example:

- To achieve core stability, the transverse abdominis should contract approximately 150ms prior to movement of the extremities to stabilize the spine prior to motion
- Gluteal muscles 'firing' should fire prior to the hamstrings or erector spinae to prevent back pain

The efficacy of movement screens and their ability to predict injury is highly debateable. There is little evidence that functional movement screens predict injury (Dorrel et al., 2015). This is not to say functional movement screens are not useful, just that pain and injury are complex and clear statistical relationships can be difficult to establish. Whilst useful, the table above is an over-simplification.

Biomechanics provides a useful insight into 'ideal' movement. The problem is, in function, circumstances are rarely ideal. Functional movement is complex and varied. No two movements are ever the same and 'correct' form and technique is therefore impossible to define.

Variations in individual structure and function mean that what works for one, may not work for another. We all *compensate* for intrinsic deviations in structure and function. Compensatory patterns are complex and vary from moment to moment, task to task and from person to person. This means that providing overly rigid guidelines for movement or drawing conclusions from movement screens can be problematic.

## Corrective Exercise

After identifying poor form and technique, most instructors will provide 'correction' exercises. Instructors will diagnose the cause of faulty movement and then provide exercises to correct these issues. Weak or restricted muscles influence movement, altering an individual's ability to maintain correct form. '*Corrective exercises*' are prescribed to address these 'dysfuntions', to strengthen weak muscle or stretch tight muscle – the assumption being that gains in performance will transfer to function and reduce the risk of injury.

If an instructor sees a 'winging scapula', when the inferior angle of the scapula pulls away from the rib cage during a 'press-up', for example, they might prescribe corrective exercise to strengthen the serratus anterior muscle. This exercise would theoretically strengthen the muscle responsible for keeping the scapula adhered to the rib cage, improving scapulo-thoracic rhythm to prevent future shoulder injury. There are several flaws with a biomechanical approach though. There is little clinical evidence to support the noton that:

- A 'winging scapular' is actually 'abnormal' or 'dysfunctional'
- Altered scapula-thoracic rhythm predisposes injury
- Clients can isolate individual muscles
- That strengthening muscles alters movement behavior
- That gains in strength transfer to function

In conventional training, instructors encourage everyone to try to maintain 'correct' form and technique. Variations are considered as dysfunctions to be corrected. More often than not, instructors fall for the 'physiological fallacy' that suggests that asymmetries and altered patterns of movement arise due to tight or weak muscle.

## A Functional Perspective

We have to re-evaluate a biomechanical approach in the light of emerging neuroscience. In reality we are all different. Variation is, for all intents and purposes, quite normal. We all have structural and functional variations that influence how we walk, bend and lift. There are countless different factors that impact movement. By emphasizing muscle tightness and weakness, we might neglect the countless other *structural*, *biomechanical*, *neurological* or *behavioral* issues influencing movement.

### Structure

We all have variations in the shape of bones, orientation of joints, and origin and insertion of muscles that impact movement. Structural abnormalities can be inherited or are acquired over long periods of time or through traumatic injury. Unlike physiological factors, structure is unlikely to change with training.

### Physiology

The physiological state of muscles, tendons, ligaments and fascia impacts function and movement ability. A restricted psoas muscle might limit hip extension, pulling the spine into an arch and placing stress on the hip and lower back, for example. But trainers should always ask 'why are muscles or fascia tight or weak?'

### Neurology

Altered patterns of coordination, sensation, activation and recruitment all have a huge impact on function and are extremely sensitive to training. Very rarely do we consider the neurological factors that create asymmetries in movement.

### Behavior

How a client responds to different situations and circumstances varies depending on where they are, what they are doing and how they feel. Behavior is driven by how client's think, their emotions and expectations.

When a client 'weight-shifts' during a squat, there could be various factors driving compensatory patterns. A restricted ankle joint, tight hip capsule, restricted pelvis, painful sacroiliac joint or restricted facet joint could all be potential causes of this compensatory pattern. An ankle joint could be restricted as a result of osseus abnormality, bone degeneration, cartilage damage, restricted bone motion, or tight or over-active muscle. The causes of altered motion can be countless.

There doesn't even need to be a physical reason for altered movement. Imbalances, asymmetries, instabilities and rigidities can manifest due to poor coordination, altered patterns of recruitment, concern over an old knee injury or a learned pattern of behavior relating to negative past experiences and pain. Fortunately, it is the neurological and behavioral factors that are often fastest to change.

Movement is 'subconsciously controlled'. The subconscious strives to preserve certain 'biological priorities', namely *homeostasis*, *survival* and *ease*. The subconscious strives for ease and efficiency (Kamm et al., 1990) and therefore form and technique is unlikely to emerge if it expends additional energy and effort or in some way causes pain, apprehension or discomfort. It takes a great deal of concentration and focus to maintain a form and technique that threatens subconscious priorities. Trainers have to appreciate the subconscious strives for:

- Positions of ease
- Paths of least resistance

## Positions of Ease

We all fight an unrelenting battle against gravity. Posture reflects the ability to resist the gravitational loads that work to compress and squash us into the ground. Overcome gravity and not only can we stand up tall and upright, but we can run, jump and climb. Lose the war against gravity and we slump towards the ground, sinking into postures that reflect injury and old age.

Ask a 'motionless' street performer how hard it is to maintain static posture. Remaining still and stabilizing, postural muscles quickly fatigue, triggering postural stress and pain that drives the body to shift posture. The subconscious continually strives to find 'postures and positions of ease'. We intuitively search for places to rest – bars to lean on or chairs to sit in.

Movement is our greatest weapon in the war against gravity. Stand still and we start to shift weight from one foot to another. Stand to attention, like a soldier on parade and we subconsciously sway in a subtle, penduluous motion. Biomechancial studies have measured '*postural sway*' using force plates.

Sit, and we soon start to fidget. Fidgeting is a functional movement strategy designed to rest tissues and share load. Maybe let your child fidget as they sit at the table. Even at night, we shift position 30 or 40 times to avoid stiffness and tension. We are simply not designed to remain still. No matter what we are doing, there is no single, ideal posture. Posture is a dynamic state, one in which we shift from one positon to another.

Postural strategies emerge depending on 1) the tasks and activities we perform, 2) an individual's capacity (i.e. strength, endurance, mobility etc.), 3) how they feel, and ultimately 4) the subconscious drive for ease and efficiency. Influencing '*postural strategies*' is not easy. Instructing clients to simply 'stand-up straight' will not work. A trainer can only change a client's postural strategy by:

- Modifying tasks
- Adapting environments
- Building capacity
- Managing emotion

### Modify Tasks

A trainer can bias certain postures and positions by adapting the tasks clients perform. Setting realistic goals for how long to work, how much

**Figure 7.14** Task Driver of Postural Strategy. An overhead squat to 'drive' upright posture whilst squatting.

**Figure 7.15** Band Squat.

weight to lift, the types of objects we lift and the tools we use, can all support positive postural strategies. In the gym, a trainer can modify exercises to drive certain postures and positions. Asking a client to reach overhead as they squat drives a more upright stance, for example (see Figure 7.14).

## Adapt Environment

Ergonomics is the practice of adapting the environment, particularly at work, to improve posture and reduce repetitive stress and strain. Ergonomical intervention for an office worker might be to move a monitor above the eye-line to encourage upright posture, provide back support to maintain the arch in the lower back whilst sitting, wrist supports for laptops and so on. Whilst ergonomic chairs are popular, a more effective way to reduce postural stress might be to switch to a 'swiss-ball'. Sitting on a mobile ball encourages movement and activates core muscles.

In training, we can introduce external drivers of posture – tools, obstacles and targets that drive more functional postures and positons, for example placing a band around the knees to alter knee alignment (see Figure 7.15). External drivers are more effective tools than instructions in influencing posture and position.

## Build Capacity

The subconscious strives for postures and positions of ease. We instinctively shift towards positions of strength, mobility and stability. If a client has weak erector spinae muscles, a rigid thoracic spine and poor balance, they will tend to shift into a flexed postion. There is always a subconscious drive to feel stable, safe and secure.

A trainer can encourage functional postures and postions by making them easier to maintain. Individuals tend to drift towards postures and positions of ease, strength and stability. By developing strength, mobility, flexibility, stability and balance within functional positions, we make it more likely that functional postures and positions will emerge within function.

## Manage Emotion

Emotion drives posture. Posture is a form of communication and our thoughts, feelings and emotions drive the postures we adopt. It is not uncommon for tall clients or women with a large chest to slump to avoid attention. Asking clients to 'stand-up straight' neglects the emotional factors driving postural strategies.

Feeling 'threatened' or in pain tends to drive a flexed posture and position – an almost 'self-hug' if you like. The brain activity or neurotags associated with physical pain are very similar to those associated with emotional pain. As far as the brain is concerned, physical and emotional pain are alike. Physical and emotional pain drive dysfunctional postural strategies. Training can positively influence posture by helping clients manage emotion, build confidence and reduce both physical and emotional pain.

## The Path of Least Resistance

Biomechanical models provide a valuable insight into 'ideal' patterns of movement, but they should not be applied universally. Biomechanics views people like machines to be maintained, with parts to be fixed. This mechanistic perspective is known as the *Cartesian view* (Torrents and Balague, 2006).

People are not machines. They are living, breathing, thinking entities with anomalies and oddities that make generalization and standardization problematic. All clients have variations in structure and function that force them to *adapt* and *compensate*. Patterns of compensation vary from person to person and moment to moment.

- Adaptation – altered movement strategy in response to task and environmental variation
- Compensation – altered movement strategy in response to intrinsic variations in capacity (i.e. segmental mobility, flexibility, strength or stability)

*Compensation* can be *local* to the point of altered function or *distal*, in other parts of the kinetic chain.

- Local compensation – proximal to the site of altered function
- Global compensations – distal to the site of altered function

The *structural*, *physiological*, *neurological* and *behavioral factors* that drive posture can be difficult to diagnose. Clues as to which are dominant can be drawn from the extent to which postural asymmetries are:

- Subject to change
- Specific to a context
- Linked to emotion

Neurological or behavioral factors vary depending on a client's state of mind and the context, making them highly responsive to training. Structure is fixed and stable regardless of context or emotion, and therefore is unresponsive to training. If functional asymmetries are structural in origin, training should focus on developing a client's ability to adapt and compensate.

Imagine a client over-pronating, with collapsed arches and knees rolling in as they run. A biomechanical approach labels 'over-pronation' as a dysfunction that needs to be corrected. 'Flat feet' are often identified as a cause of biomechanical stress leading to lower limb pain. Patients with flat feet are often prescribed orthotic inserts.

