Chapter 2 Factors Affecting Performance
HSC Core 2

After completing this chapter, you will be able to demonstrate knowledge of:

• the effects of training on performance
• the impact of psychology on performance
• the effects of nutrition and recovery strategies on performance
• the impact of the acquisition of skills on performance.

Key terminology

- adenosine triphosphate (ATP)
- atrophy
- cardiac output
- concentration
- continuous training method
- extrinsic motivation
- fartlek
- fast-twitch muscle fibres
- glycogen
- glycolysis
- goal-setting
- haemoglobin
- imagery
- intrinsic motivation
- kilojoule (kJ)
- lactate
- lung capacity
- lysis
- mechanical energy
- muscle fibres
- muscle hypertrophy
- negative motivation
- oxygen uptake
- positive motivation
- pyruvate
- relaxation
- resting heart rate
- resynthesis
- VO\(_2\) max
2.1 The effects of training on performance

Driving question 2.1

Select a sport and list all of the training activities involved in a typical week. For each training activity, identify the primary reason for this activity in relation to their competitive performance.

Energy systems

Going further 2.2

Communicate
As a class, discuss the following questions.
1. If cars use petrol for fuel, what is the source of the fuel used for human movement?
2. If you started sprinting and continued for as long as you could, how long could you last? What causes you to slow down or stop?
3. If you started jogging at a slow pace, and you didn’t stop until you collapsed, what would cause this?
4. Discuss the phenomenon of fatigue, and examine the different ways in which people experience it. Is it more mental or physical? What do you think causes fatigue?

The living human body is a complex machine, consisting of a number of interdependent body systems (such as the cardiovascular, digestive and muscular systems), carefully organised to produce an amazing system characterised by balance – the ability to sustain itself and produce vast amounts of mechanical and intelligent output. All of these functions require a constant source of energy or fuel to enable each cellular process.

It could simply be assumed that the food we eat is directly responsible for providing the vast energy needs of an active human being. Carbohydrates are often described as the body’s best fuel source; however, this is a very limited understanding of the body’s energy supply.

Consider a house, with its many power outlets and electrical devices. Each appliance has a unique function; however, a consistent energy source is needed to enable the use of all of them. Likewise, the human body has a range of specialised cells and organs, such as the heart, brain, digestive system and muscles, each of which carries out a unique function. The fuel or energy source for all of these separate organs and bodily functions is stored within the high-energy chemical bonds that join atoms together within a particular molecule known as adenosine triphosphate (ATP). As these bonds are broken, energy is released for cellular function, including the contraction of a muscle cell for the sake of movement. Compared with the equivalent energy value of food in its eaten form, this is a much lighter, smaller and more efficient form of fuel storage. During a marathon, the total weight of the molecules used to fuel the movement is almost the same as that of the person themselves. Obviously the runner does not store twice their body weight in fuel prior to a run, which demonstrates the unique way in which the body

<table>
<thead>
<tr>
<th>Nutrient</th>
<th>Food example</th>
<th>Basic form</th>
<th>Stored form</th>
<th>Stored location and amount</th>
<th>Energy value per gram</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbohydrate</td>
<td>Bread, rice</td>
<td>Glucose</td>
<td>Glycogen</td>
<td>Blood 20 g, Muscle 500 g, Liver 100 g</td>
<td>17kJ</td>
</tr>
<tr>
<td>Fats</td>
<td>Olive oil, butter</td>
<td>Lipids</td>
<td>Triglycerides</td>
<td>Adipose tissue (body fat), 12 kg, Muscle triglyceride 300 g</td>
<td>37 kJ</td>
</tr>
</tbody>
</table>

Table 2.1 Nutrient values, forms and locations
converts energy from food into stored energy for living and exercise.

It is worth noting that there is a change in the form of energy when the body produces movement. The basic energy provided through foods such as carbohydrates and fats is known as chemical energy (measured in kilojoules or calories). The body uses chemical-based energy systems to fuel muscular contractions, and mechanical energy is created as the body produces movement. These nutrients undergo a series of chemical reactions to break them down into a form suitable for short- to long-term storage.