In a functional approach, flat feet are considered to be a functional variation that could be completely normal. If a functional trainer considers increased pronation to be a factor in causing pain, the next question would be 'why is this client over-pronating?' If we assume the subconscious always takes the path of least resistance, what makes over-pronation advantageous for that person? What benefit is over-pronation to them? Why is this movement pattern emerging?

Altered movement emerges due to variations in function that can exist anywhere within a kinetic chain. Asymetries in strength and mobility almost anywhere within the body could manifest in increased pronation. A rigid ankle, unstable hip or painful pelvis could all cause the limb to collapse inwards. Issues even further upstream could cause a chain reaction leading to altered movement. The causes of dysfunction can be difficult to diagnose.

Rather than inserting pieces of plastic in people's shoes, a functional approach attempts to address functional asymmetries wherever they appear. Addressing imbalances in terms of mobility, stability, strength, endurance and balance throughout the kinetic chain without the need for complex, confusing and worrying biomechanical diagnoses.

Rather than forcing clients to conform to a biomechanical model of ideal, a functional approach aims to enhance functional performance and encourage symmetry by emphasizing dysfunctional patterns and developing:

- *Coordination* – the ability to organize movement
- *Variability* – the ability to adapt, react and recover
- *Knowledge* – the ability to predict and anticipate outcomes
- *Confidence* – the expectation of successful outcomes

A functional rehabilitation program focuses on improving movement patterns that are ill-coordinated or those in which the client lacks confidence. Rehabilitation seeks to address unstable or chaotic motion, or alternatively to develop adaptability in patterns that appear overly rigid or consistent. A functional approach assumes improved confidence, coordination and skill will reduce the risk of injury. The goal is not to diagnose problems but to recover function.

## Functional Evaluation

Biomechanical assessments are usually performed in a clinic or studio with the client aware they are being assessed. Conscious attention prevents instinctive and intuitive reactions and are therefore of limited benefit. In an ideal world a trainer would observe a client's natural movement, performing relevant and useful tasks in natural circumstances. This can be difficult. I often watch a client get-up, bend, pick up a bag and walk as they come to my treatment room. In those few moments, I see natural, authentic functional movement. This can be far more revealing than any abstract, biomechanical assessment.

Rather than a collection of abstract movement screens, a *functional rehabilitation evaluation* should include a client's *pain patterns* and a series of *primary*, *secondary* or *travel movement patterns*. Imagine a footballer recovering from knee injury, with pain on the inside of the knee triggered on passing the ball with the instep. After an initial consultation, a functional evaluation might include a series 'primary movements' (sit, squat, bend, lift and twist), 'travel patterns' (*walk*, *run* and *jump*), 'secondary movement patterns' (like shooting, passing and dribbling a ball) and, of course, the client's pain pattern (which in this case is kicking with the instep).

To minimize conscious reflection and correction, and encourage instinctive patterns of movement, a trainer should incorporate external drivers, tools, obstacles or targets. Introducing a football into the assessment makes perfect sense for this client.

The trainer observes the client 'within-task', identifying functional asymmetries, identifying imbalances in mobility, stability, speed and distance of motion of one leg compared to the other. Can we identify areas of stiffnes and rigidity, instability or 'chaotic motion' in the hip, knee or ankle? Does function change when we introduce intelligent variation with movement in different speeds, distances and directions? A trainer has to evaluate to what extent movement strategies are:

- Functional (i.e. support performance)
- Dysfunctional (i.e. hinder performance)
- Overloaded (i.e. is inadequate to complete the task)

Dysfunctional patterns tend to:

- Trigger pain (i.e. the client's pain patterns)
- Trigger apprehension
- Lack coordination

- Appear:
    - Unstable
    - Weak
    - Slow
    - Rigid
    - Asymmetrical

A trainer should identify specific areas of the body that appear dysfunctional, scanning for areas of:

- Pain
- Irritatation
- Rigidity
- Instability

A trainer may even be able to identify patterns of compensation, noting when asymmetrical movement in one area is related to altered movement in other areas.

Consistency of compensatory patterns may give clues as to whether altered function is due to changes in structure, physiology, neurology or behavior.

- Structural
    - Unchanging and consistent – consistent over multiple repetitions and within multiple patterns
    - Unaffected by context
    - Unresponsive to intervention
- Physiological
    - Slow to change
    - Responsive to altered pattern or position
    - Responsive to use
- Neurological
    - Inconsistent
    - Responsive to intervention and attention
- Behavioral
    - Inconsistent and responsive to change
    - Influenced by context, expectation and education

The client's initial consultation, medical history and injury profile should highlight potential triggers for pain and apprehension, including past injuries, patterns of overuse and underuse, and unhelpful attitudes and beliefs.

On identifying functional asymmetries, painful, dysfunctional or overloaded movement patterns, and potential triggers, a trainer can build a functional rehabilitation program. This program focuses on reintroducing pain patterns, but at levels that do not trigger pain and aim to develop functional capacity (strength, stability, mobility, balance, endurance etc.) within various travel, primary and secondary patterns. Exercises should aim to develop a client's task-specific coordination and confidence, applying STRIVE principles as discussed in the first part of this book.

Decreased pain and dysfunction is not the primary goal but is a byproduct of improved 'function'. Rather than treating symptoms, diagnosing dysfunction or prescribing corrective exercise, the goal of functional training is to develop 'movement ability'.

## Developing Movement Ability

*Mobility* is the 'ability to move freely and easily' or 'the ease with which joints can move' (Oxford Dictionary). In conventional rehabilitation, mobility is generally associated with the movement of joints. A loss of mobility hampers a client's ability to maintain biomechanically sound form and technique. When we walk, for example, the ankle is required to move through aproximately 20 degrees of dorsiflexion. Most healthy adults have 25 degrees of motion at the ankle. Even a small loss of ankle range forces a degree of compensation, increasing biomechanical stress and strain and potentially predisposing injury.

A conventional approach to rehabilitation would be to 'mobilize' the ankle to restore motion and reduce the need for compensatory patterns. Joints are mobilized either passively, with a client lying on a treatment coach, or using abstract exercises, such as stretches for the calf muscles.

There are several flaws with this approach. Firstly, passive mobilization and abstract stretches assume some sort of physiological restriction. If reduced ankle mobility relates to a neurological or behavioral problem, a bone abnormality, osseous change or a fear of movement, for example, passive stretches are unlikely to work.

Secondly, mobilization may improve movement in one direction in the gym, but mobility may not transfer to function in which the ankle is required to move in many different directions, at different speeds and angles. Ankle stretches fail to account for the fact that the ankle has to be able to work within different movement patterns, over uneven ground, in different contexts and situations. Functional training has to try and account for all these different variations.

Rather than stretching or mobilizing, functional training seeks to develop '*movement ability*' – the ability to move with accuracy, precison and skill, over varying distances, through different planes, at different speeds, without undue stress, strain or pain. If we can improve 'mobility' under these conditons, training should effectively transfer to function.

Functional mobility drills must be 'task-orientated', reflecting the tasks and activities we perform on a daily basis, involve instinctive and intuitive reactions to the external triggers, and incorperate intelligent variation, moving joints through different postures and positions, in different directions and at different speeds. To account for behavioral factors, mobility drills should be performed within different situations and scenarios and incorporate emotional content, such as stress, competition and play.

For a client with restricted extension in the thoracic spine, for example, a trainer might prescribe twisting and reaching overhead. To make the drill more 'functional', we might place the client into different postures or positions (either assisting or challenging mobility), we might select different tools to reach with and provide targets to reach towards. A trainer can tweak direction of movement by repositioning targets, speed of motion, asking the client to move more quickly or slowly and so on.

The client should move comfortably, into and out of restriction, without triggering pain. If movement is asymmetrical, spend more time on the restricted side. You may find that neurological or behavioral restrictions resolve instantaneously. Physiological restrictions may take more time and rely on repeating drills consistently over days or weeks. In the case of structural restrictions, mobility may not improve and training should focus on the client's ability to adapt and compensate, by improving function within other areas of the kinetic chain.

Increasing a client's movement 'vari-ability' enhances adaptability and *redundancy* and *resistance to fatigue*. See Figure 7.16 for an example of a functional mobility drill for the ankle.

We cannot 'instruct' clients to change form and technique. Instruction rarely impacts subconscious behavioral responses. To improve mechanics, a trainer should develp a client's movement ability and variability. Given time, *the path of least resistance* should change and the subconscious should gravitate towards new movement strategies.

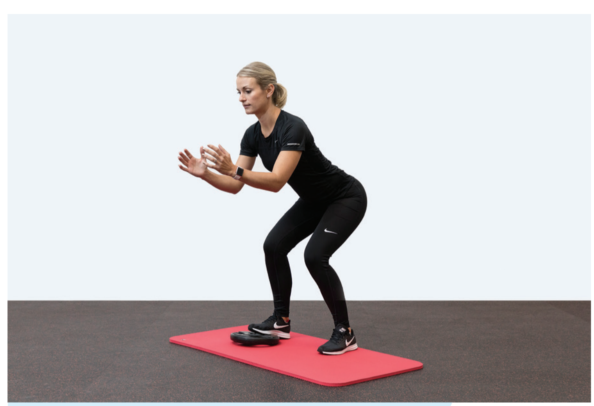

**Figure 7.16** Functional Ankle Mobilization.

## COMPLEX MOVEMENT

One of the most effective ways to improve posture, mobility and mechanics is through '*complex movement*', moving skillfully in interesting ways and in lots of different directions. Varied movement mobilizes joints, stretches myofascia and desensitizes the client to novelty.

A functional trainer should create awkward and unusual movement challenges, forcing the client to adapt and react, and explore new and interesting ways of moving. As the client builds a database of new positive experiences, you may be surprised to see that pain and dysfunction diminish (see Figure 7.17).

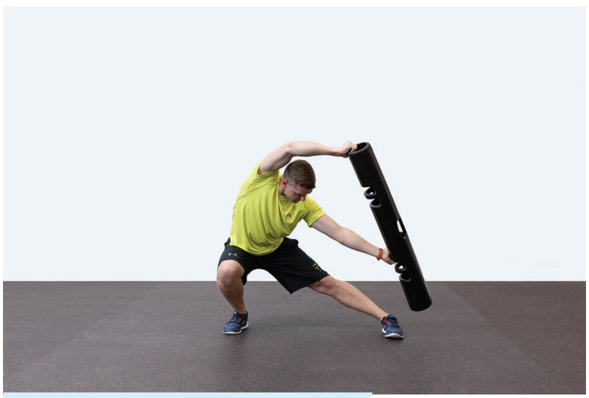

**Figure 7.17** Complex Movement.

### Bringing It Together

Whilst a conventional biomechanical approach to injury prevention emphasizes a return to normal or ideal patterns of movement, the reality is that clients are rarely normal or ideal.

We all have to adapt and compensate for intrinsic variations in form and function, the most effective way being to improve the body's ability to adapt and react. An FT can:

- Influence subconscious decision-making by making functional movement strategies less threatening and easier and more efficient
- Remove physiological, neurological and behavioral roadblocks
- Support training clients to be confident moving in lots of different ways, in different directions and at various speeds and distances

In the last section, we look at some examples of functional rehabilitation programs.

**MOVEMENT FLOW**

*Movement flow is an exploration of movement ability to expand the 'movement bubble'. In movement flow the client transitions between different positions and postures, integrating varied patterns of reaching, bending and shifting, through different ranges, in a smooth, flowing manner. The goal is for the client to explore the limits of movement.*

*Movement flow is underrated and underutilized in western exercise. Less so in the east, where movement flow incorporating meditation and mindfulness is seen in Tai Chi and Qigong.*

# REGIONAL INTERVENTIONS

- Functional rehabilitation inteventions
- The Lower Back
- The Thorax
- The Neck or Cervical Spine
- The Hips and Pelvis
- The Knees
- The Feet and Ankles
- The Upper Extremity
- Transition to Function

So far in this book, we have discussed injury, pain and pain management. We have introduced a form of 'functional biomechanics' in which mobility drills are used to encourage movement symmetry.

In this last section, we outline common injuries for each region of the body, discussing possible rehabilitation strategies. We introduce a range of '*extra-functional*' rehabilitation exercises, used to hep restore sensor-motor function after serious injury or episodes of persistent pain.

To expand and discuss these concepts and theories please visit www.strivemovement.com.

## Functional Rehabilitation Interventions

Following a functional evaluation, a trainer should have identified a client's pain patterns, 'dysfunctional' or 'overloaded' patterns of movement, asymmetries and regions of the body that appear weak, unstable, rigid or immobile.

Functional exercises targeting each of these can be prescribed to improve movement ability and functional capacity. These can be supported by a program of 'extra-functional' exercises designed to restore normal sensor-motor function. These exercises have been placed into one of four catagories:

- Mapping
- Inhibition
- Activation
- Mobilization

### Mapping

*Mapping exercises* are designed to restore sensor-motor function following a period of pain or injury. Pain distorts *internal body maps*, disrupting the brain's ability to sense the body in space and the ability to recruit and coordinate muscle. Mapping exercises are designed to restore internal maps, the result being improved coordination, which in turn leads to increased strength, stability, flexibility and mobility.

Mapping exercises are generally isolated movements of a specific joint or region of the body, performed in a safe secure posture so that attention can remain on the area in question. The client should be mindful of the muscles they are activating and the movements they are performing. Mapping is usually performed:

- Slowly
- Over an extended period (30 seconds to two minutes)
- Mindfully (i.e. with an internal focus of attention)
- In a safe and secure environment
- In a stable posture or position
- Free from distraction
- Free from pain or irritation

To 'map' motion in the neck/cervical spine, a client might lie comfortably on their back with their head supported by a pillow. The client would softly flex the neck in a controlled 'nodding' type movement, as if squeezing a tennis ball under the chin while focusing on sliding the back of the head up the pillow. Movement would be performed over 60 seconds and would be coupled with breathing to encourage relaxation.

A cervical mapping drill develops the brain's motion sense in the upper neck, activating deep cervical stabilizing muscles and relaxing the suboccipital muscles found at the base of the skull, which are frequently found to be hypertonic and tense. The exercise might be progressed into different postures and positons, from sitting, standing or all-fours, for example.

To map the ankle, a client might repeatedly flex and extend the foot, invert and evert or circumduct, rolling the foot in a smooth controlled circle. *Intelligent variation* should always be introduced to progress mapping drills. For any mapping drill, a trainer might 'tweak' the exercise, moving from different postures and positions, moving in different directions, at different speeds or by adding environmental drivers like tools, obstacles and targets. For example, to progress neck mapping, a trainer might ask a client to smoothly rotate the head to look over the shoulder towards a target, keeping the spine still and the shoulder relaxed. Again, these drills are limited only by the imagination and creativity of the trainer.

## Inhibition

*Inhibition* describes a range of techniques designed to reduce myofascial tone and normalize patterns of recruitment in hypertonic muscles to improve range of motion and mobility. Inhibition is applied using either *static stretch* or *direct pressure* to hypertonic muscle, and is held for upwards of 30 seconds, facilitated by mindful breathing and active release of tension on outbreath.

Say we thought a hypertonic hamstring or posterior chain was restricting forward bending. We could ask the client to sit and reach towards their toes and hold a stretch for over 30 seconds as muscles relax. We would then re-test their range of motion by returning to the forward-bend, assessing whether range has improved.

Direct pressure applied to myofascia is referred to as *self-myofascial release* (SMR). SMR can be applied using a specifically designed device, like a foam roller, balls or other tools. Pressure should be applied:

- From a comfortable, supported posture and position
- Along a line of tension or discomfort
- On the most tender area
- At a level that triggers a sensation of deep pressure but not pain
- Held until pressure eases
- For no more than three minutes
- In no more than three to four areas

## Activation

*Activation exercises* take advantage of *post-activation potentiation* (PAP) to increase the recruitment of specific muscle groups. Activation can look very similar to mapping drills but tends to include some element of loaded movement in which muscles are engaged at a higher level to excite motor neuron pools and increase activation during subsequent movement.

To 'activate' the muscles of the outer hip, the gluteus maximus, for example, a trainer might ask a client to lie on their side, stabilize the pelvis and lift a knee, keeping heels together in a 'clam' like movement. Motion could be resisted manually or using bands to increase levels of activation. The client would then return to a function, a step or lunge for example, to test whether stability has improved.

## Mobilization

Mobilizations are exercises designed to improve *functional range of motion* at a joint. During mobilization, the client moves a specific joint or region through a full, but pain-free, range of motion, the intent being to gradually increase the range of motion over time. Mobilization is generally applied:

- In a slow, low and controlled movement
- Using a useful or relevant movement pattern

- By repeatedly moving a joint into and out of a full physiological range of motion
- From the point of comfortable tension back to mid-range
- In various directions
- In various positions
- At varying speeds and loads

In the next section, we provide examples of functional rehabilitation exercises, including mapping, inhibition, activation and mobilization applied to each region of the body. We have also outlined relevant anatomy, common injures and biomechanical considerations for each region.

## The Lower Back

The *lumbar spine* is composed of five vertebral segments. Each segment articulates with the segment above and below via *facet joints* on either side of the spine and with the intervertebral disc directly above and below, attaching to each vertebral body. In the lumbar spine, facet joints are orientated to allow flexion, extension and side-bending, but to restrict rotational movement (see Figure 7.18).

The intervertebral disc is composed of a fibrous outer layer called the *annulus* and a fluidic, jelly-like inner *nucleus*. A complex network of ligaments and dense layers of muscles support each vertebral segment and the associated disc (see Figure 7.19).

*Lower back pain* (LBP) and *lumbar dysfunction* are the most common reasons why people in pain visit a GP. One in five people experience an episode of persistent '*non-specific back pain*', i.e. pain with no discernable cause.

The lack of clear causality in non-specific LBP is a challenge for mainstream medicine. Predisposing factors for LBP include a sedentary lifestyle leading to underuse, long periods spent sitting and increased abdominal weight gain. LBP is commonly associated with dysfunctional patterns of twisting, turning, lifting and bending.

THE STRUCTURE OF THE VERTEBRAE

(Side view)

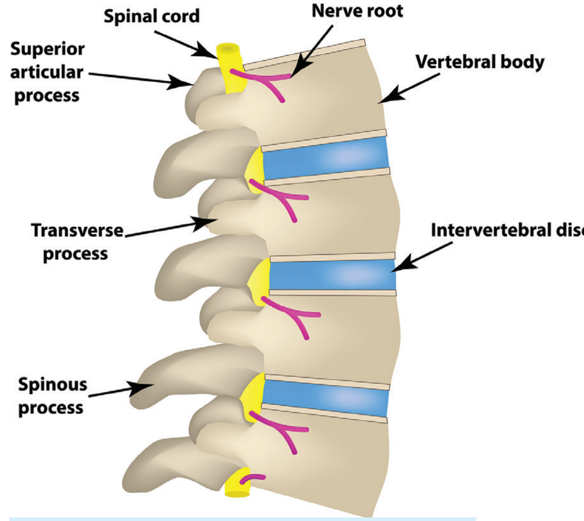


**Figure 7.18** Lumbar Spine Segment and Disc.

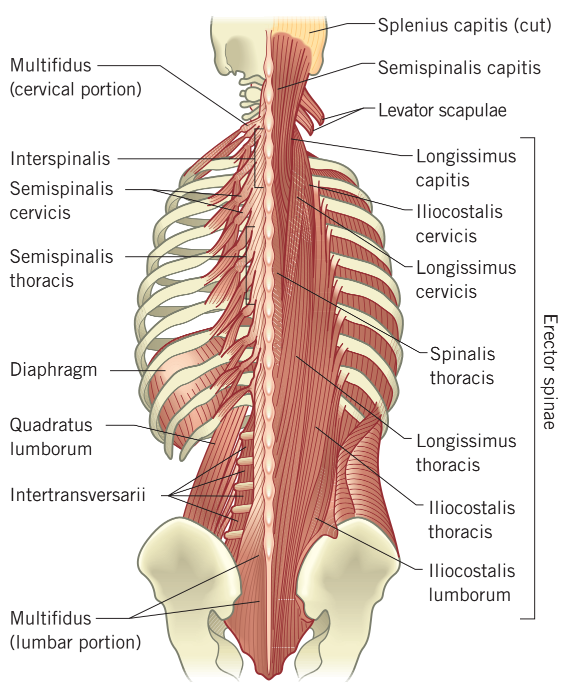


**Figure 7.19** Lower Back Musculature.

## Common Medical Diagnoses for Lower Back Pain

- Facet joint impingement
  - Irritation of facet joints
  - Characterized by:
    - Unilateral pain
    - Sharp in nature
    - Aggravated by side-bending and extension
- Myofascial referred pain
  - Pain referred from local muscles
  - Commonly quadratus lumborum, erector spinae, psoas and even gluteus minimus and medius
  - Characterized by:
    - A diffuse dull ache around the lower back
- Lumbar muscle strain
  - Damage to soft tissue in the lower back
  - Related to a traumatic incident
  - Characterized by:
    - Sharp pain on stretch or loading
- Lumbar ligament strain
  - Damage to lumbar soft tissue (including disc)
  - Related to traumatic incident
  - Characterized by:
    - Sharp pain and apprehension on stretch
    - Specifically, pain on lumbar flexion
    - Often aggravated by sitting
- Lumbar osteoarthritis
  - Degeneration of the lumbar spine joints
  - Could include discogenic pain, spondylosis, stenosis
  - Characterized by:
    - Dull aching pain
    - Sometimes becoming sharp on movement
    - Aggravated by load and overuse

Twisting and turning are key functions associated with the lumbar spine. In terms of movement strategy, to generate power the shoulders should rotate prior to the hips. Turning therefore relies on the ability to dissociate spine and hip motion.