Protein also has an energy value, and is broken down into the form of amino acids, which are used to repair and form new body tissue where necessary. However, the use of protein as an energy source generally only occurs during extreme circumstances, such as a famine, when all other stores are exhausted. Where excess protein is consumed, it is converted into triglycerides, which can easily be stored by the human body as excess body fat or adipose tissue (stored under the skin).

As mentioned earlier, the primary source of the body’s energy lies within the high-energy covalent bonds of a unique molecule known as adenosine triphosphate (ATP). This molecule is present in every living human cell, and it powers the individual functions of each cell.

Adenosine triphosphate, as the name suggests, is a molecule that contains an adenosine nucleotide attached to three phosphate groups. The bonds between these are high-energy covalent bonds that, when broken down (known as hydrolysis), release energy for muscular contraction (and the rest as heat). This process is outlined in the diagram on this page.

Interestingly, the human body only has enough ATP to survive for approximately 10 seconds, and less if it attempts to produce intense movement (2–5 seconds). It is estimated that in our entire body there is approximately 70 grams of ATP (which equates to trillions of ATP molecules). During a marathon, the body will require over 50 kilograms of ATP. A similar amount is needed to power an adult through a regular day.

So how is it possible to use the equivalent of over half our body weight in energy in a single day if we have such a small and limited supply? This is where the stored fuel or energy reserves in the body are efficiently utilised to power the resynthesis of ADP into ATP. There are three distinct energy pathways.
or systems that are used to ensure the body is never depleted of its ATP stores:

- phosphocreatine system (ATP-PC)
- anaerobic glycolysis
- aerobic energy system.

Each energy system plays a unique role in helping the body to have sufficient ATP molecules and energy at various intensities and duration of activity. The first two pathways are unique, as they function in the absence of oxygen – otherwise known as an anaerobic pathway – whereas the third system relies on the presence of oxygen, and is therefore known as an aerobic pathway. It should be noted that these three systems do not work independently of and exclusively from each other, but as a coordinated response of all energy pathways, working together to varying degrees to supply ATP at different intensities of effort.

Alactacid system (ATP/PC)

The initial system used to resynthesise ATP is called the phosphocreatine system. This is commonly abbreviated to ATP-PC. Other names for this are the creatine phosphate system or the alactacid system.

The energy from this system is stored within the high-energy bond that joins a creatine and phosphate molecule together, called phosphocreatine (PC). As the bond between these is broken, energy is released to help rejoin a spare phosphate group to an ADP molecule. This process is outlined in the figures on this page.

The ATP-PC system’s greatest advantage is the speed at which it can provide energy for ATP resynthesis. During maximal activity, where ATP stores can be depleted in less than five seconds, this is an essential characteristic of the ATP-PC system. However, the shortfall of this is that only a limited supply of PC can be stored within the muscle cells of the body. Therefore, maximal and high-intensity activity can only be sustained for five to 10 seconds before PC stores are depleted. PC is the dominant energy source for the first five seconds, after which the second energy system has been activated and is starting to supply energy to resynthesise ATP. After the PC stores are exhausted, two to three minutes’ rest is required to fully replenish the PC stores.
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Athletes in sports that involve a short and maximal effort focus their training on the development of the ATP-PC system. Examples include 100-metre sprints, weightlifting and high jump.

### Lactic acid system

The second system used to resynthesise ATP is called anaerobic glycolysis. Another common name for this is the lactic acid system. However, most sources recognise this as a misnomer, as lactic acid is not actually found in the human body, and is often confused with lactate, which is found in the body.

The energy from this system comes from the breakdown of the simple sugar glucose, known as glycolysis. When this process occurs in the absence of oxygen, it is known as anaerobic glycolysis. The body is only able to store a small amount of glucose in the blood, and any excess is converted to its stored form of glycogen. As specific enzymes break down glucose, the energy released