Lower back pain and dysfunction are often associated with *sensor-motor deficits*, including a loss of *position sense* and *movement sense* of the lumbar spine. Clients suffering LBP tend to lose their ability to dissociate motion of individual vertebral segments and motion of the spine from the hips and pelvis. This affects their ability to twist and turn.

Deep abdominal muscles like the transverse abdominis (TVA), coordinate with the thoracic diaphragm and pelvic floor to maintain *intra-abdominal pressure* on lifting. The ability to 'pre-tension' the abdominal wall is thought to be a key mechanism creating 'core stability' prior to lifting. Pain and dysfunction interfere with normal patterns of recruitment, inhibiting stabilizing muscles such as the TVA and multifidus, undermining attempts to maintain intra-abdominal pressure, evident because the abdomen protrudes outwards on lifting.

When the subconscious perceives an increased threat of 'overload' due to spinal instability, muscles such as the quadratus lumborum (QL), psoas and erector spinae tend to become *facilitated*, creating spinal rigidity. Under these conditions, the lumbar spine tends to extend, increasing compressive forces on lumbar segments.

Motion of the lumbar spine integrates with that of the pelvis and hips to create *lumbo-pelvic rhythm*. The pelvis, hips and thoracic spine are all prone to rigidity and stiffness, which can place stress on the lumbar spine which is relatively mobile, especially in flexion and extension. This makes the lumbar spine particularly susceptible to compensatory patterns, making it a common area of *overload* and *overuse injury*. Maintaining stability of the lumbar spine and mobility of the hips and thorax is essential for spine health and function.

## Functional Movement Strategies

- Get close to loads when lifting
- Maintain a long spine when lifting heavy loads
- Allow spinal motion to bend and lift lighter loads
- Avoid abdominal distension or protrusion on lifting, i.e. 'draw the stomach in' on lifting
- Rotate the shoulders prior to hip rotation when turning

Functional lifting strategies vary depending on the nature of the load we lift. Clients should practice getting close to heavy loads, maintaining a natural lordotic lumbar curve on lifting to prevent overloading the lumbar spine. Maintaining spinal alignment is less critical when lfting lighter loads, such as lifting a pencil off the ground, for example.

# Lower Back Corrective Exercises

## Mapping and Mobilization

### Pelvic Tilt

- Slowly rock the hips forwards and back, becoming aware of the segmental motion of each segment of the lumbar spine
- Visualize each segment moving individually as it imprints and pulls away from the floor

**Figure 7.20** Pelvic Tilt.

### Knee Rolls

- Hug the knees to the chest and roll the knees in a gentle circle
- Become aware of the fluid rounding of the lower back

**Figure 7.21** Knee Rolls.

### Four-Point Flexion and Extension

- From all fours, gently round and arch the lower back, making a smooth C-shape in each direction
- Smoothly roll from one position to the next
- Focus the smooth fluid movement of the spine

**Figure 7.22** Four-Point Flexion and Extension.

Always be aware, the exercises above are only a starting point. STRIVE principles can be applied to systematically progress exercises, building challenge and complexity through *intelligent variation*, moving in different directions, speeds and under increasing loads. Exercises should be performed in different postures, positions (progressing to sitting then standing) and varying situations and contexts, i.e. at work, in the car, before sport or at work. For more examples visit www.strivemovement.com.

## Inhibition

### Kneeling Flexion

- From all fours drop the hips to the heels as far as is comfortable
- Become aware of a comfortable sense of stretch in the lower back and hold

**Figure 7.23** Kneeling Flexion.

### Prone Extension

- From prone, with hands by shoulders, push the chest into the air, leaving the hips behind
- Push the hips towards the ground
- Become aware of the stretch within the lower back

**Figure 7.24** Prone Extension.

### Stability Ball Extension

- Sit on a stability ball, then walk out, laying back over the ball
- Reach overhead and feel a comfortable level of stretch through the abdominal area

**Figure 7.25** Stability-Ball Extension.

### Stability Ball Side-Flexion

- Sit on a stability ball, then walk out to one side, laying back over the ball with the ball on the waist
- Reach overhead with the upper arm and feel a comfortable level of stretch through the waist

**Figure 7.26** Stability-Ball Side Bend.

### Deep Back Stabilizers SMR

- Lie over a foam roller or other suitable tool
- Apply pressure to an area of tension or discomfort on the waist and lower back myofascia

**Figure 7.27** Deep Back Stabilizers SMR.

## Activation

### Prone Reach

- Lying face down, reach up towards a target in front of you
- Do not allow excessive protruding of the stomach or overly extend the spine
- Try single arm reach or bilateral reach
- Vary positions (prone single, double, prone elbows, four-point, four-point plank)

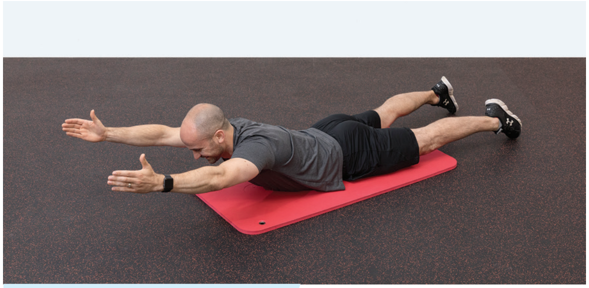

**Figure 7.28** Prone Reach.

### Supine Leg Reach

- From a supine position, extend a leg out to touch a target
- Be aware to prevent arch of the spine away from contact with the floor
- Progress distance, or from one leg to two

**Figure 7.29** Supine Leg Reach.

**Figure 7.30** Supine Reach Progression – Stage 1.

**Figure 7.31** Supine Reach Progression – Stage 2.

**Figure 7.32** Supine Reach Progression – Stage 3.

## From a Four-Point Position

### Crawl Towards a Target

- Be aware not to allow an excessive arch of the lumbar spine
- Try motion in different directions or provide objects to crawl under or through

**Figure 7.33** Crawl.

## Functional Mobilization

### Deep Crouch

- Sit into a deep crouch
- Become aware of the sense of a stretch into the lumbar spine
- Move into and out of the position
- Depending on a client's degree of mobility, they may need varying levels of support

**Figure 7.34** Deep Crouch.

## The Thorax

The thoracic spine is distinguished by its 12 ribs, attaching either side of 12 thoracic vertebrae (see Figure 7.35). Each rib attaches to its vertebrae at two points, the costovertebral and costotransverse joints. The rib circles around the body and attaches anteriorly to the sternum via the costal cartilage. The function of the ribs is to protect the vital organs – the heart, lungs, kidneys and liver – from traumatic injury.

The thorax, thoracic spine and ribs create the *thoracic cavity*. At the base of this cavity is the *thoracic diaphragm*, a muscular dome that draws air into the lungs during breathing. On top of this cavity is the *cervical fascia* that forms the lid of

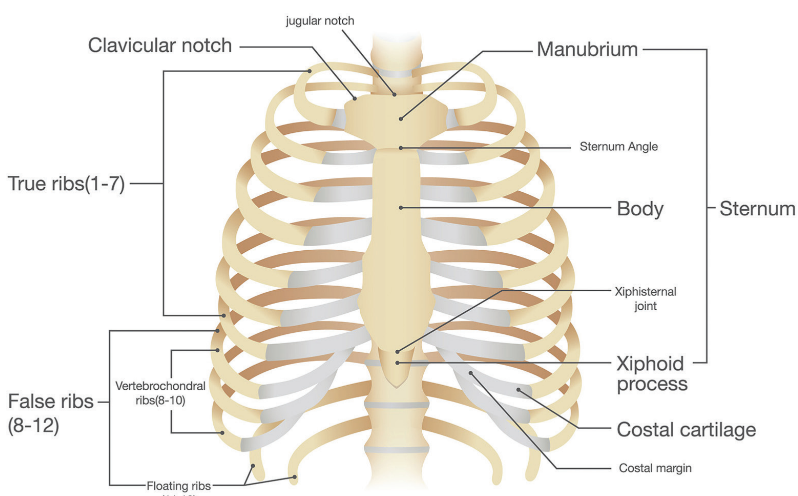


**Figure 7.35** Thoracic Spine.

the thoracic cavity. Rhythmic motion of the thoracic cavity created by movement and breathing pumps fluid around the body and back to the venous circulation.

As we take an in-breath, the thoracic diaphragm pulls downwards, expanding the thoracic cavity and drawing air into the lungs. During normal unloaded movement, a deep inhalation increases intra-abdominal pressure, causing the abdomen to expand and protrude. To allow the increase in volume of the lungs as we breathe in, the mid- and lower-ribs expand outwards.

During lifting, deep abdominal muscles should contract, preventing protrusion of the abdomen, increasing cavity pressure. Intra-abdominal pressure helps stabilize the spinal column on lifting. Spinal stability is harder to coordinate when we are breathless, as the stabilization and respiratory systems are intertwined. Efficient and effective coordination and integration of breathing and respiration is an essential component of functional lifting.

The motion of the different sections of the ribs is functionally important. During relaxed breathing, the first half of the breath should enter the abdomen as the diaphragm draws down. The second half of the breath should drive an expansion of the lower ribs. Only during increased cardiorespiratory load should the upper ribs tilt upwards, like handles on a bucket.

Upper rib motion in the absence of intense exercise can be a symptom of stress and anxiety, and a common cause of neck tension. Clients with mild breathing dysfunction tend to hyperventilate and breathe too fast. The increase in oxygen intake impacts the blood pH, altering blood chemistry and causing a sensation of stress and anxiety. A client with a mild breathing dysfunction might unwittingly expel excess oxygen by yawning, sighing, coughing or clearing their throat more than usual.

Poor posture at rest, particularly sitting or lying, can cause dysfunction of the thoracic spine. Emotional stress and anxiety can also cause poor breathing patterns that predispose dysfunctional movement strategies. The thorax and ribs are particularly important in twisting, pulling, pushing and reaching tasks.

The ribs ceat stability within the thoracic spine but reduce mobility, particularly in extension and rotation. Mobility in costotransverse and costovertebral joints is particularly important during rotational movements. Dysfunction of the thoracic spine tends to cause clients to drop into a flexed posture, a position that hampers the ability to twist and turn.

Thoracic restriction often causes compensatory motion in the lumbar spine. Rib restriction, and particularly loss of thoracic extension, tends to be compensated for by extension in the lumbar spine, stressing lumbar joints and causing repetitive strain and lower back pain. Mobilizing the thoracic spine in extension or rotation can often resolve lower back issues.

Thoracic motion integrates with motion of the arm during pulling and reaching movements. The

## Medical Diagnoses for Thoracic Pain

### Rib sprain

- Subluxation of the Costotransverse or Costochondral joints
- Causing impingement on movement
- Characterized by sharp pain on movement
- Particularly breathing in, coughing, twisting, reaching

### Intercostal sprain

- A tear in the intercostal muscles found between the ribs
- Characterized by:
  - An acute injury
  - Sharp pain on movement
  - Particularly on twisting and reaching, and especially overhead

relative balance in motion between the thorax, scapula and arm is referred to as *scapulo-humeral rhythm*. To pull and twist, the thoracic spine needs to extend and the ribs lift to allow smooth motion of the scapula over the thorax. Thoracic restriction impacts the ability to both pull and twist, predisposing dysfunction of the shoulder.

## Mapping

### Breathing

- Take a deep inhalation, in through the nose and out through pursed lips
- Become aware of the length of the outbreath, increasing the outbreath until it is approximately six to ten seconds in length
    - Note – a long exhalation activates a parasympathetic response that induces relaxation
- Release tension
    - Progressively move through the body, becoming aware of and releasing areas of tension
    - This is known as a progressive relaxation
    - Common areas for tension are the lower back, neck and shoulders
- Identify faulty breathing patterns
    - Place one hand on the stomach and one on the sternum
    - Become aware of the rise of the stomach and lack of motion in the sternum
    - A reverse of this pattern with sternum moving and no movement of the abdomen represents a dysfunctional breathing strategy
    - Then place hands on the ribs. As you inhale become aware of the outward movement of the ribs and relaxation of the neck
    - Any hiking of the shoulder upwards may represent a dysfunctional breathing strategy
- This exercise can be repeated from different postures and positions
    - Sitting, standing, even at a work desk or whilst walking
    - For athletes, breathing exercises can be used to calm the mind during high pressure situations like taking a penalty kick

### Postural Mapping

- From a seated position, lift the sternum to extend the thoracic spine
- Maintain a tucked position of the neck and natural position of the lumbar spine
    - Do not allow either the head to tip back or the lower back to arch
    - Become aware of the shoulders dropping back and down
- Return to a slumped position and repeat
- Always finish in a nice upright position

### Shoulder Blade Squeezes

- Starting from a good posture, squeeze the shoulder blades together
- Become aware of the chest lifting and thoracic spine extending
- Become aware of the muscles between the shoulder blades

## Inhibition

### Thoracic SMR

- Lie on a foam roller
- Roll through the thoracic spine looking for tender areas or areas of stiffness
- To progress the exercise:
    - Hold on a tender spot
    - Rock on that spot
    - Arch over a tender spot
    - Repeat with arms extended overhead

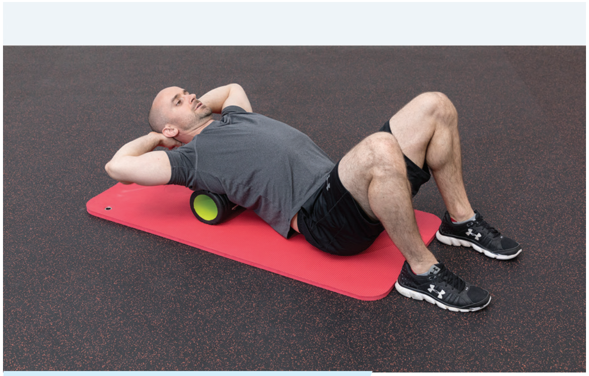

**Figure 7.36** Thoracic SMR.

## Activation

### Prone Extension

- Lying prone with your palms face down, lift your chest, focusing on extension of the thoracic spine, rotate shoulder back, turn palms out and squeeze shoulder blades together
- Be aware of the work between the shoulder blades

## Functional Mobilization

### Twist

- Twist as far around as possible, becoming aware of the sense of stretch in the waist
- Tools can be adapted but a band is ideal
- Position can be adapted to integrate or remove the hips from the twist (standing, sitting, kneeling)

**Figure 7.37** Band Twist.

## The Neck or Cervical Spine

The neck is composed of seven cervical vertebrae, the first two of which are of particular interest. The *atlas* (C1) holds the weight of the head, the boney articulation allows a slight nodding motion. The *axis* (C2) sits underneath the *atlas* and is almost like a circular disk with a vertical protuberance called the *dens*. The atlas spins on the dens creating a great deal of rotational motion.

The neck's key function is to orientate the head. The position of eyes is important for maintaining balance and stability, and the neck orientates to maintain the eyes level with the horizon. The neck muscles are highly innervated with sensory receptors that contribute to *position* and *balance sense*. The vestibular apparatus also contributes to position sense, orientation and balance.

Muscles in the upper neck frequently become hypertonic, causing neck pain and referred headaches. When the neck is overloaded, the *deep neck flexors* tend to become inhibited, allowing the entire cervical spine to drop into an extended position, compressing cervical facet joints. We call this a 'forward head posture' or 'chin-jut'.

To coordinate movement and maintain balance, we need to keep the head and eyes level with the horizon. Therefore it is important to maintain mobility of the cervical spine, especially the upper cervical (C1–C2). A loss of motion or rotational compensatory patterns in lower regions of the spine have to be compensated for in the upper neck, at the atlas and axis. Neck pain and dysfunction is often alleviated by maintaining function within lower levels of the spine.

The neck is particularly susceptible to poor resting postures. Choice of sitting and lying postures, the type of bed, chairs and pillows we choose, all impact cervical function. The function of the neck is also intimately linked with that of the jaw (aka the temporomandibular joint) and with breathing. Dentistry work, restriction of the jaw one side, maybe after a blow, or a stressed breathing pattern can all cause cervical dysfunction and pain.

To maintain cervical function, it is important to maintain mobility of the jaw. Temporomandibular dysfunction is apparent if the jaw opens unevenly or clicks or snaps on movement. A client with jaw dysfunction will tend to eat food on one side of their mouth.

## Medical Diagnoses for Cervical Pain

### Cervicogenic headache

- Neck dysfunction, especially of the upper neck, can often refer pain into the base of the skull and head, causing the pain we would associate with a headache

### Torticollis

- Neck muscles can go into spasm, pulling the neck out of alignment and causing acute pain

Dysfunction of the neck affects head turning. Clients will often complain of problems reversing the car or other functional tasks. Neck dysfunction can also affect balance and increase general ‘threat perception’, due to global instability and loss of balance. Clients with upper neck dysfunction or pain will tend to lose movement ability, power and performance, and will tend to drop into dysfunctional flexed postures.

# The Neck or Cervical Spine Corrective Exercises

## Mapping

### Chin Tuck

- Lying supine, gently nod the chin, drawing the chin towards the throat (as if you were giving yourself a double chin)
- Feel the neck flatten and the head extend up the pillow on the floor
- (Note, this exercise will map the upper cervical spine in particular)

### Head Turn

- Smoothly turn the head from one side to another, becoming aware of the easy rotation
- Be aware of keeping the shoulders relaxed, back and down

### Side Bend

- Tilt the head to one side
- Be aware of keeping the shoulders relaxed, back and down

## Inhibition

### Neck Stretch

- Fix the opposite shoulder by holding the wrist behind the back
- Tilt the neck away until you feel a stretch in an appropriate line of tension

**Figure 7.38** Neck Stretch.

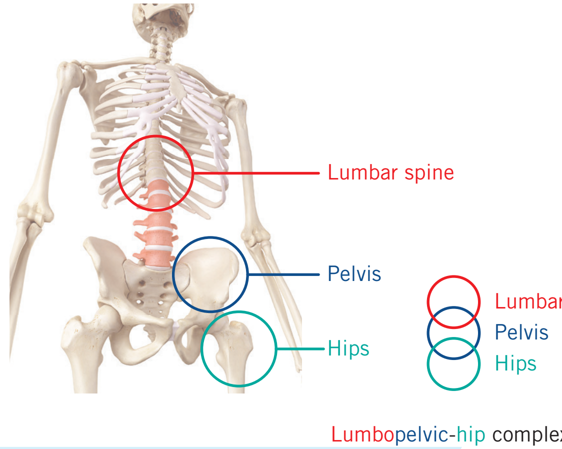


**Figure 7.39** The Lumbo-Pelvic Hip Complex.

## Activation

### Head Lift

- Lying supine, with the tongue in the roof of the mouth, slowly lift and hold the head, keeping the chin tucked

## The Hips and Pelvis

The lower back, pelvis and hips integrate to create the *lumbo-pelvic hip complex* (LPHC) (see Figure 7.39). The head of the femur sits within the acetabulum of the pelvis to form a ball and socket joint. The pelvis is formed from three pelvic bones, the ischium, ilium and pubis. Posteriorly, the pelvis articulates with the sacrum at the *sacroiliac joint (SIJ)*.

The sacroiliac joints are important in that they transmit load from the pelvis to the spine. The SIJs are highly stable, held together by strong ligaments to allow little or no movement. Anteriorly, the right and left pubis bones join to form the *pubis symphysis*, a joint that allows a rotational spin when the pelvis rotates.

The LPHC is relevant to many functional tasks, including stepping, walking, running, jumping, bending and lifting. The LPHC has to balance the demands of both mobility and stability to absorb and redistribute tremendous forces generated during running and jumping.

The hip has to be highly stable to absorb GRF. Powerful ligaments and a thick synovial capsule attach to various parts of the hip joint to provide stability. The loads passing through the pelvis created during functional activities are huge. An 80kg man has to absorb 160–400kg of load on one leg as he runs:

- Walking – 1–1.5 times body weight
- Running – 2–5 times body weight
- Jumping – 4–12 times body weight

The large muscles around the hip, the gluteal muscles, the quadraceps, psoas and adductors, are all large powerful muscles that work to propel us forwards. These muscles also stabilize the hips, pelvis and lumbar spine, especially as the foot hits the ground. Even whilst absorbing these huge forces to allow us to step, walk, run, jump, bend and lift, the hip has to maintain mobility.

## Common Medical Diagnoses for Hip Pain

Hip osteoarthritis

- Degenerative changes to the hip joint
- Identified by loss of joint space and osteophytes as seen with radiology
- Characterized by groin pain, stiffness, worsening with use

Hip bursitis

- Irritation and inflammation of the fascia and bursa, the fluid filled sack designed to prevent friction, on the outside of the thigh, local to the greater trochanter
- Characterized by pain on walking or running

Hernia (femoral, inguinal, abdominal)

- Acute pain on the anterior of the hip or abdomen
- Palpable lump
- Aggravating by lifting or loading, coughing or bearing down

Piriformis tension

- Hypertonicity of the piriformis muscle on the lateral hip
- Can impinge the sciatic nerve causing sciatic symptoms

Sacroiliac dysfunction

- Irritation of the sacroiliac joint
- Caused by dysfunction of the pelvis
- Characterized by:
  - Sharp pain
  - Pain on turning
  - Unilateral weight bearing (particularly running, stepping and getting up from sitting)

Sciatica

- Compression or irritation of the sciatic nerve
- Either at the lumbar spine, often due to herniation of an intervertebral disc, or by the piriformis muscle of the hip, referred to as piriformis syndrome
- Characterized by:
  - Sharp lancinating pain
  - Radiating in a thin line down the posterior thigh
  - Possibly accompanied by altered sensation such as pins and needles, numbness, weakness in the leg

Pain or dysfunction of the hip tends to inhibit the large gluteal muscles, the largest muscles of the body and those that stabilize the hip, pelvis and lumbar spine. Inhibition of the hip muscles predisposes pelvic and lumbar instability. When large gluteal muscles fail, other smaller, deeper muscles of the hip and pelvis tend to become hypertonic in an effort to stabilize the LPHC. Inhibition of the psoas and piriformis can often resolve hip and back pain.

## The Hips and Pelvis Corrective Exercises

### Mapping

- Knee Circle
  - Lying supine, pull the knee towards the chest and make small circles, exploring range of motion
  - Become aware of the easy motion of the hip
  - Note, inability to easily get the knee to the chest is generally an indication of LPHC dysfunction

### Inhibition

- Hip Flexor Stretch
  - Kneeling, lunge forwards
  - Be aware not to allow the back to arch or the pelvis to tilt forwards
  - Be aware of the contraction through the stomach and/or hip
  - Become aware of the sense of stretch in the anterior hip

- Figure-4 Stretch
  - Supine, rest the lower leg on the knee and then pull the knee towards you
  - Become aware of the sense of stretch on the lateral hip, local to the piriformis

- Lateral Hip SMR
  - Sitting on the foam roller, rest leg on knee as in Figure-4 stretch, turn to the hip and local tender areas

**Figure 7.40** Hip Flexor Stretch.

**Figure 7.41** Figure-4 Stretch.

- Reach Towards Toe
  - With a foot onto a step or raise, reach towards the toe, keeping the front leg straight
  - Become aware of the stretch into the posterior thigh

## Activation

### Side-Lying External Rotation (Aka Clam)

- Lie on your side with your legs bent and shoulders, hips, knees and ankles stacked
- Place hand onto hip to help stabilize the hip during movement
- Lift a knee keeping the ankles together
- Be aware of the work into the lateral hip
- Prevent the hip from rolling or the back arching

### Prone Extension

- Lying prone, lift one leg into the air, being aware of the work in the posterior hip
- Prevent the back from arching or the hips from tilting

### Side-Lying Abduction

- Lie on one side with your shoulders and hips stacked, bottom leg bent, top leg straight and slightly behind the hip
- Lift the top leg leading with the heel and pointing your toe towards the ground

**Figure 7.42** Lateral Hip SMR.

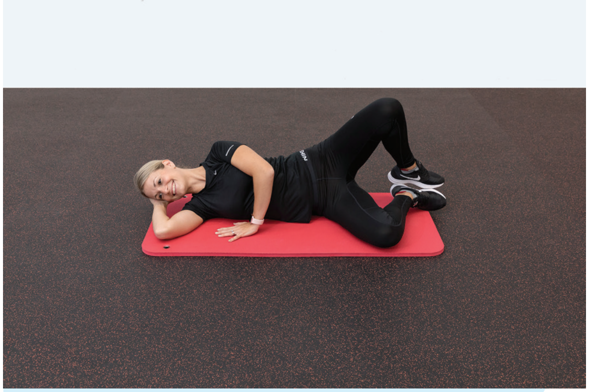

**Figure 7.43** Side-Lying External Rotation (aka Clam).

**Figure 7.44** Side-Lying Abduction.

**Figure 7.45** Supine Bridge.

- Make sure the pelvis and back remain square and stable
- Be aware of muscles working on the lateral hip

### Supine Bridge

- Lying supine, raise the hips into the air
- Focus at opening and gaining good height in the hips
- Be aware of the gluteal muscles working
- Try not to overextend the spine

### Band Posterior Step

- With a band or alternative resistance, step back
- Become aware of the work in the posterior gluteal muscles
- Be aware not to over extend the spine


**Figure 7.46** Band Posterior Step.

### Band Lateral Step

- With a band or alternative resistance, step out to the side
- Become aware of the work in the lateral gluteal muscles
- Be aware not to tilt the pelvis, lifting the hip

## Functional Mobilization

### Forward Step and Reach Overhead

- Taking a long lunge step, drive your weight forwards, bending the knee and reaching overhead
- Become aware of the stretch into the anterior hip


Figure 7.47 Band Lateral Step.

Figure 7.48 Forward Step and Reach Overhead.

### Step, Reach Towards Toe

- Step forwards and reach towards the foot, keeping the front leg straight
- Become aware of the stretch in the posterior thigh

Figure 7.49 Reach Towards Toe.

## The Knees

The knee is generally considered a hinge joint, flexing and extending as we step, walk, squat and crouch. The knee actually rotates in three dimensions as it bends and is designed to resolve rotational forces created at the foot and hip. Hip or ankle dysfunction can often be the cause of knee injury. The motion at the knee is actually highly complex and worth studying in greater depth.

The knee absorbs tremendous forces on heel strike during running and jumping but lacks sizeable local stabilizing muscles, so relies on an infrastructure of stabilizing ligaments and a robust joint capsule (see Figure 7.50).

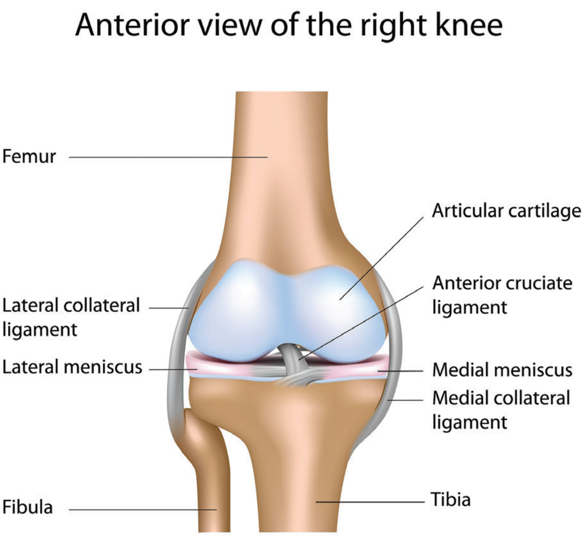


Figure 7.50 Knee Ligaments.

## Common Medical Diagnoses for Knee Pain

- Muscle sprain
  - Acute injury to local muscle
  - Characterized by:
    - Acute onset of sharp pain
    - Pain on subsequent contraction or stretch
- Iliotibial band syndrome
  - Irritation of the lateral aspect of the knee caused by friction of the iliotibial band (ITB) on the lateral condyle of the knee
  - Characterized by tension within the ITB
  - Pain on walking or running, increased with use
- Patellar tendonitis (aka jumper's knee)
  - Inflammation of the patellar
  - Characterized by:
    - Anterior knee pain
    - Aggravated by quadriceps loading
    - Particularly running, jumping, stepping up or down

*Pre-patellar pain*

- Pain caused by irritation of the posterior surface of the patellar
- Caused by grinding of the patellar on the femoral condyle
- Predisposed by tight quadriceps muscles
- Characterized by sharp pain on loading of the knee, particularly stepping up and down

*Knee osteoarthritis*

- Osteoarthritic generation of the knee joint
- Aggravated by loading or excessive use
- Characterized by:
  - Sharp pain on loading
  - Instability and or tightness

*Ligament sprain*

- Damage to one of the ligaments of the knee
- Either the medial or lateral collateral or cruciate ligaments
- Characterized by:
  - Pain on stretch or loading of the knee
  - Instability and weakness

*Cartilage tear*

- Acute injury causing a tear in the cartilage of the knee
- Can often cause a flap of cartilage that drops into the joint space
- Characterized by:
  - Locking, catching and giving way
  - Sharp, dagger-like pain

The *vastus medialis obliques (VMO)*, located on the distal, medial aspect of the knee, works particularly hard to stabilize the first 20 degrees of knee flexion in a standing position, controlling rotational forces that act on the knee. Pain and dysfunction at the knee inhibit the VMO, contributing to rotational knee instability.

The muscles of the lateral hip, the gluteus maximus, minimus and medius, play an important role in stabilizing rotational forces at the knee, controlling motion of the femur on heel strike. Inhibition of powerful hip muscles can contribute to knee instability and dysfunction.

Healthy loading of the knee occurs when the joint is aligned so that the patellar tracks over the second toe. On landing, and as the arch flattens, foot pronates and tibia and femur rotate inwards, rotational forces tension fascial chains that link the knee with the lateral hip musculature. Tension within this chain assists in stabilizing the entire lower extremity. Loss of motion in these areas could contribute to instability.

## Knee Corrective Exercises

### Mapping

- Knee Swings
  - In sitting position, hold the underneath of the thigh and gently swing the leg forwards and back, creating relaxed movement through the knee joint

### Inhibition

- Iliotibial Band SMR
  - Lie on your side on a foam roller, working through the lateral thigh to find tender spots and areas of tension

**Figure 7.51** Knee Swings.

**Figure 7.52** Iliotibial Band SMR.

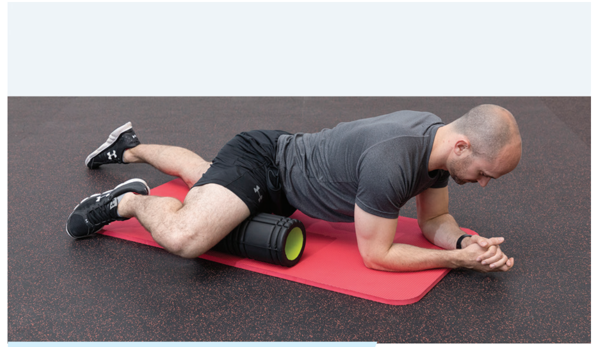

**Figure 7.53** Adductor SMR.

**Figure 7.54** Single Leg Dip.

- Adductor SMR
  - Lie prone with your knee to 90 degrees resting on the foam roller
  - Explore the inner thigh for tension and tender spots

- Activation
  - End Range Knee Extension
  - Lying supine with a support under the knee, straighten the leg
  - Become aware of the work in the quadriceps muscles

- Single Leg Dip
  - Either stepping or balancing on one leg, load the knee, allowing it to bend but maintaining knee alignment so the patellar tracks over the second toe.

## The Feet and Ankles

The ankle is formed by the tibia and fibular sitting on top of the talus. The articulation between these bones allows plantarflexion and dorsiflexion of the foot during walking, running, sitting, squatting and stepping.

### Ankle Bones and Joints

Along with the ankle joint, there are numerous other boney articulations within the foot itself, the mechanics and motion of which are far too complex to describe here. Needless to say, the function of the foot and ankle relies on each and every one of these articulations, making the foot a fascinating area.

The foot is the first point of contact with the ground and the base from which to generate propulsive force. On landing, huge ground reaction forces pass through the foot into the lower extremity. The ability to stabilize and utilize these forces is fundamental for efficient walking, running and jumping.

As well as absorbing GRF, the foot has to mold itself around uneven terrain, adapting to awkward and unstable surfaces to maintain balance and stability. To adapt, the foot has numerous bones, articulations, three different arches and a semi-collapsible fascial diaphragm, which all work to adapt and absorb load.

The plantar-fascia, supported by a network of strong ligaments, combine to create the primary source of arch support. Supporting these ligaments is a myofascial 'stirrup', formed by the peroneus longus and tibialis anterior muscles wrapping around the foot. After the heel strikes, the arch flattens and the plantar-fascia stretches, triggering reflex activation of stabilizing muscles in the foot and further up the kinetic chain, including the muscles of the lateral hip, which include the gluteus maximus. The function of the foot is critical to the stabilization of the lumbo-pelvis.

As it strikes the ground, the heel rotates, unlocking the mid-foot and allowing the arch to soften and absorb load. On 'toe-off', the arch reforms, solidifying the mid-foot and converting the foot into a solid platform from which to produce force. As the foot pronates, the lower limb rotates, stretching fascial chains and activating hip muscles, in particular the large gluteal muscles. Reflex activation of the hip stabilizes both the lower extremity, lower back and pelvis on heel strike, an important mechanism for creating core stability.

The architecture of the foot varies from person to person. Some clients have a flattened arch, others a high stable arch. Variations in the foot alter how the foot absorbs and distributes load, with a flat medial arch thought to predispose biomechanical stress and injury. Whether 'flat feet' predispose injury is far from conclusive, but it is still common for practitioners to insert orthotic supports in shoes. The problem with this is that inserts reduce the ability of the foot to move, and in doing so prevent the chain reaction that activates hip muscles.

Foot dysfunction can be caused by a sudden increase in activity levels, starting running for example. Footwear can also be an issue – too

**TEST FOR ANKLE DORSIFLEXION**

*Place your toe on a wall. Keeping the heel flat can you touch the wall with the knee. Slide the foot back 2cm and retest. See how far away from the wall you can get before you are unable to touch it with the foot.*

much time spent wearing high heels, for example. The foot is not designed to wear shoes at all, but it is also not designed to walk on unforgiving surfaces like concrete.

## Common Medical Diagnoses of Foot and Ankle Pain

*Achilles tendonitis*

- Pain and irritation of the Achilles tendon

*Plantar fasciitis*

- Pain and tension of the plantar-fascia
- Predisposed by tension in the posterior chain fascia
- Characterized by pain on the sole
- Aggravated by repetitive loading, such as standing or walking

*Ligament sprains*

- Acute injury to the ankle lateral (inversion sprain) or medial (eversion sprain) collateral ankle ligaments
- Causing pain on stretch and instability

*Shin splints*

- Pain on the medial border of the tibia
- Various causes including:
  - Muscle tension either in the tibialis anterior or tibialis posterior muscles
  - Stress fracture arising from excessive loading from long distance running

## Feet and Ankle Corrective Exercises

### Inhibition

- Calf Stretch Straight Leg
  - In split stance, lean forward to create a stretch on the Achilles long calf muscles (gastrocnemius and plantaris)

**Figure 7.55** Calf Stretch Straight Leg.

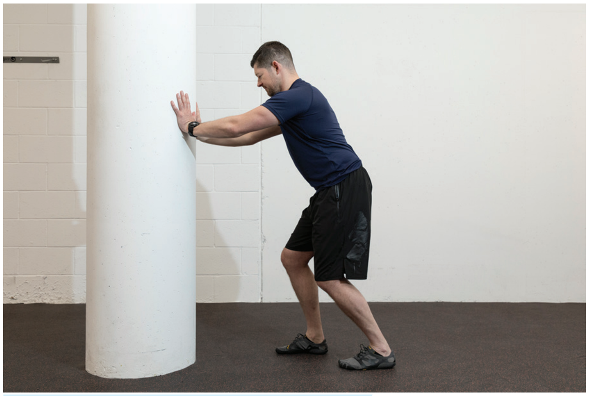

**Figure 7.56** Bent Leg Calf Stretch.

- Bent Leg Calf Stretch
  - In split stance, drop the hip back and push knee forwards to stretch the deeper short calf muscles (soleus, tibialis posterior)
- Calf SMR
  - Lay the calf on a foam roller and roll to find areas of tenderness
- Plantar Fascia SMR
  - Standing on a small ball (a golf ball can work well), roll through the foot to find areas of tension

**Figure 7.57** Calf SMR.

### Activation

- Calf Raises
  - With the heels dropping off the edge of a step, bring yourself onto tiptoes and back down again
  - Progress to single leg
- Toe Walk and Heel Walk
  - Walking with toes only, activate the plantar-flexors/calf muscles or heels only to activate the dorsi-flexors of the lower leg and sling muscles of the arch

## Functional Mobilization

### Deep Squat Knee Drive

- Sit into a deep squat then drive one knee forwards and back

## The Upper Extremity

The upper extremity performs a wide variety of movement tasks, reaching, grasping, pushing, pulling, hanging, climbing, striking, throwing. A whole book could be dedicated to the function of the upper limb. This is only a concise introduction.

The shoulder or *glenohumeral joint* is a highly mobile ball and socket joint designed to peform a wide variety of movements over large ranges to orientate the hand. The humeral head sits in a shallow *glenoid* socket, like a golf ball sitting on a tee, making the glenohumeral joint mobile but also unstable. To increase stability, a fibrocartilage disc known as the *glenoid labrum* sits on top of the glenoid. The labrum deepens the shallow socket, creating a more stable structure, although the labrum can be torn by traumatic injury.

The shoulder joint is supported by a number of ligaments and a group of muscles, known as the *rotator cuff*. The rotator cuff is formed by the *supraspinatus* superiorly, the *subscapularis* anteriorly, the *infraspinatus* posteriorly and the *teres minor* inferiorly (see Figure 7.58). The main function of the *rotator cuff* is to draw the head of the *humerus* into the *glenoid*, stabilizing the shoulder. Dysfunction of the *rotator cuff* following *overuse* or *overload* is a common cause of shoulder dysfunction.

Movement of the shoulder is supported by the *shoulder girdle*, the pseudo-joint formed by the *scapula* gliding over the *thorax*, and the articulation between the clavicle and sternum medially (the *sternoclavicular joint*) and acromion process laterally (the *acromioclavicular joint*).

As the arm reaches, the scapula glides over the thorax and the clavicle tilts, rolls and spins.

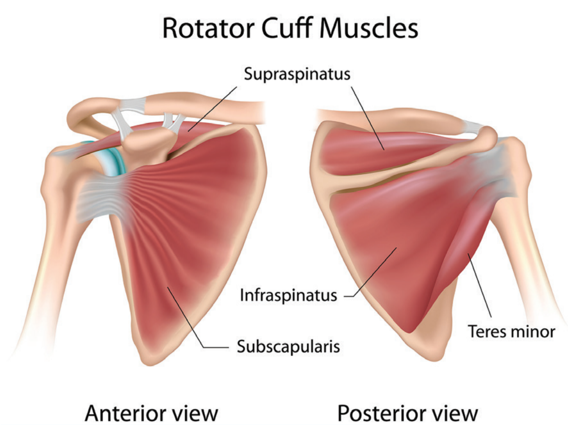


**Figure 7.58** Rotator Cuff.

Balanced motion between the shoulder and shoulder girdle is referred to as *scapulo-humeral rhythm (SHR)*. SHR can easily become disrupted by joint restriction, capsular restriction, injury or altered activation of the rotator cuff muscles. Larger muscles can also impact joint motion, not least the latissimus dorsi and pec minor, which are powerful internal rotators of the shoulder.

The function of the shoulder impacts the entire upper extremity, including the elbow and hand. Likewise, the elbow and hand can impact shoulder and neck function, but the details of these relationships are complex and best left for another time.

## Common Medical Diagnoses for Upper Extremity Pain

### Rotator cuff strain

- Acute strain of the deep stabilizers of the shoulder
- Characterized by:
  - Pain on stretch or contraction of the relevant muscle
  - Pain on reaching or tasks that require shoulder stability

### Supraspinatus impingement

- Impingement of the supraspinatus muscle under the acromion process as we reach overhead
- Characterized by:
  - Catching pain at 90 degrees of abduction, known as a painful arc
  - Absence of pain before and after this painful arc

### Labral tear

- Damage to the labrum of the shoulder
- Acute injury
- Resulting in instability, catching, deep pain, shoulder restriction

### Bicep tendonitis

- Overuse injury of the bicep tendon on the anterior of the shoulder
- Characterized by aching anterior shoulder pain at the bicep tendon within the bicipital groove

## Pull-Down Vs. Hang

Trainers should encourage a balance between pushing and pulling exercises. Many trainers suggest balancing a press with 'pull-down' exercises to work the latissimus dorsi muscles. The lats actually generate an internal rotation force at the shoulder, which rather than helping maintain good posture actually pulls us into a rounded, internally rotated position. This position closes the shoulder down, disrupts function and predisposes shoulder impingement, especially when we reach overhead. Pull-down exercises do not create balance with pushing exercises, they actually create imbalance.

A 'pull-down' is not a function we use regularly or one that is particularly useful. We rarely pull things down from above our head. The body has been designed to 'climb'. The powerful 'lats' have a twist near their insertion that creates extra tension and incredible force. 'Hanging' is far healthier for the shoulder because it stretches the shoulder and mobilizes the ribs, cervical spine and jaw. The shoulder is actually designed to 'hang'. We were designed to hang and swing, not pull down.

## Upper Extermity Corrective Exercises

### Mapping

- Shrugs
  - Roll shoulders in a circular motion
  - Become aware of a release of tension as the shoulders drop back
- Arm Circles
  - With straight arms, circle the arms, reaching overhead and behind, and becoming aware of the sense of stretching through the shoulder
- Wall Press
  - With hands resting against a wall or the floor and keeping arms straight, protract and retract the shoulders, rounding and arching the back

**Figure 7.59** Wall Press, Protraction.

**Figure 7.60** Wall Press, Retraction.

**Figure 7.61** Shoulder Extension.

### Inhibition

- Shoulder Extension
  - With the arm stabilized in a narrow position behind, step forwards
  - Become aware of the stretch through the anterior arm and shoulder
- Shoulder Posterior Glide
  - Lie over a foam roller lengthways
  - Allow the shoulders to drop

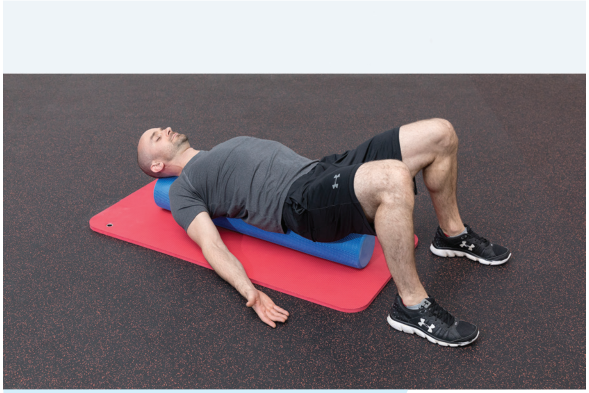

**Figure 7.62** Shoulder Posterior Glide.

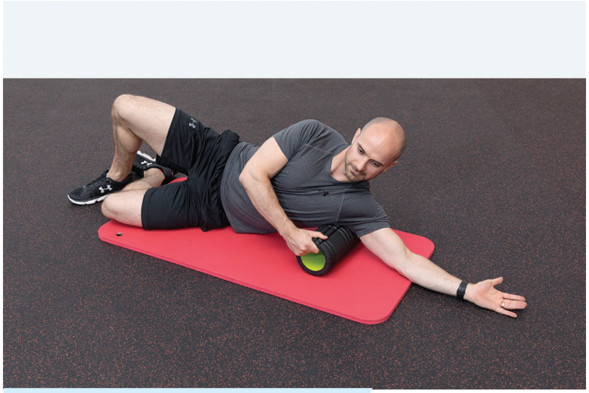

**Figure 7.63** Under-Arm SMR.

**Figure 7.64** Abduction.

- Under-Arm SMR
  - Lie on a foam roller so that it places pressure on the bundle of muscle under the arm
  - Roll, looking for areas of tension or tenderness
  - (Note, the muscles located here include the latissimus dorsi, subscapularis, teres minor and major)

### Activation

- Scapular Retraction
  - Keeping the chest lifted, draw the shoulders back and pinch the shoulder blades
  - Become aware of the muscles' work between the shoulder blades
- Shoulder Abduction
  - Using a low band or cable resistance, draw the arm across the body and to the shoulder, keeping the palm down
  - Become aware of the work in the shoulder muscles
  - The exercise is specifically aimed at working the supraspinatus
- Horizontal Extension
  - Using a chest high band or cable resistance, draw the arm across the body, keeping the palm forwards
  - Become aware of the muscles working in the posterior shoulder
  - The exercise is specifically aimed at working the infraspinatus
- Four-Point Stabilization
  - Maintain a four-point stance, lift and reach with an arm whilst maintaining stability in the loaded shoulder

### Functional Mobilization

- Hang
  - Grip overhead and allow the body to hang from tiptoes our with feet up
  - Try advancing to a single arm

**Figure 7.65** Horizontal Extension.

**Figure 7.66** Four-Point Stabilization.

**Figure 7.67** Hang.

The exercises detailed above only skim the surface of the potential inhibition, activation and mapping exercises that could be applied to any region of the body. A trainer should progress any exercise applying STRIVE principles, asking clients to progress to exercises that:

- Reflect useful and relevant tasks
- Integrate relevant tools and obstacles
- React to external targets
- Apply intelligent variation
- Vary posture and position, direction, speed and distance
- Introduce emotion by reflecting relevant contexts, situations and circumstances relating to pain and apprehension

Say, for example, we wanted to rehabilitate a client who has been experiencing shoulder pain on reaching overhead. A rehabilitation program might start with a simple mapping exercise of the shoulder girdle, shoulder rolls for example, then activation of deep rotator cuff muscles with a band resisted shoulder abduction.

The program might progress onto a band resisted 'reach' at shoulder height. A trainer could integrate a reach towards a target and progressively raise the height of this target to build confidence 'reaching' overhead. The exercise can be progressed by reaching in different directions, speeds and distances. Intensity could be progressed by asking the client to strike a moving target rather than simply reaching towards it. To create contextual similarity, different tools could be introduced that the client uses every day. Rehabilitation exercises are limited only by the imagination.

## Transition to Function

Rehabilitation exercises should always be coupled with a functional exercise. Any 'extra-functional exercise' should make an immediate impact on the movement strategy used in the subsequent functional exercise. Any mapping, activation or inhibition should have an almost immediate impact on function. For example, if we were to perform SMR to inhibit the latissimus dorsi to improve rotational function of the shoulder, we should always follow this rehabilitation exercise with a functional task, like a reach, push or pull to confirm that the SMR has had the desired impact.

Any rehabilitation exercise that does not make an immediate impact on function is unlikely to be effective. To expand on the principles of functional rehabilitation a series of discussions and case studies will be made available at www.strivemovement.com.

## Bringing It Together

An FT will evaluate clients using *observational analysis* to identify regions with altered function – instability, stiffness or rigidity. Based on this evaluation, an FT may prescribe rehabilitation exercises in the form of:

- Mapping
- Mobilization
- Inhibition
- Activation

Extra-functional rehabilitation exercises are generally coupled with useful and relevant functional tasks to evaluate their efficacy.

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# IN CONCLUSION

Functional trainers should abandon the '*physiological fallacy*' that strength gained using abstract gym exercises and resistance machines will transfer into real life. Most research suggests that transfer of performance into function is poor. We believe this is because gym exercise is neither similar to nor specific to what we do in daily life.

Neuroscience proposes that performance is less reliant on physiological factors, like the size of muscles or the volume of lungs, and more reliant on neurology, psychology and behavioral factors. To achieve astounding results and transform how clients feel, move and perform, training needs to shift from a physiological focus on muscles to a focus on the neurological factors that influence the coordination of movement. To improve functional performance, trainers should be less concerned about how we look and more concerned with a client's ability to organize movement, synergize muscle and integrate the various systems of the body.

The brain is the coordination center of the body. Training should be geared towards developing *task-specific coordination* and *domain expertise*, increasing a client's deeper understanding of the tasks, activities and skills they perform on a daily basis – the ability to lift, bend, push, pull, twist and shift in lots of different directions and lots of interesting and unusual ways.

Physical performance, including strength, speed, power and agility, are all *learnable skills* that rely less on muscle mass and more on the ability to both coordinate movement and tap into vast reserves of strength, which under normal circumstances are regulated and restrained by the 'subconscious mind'.

We cannot teach people to move differently. Instructions on form and technique rarely transfer to function. Behaviors self-organize and movements emerge from *instinctive* and *intuitive* reactions to where we are, what we are doing and how we feel. To influence behavior, instructors have to engage the subconscious mind. Neuroscience tells us exercise engages the brain when it is:

- Subconsciously controlled
- Task-orientated
- Reactive
- Intelligently varied
- Emotional

STRIVE principles help generate exercises that reflect function. STRIVE exercises are complex and varied, driving movement in three-dimensions in reaction to external tools, obstacles and targets. STRIVE exercises engage subconscious movement templates by reflecting tasks and activities that are *useful* and *relevant* to daily life, driving clients to *react* and *adapt* to awkward, unusual and unpredictable situations and circumstances.

Clients often start training with pain or having experienced an episode of injury. In the case of acute injury, pain accurately reflects the state of tissues and is a useful driver of antalgic movements that off-load damaged tissue. In the case of acute injury, functional exercise can be a useful tool in supporting soft tissue repair.

On occasions, pain persists beyond the point of healing. *Persistent pain* does not reflect the state of tissues and is not of use. Persistent pain distorts sensation and perception, negatively impacts mood, changes behavior and limits performance. Clients rarely get stronger when in a state of persistent pain.

The human subconscious is super powerful and ever-present – ever watching to ensure our 'biological priorities', *homeostasis*, *survival*, *ease* and *legacy*, are being met. To keep us safe, the subconscious continually evaluates any situation and activates motivational centers that regulate behavior.

One of the main characteristics distinguishing human beings from other animals is the ability to see into the future – to visualize events before they occur and anticipate problems. Prediction and anticipation enable the subconscious mind to identify 'threats' ahead of time and plan strategies to avoid hazards.

But the human subconscious is prone to error. Unconstructive thoughts, attitudes, beliefs and expectations arising from negative past experiences influence decision-making. Negative experiences alone with unhelpful thoughts, attitudes and beliefs make us anticipate danger where none exists.

Under a heightened sense of 'threat', the subconscious triggers fear and apprehension, restrains performance and even produces stiffness and pain. Overcoming the psychological barriers that hamper performance is one of the keys to unleashing untapped potential.

Persistent pain is created within the brain – it is neurological, not physiological. Functional exercise is a fantastic tool to manage pain. Functional rehabilitation includes a program of education, pain free movement, encouragement and support to create a series of positive new experiences, encouraging clients to re-evaluate their beliefs and break the bonds between pain and movement.

Functional rehabilitation is a process of 'threat innoculation' in which clients are progressively and systematically exposed to more threatening situations and circumstances. Functional rehabilitation is structured to avoid pain and create a new database of positive experiences. As confidence grows, subconscious threat perception reduces and pain should recede.

Through training, a client learns what their body is truly capable of. Performance improves as clients restructure thoughts, attitudes and beliefs relating to their own ability.

The key is to believe in yourself and be confident. Confidence gives us the freedom to experiment and try new things. Unimpeded by fear of failure, we can rationalize and harness emotion – from then on, you might be very surprised by what you can achieve.

## LAST WORD …

I believe this text only scratches the surface. For more discussion on these topics and many more you might want to visit www.strivemovement.com.

At this website you will find resources and further education on the application of neuroscience to movement, pain and performance. We encourage you to add to the debate, don't be afraid to be controversial and challenge any of the thoughts and opinions presented.

The problem with any textbook is that it often takes so long to write that the concepts within become dated and opinions change before the book is finished. Please contribute to the debate and offer your thoughts and opinions as they will be most welcome. I hope this text was useful and thought provoking.

# INDEX