<table>
<thead>
<tr>
<th>Syllabus point</th>
<th>Characteristic of energy system</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Source of fuel</td>
<td>Phosphocreatine (PC)</td>
<td>The energy is stored within the bond of the PC molecule. As it breaks, energy is released.</td>
</tr>
<tr>
<td>Efficiency of ATP production (speed of production and amount of ATP resynthesised)</td>
<td>Very fast 0.7 ATP per reaction</td>
<td>Instant supply of PC available; a simple chemical reaction means that it is a very efficient pathway in terms of speed; however, it produces the least amount of ATP per reaction of all three energy systems.</td>
</tr>
<tr>
<td>Duration for which the system can operate</td>
<td>0–10 seconds</td>
<td>For the first five seconds of maximal activity, it is the dominant supplier of ATP, and it will be fully utilised after 10–12 seconds.</td>
</tr>
<tr>
<td>Cause of fatigue (what causes the system to either slow down or stop, and the effect this has on the athlete)</td>
<td>Depletion of PC stores</td>
<td>As the PC stores become depleted to the point of exhaustion, the body will be able to supply energy through the second pathway, which will have been activated by this point. The athlete will not recognise fatigue directly as a result of this, but from other sources such as local neuromuscular fatigue.</td>
</tr>
<tr>
<td>By-products of energy production (what else is produced as a result of this process)</td>
<td>Heat</td>
<td>The ATP-PC system is relatively circular. Therefore, the only by-product is a result of the chemical reactions – heat, which causes no adverse reaction to the athlete (heat is produced in all chemical reactions that involve the breakdown of a chemical bond).</td>
</tr>
<tr>
<td>Process and rate of recovery (how the system recovers for subsequent efforts and how long it takes)</td>
<td>PC resynthesis through rest 2–3 minutes</td>
<td>The resynthesis of PC occurs very quickly at rest, with close to half being restored within 30 seconds. This is why people should rest between sets of heavy resistance training or sprints, to ensure the body has enough energy for the next set, to enable work at maximal capacity.</td>
</tr>
</tbody>
</table>

Table 2.2 Characteristics of the ATP/PC system

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Figure 2.11 Weightlifting training focuses on the development of the ATP-PC system

Figure 2.12 High jump involves short, maximal effort that relies on the ATP-PC system
Cambridge HSC Personal Development, Health and Physical Education

**Figure 2.13** Anaerobic glycolysis – glycogen is converted to glucose, which is then broken down. This releases energy for the resynthesis of two ATP molecules and the by-product is pyruvate.

**Figure 2.14** If insufficient oxygen is available to the working muscles, the pyruvate binds to pH-decreasing hydrogen atoms, forming lactate. This is transported to the liver to be metabolised, and converted back into glycogen.

**Figure 2.15** Soccer relies on anaerobic glycolysis because the players switch between intervals of very high intensity and intermittent rest.

**Figure 2.16** Sprinters focus their training on anaerobic glycolysis due to the intensity required over short time periods.

**Figure 2.17** Anaerobic glycolysis is utilised by rock climbers who employ short bursts of high intensity.

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pyruvate

the substance resulting from glycolysis

is used to resynthesise ATP. The by-product of this reaction is called pyruvate.

Both ATP hydrolysis and glycolysis release hydrogen atoms. If insufficient oxygen is being supplied to the working muscle, the increasing accumulation of hydrogen atoms decreases the pH within the muscle, leading to slightly increased acidity (where people describe intense work as causing a ‘burn’). This decrease in pH interferes with the muscle’s ability to contract, leading to feelings of heaviness and fatigue, as well as reduced power output.

During this type of intense exercise, pyruvate plays an important role in helping buffer against the increasing muscle acidity by helping bind to
the free hydrogen atoms, creating a new substance called lactate. During moderate- to high-intensity exercise, lactate is transported out of the muscle to the liver, where it is metabolised and turned back into glycogen, able to be used again as a fuel source.

However, if there is either insufficient or partially occluded (blocked) blood flow due to strong and very regular muscular contractions, then the rate at which lactate can be cleared out of the muscle decreases, leading to its accumulation. It is assumed that the increased lactate is the cause of increasing muscle acidity; however, this is merely evidence that the person is working anaerobically. The lactate is in fact helping to reduce the fatigue caused by vigorous physical activity.

Sports that rely heavily on anaerobic glycolysis are very intense. They may be a short sprint lasting 30 seconds to a minute (e.g. a 200-metre sprint or 100-metre swim). Sports where the athlete is working between intervals of very high intensity and intermittent rest – such as soccer, AFL, basketball and rock climbing – also utilise anaerobic glycolysis heavily.

Aerobic energy system

The third system used to resynthesise ATP is called the aerobic energy system. This energy system is by far the largest energy-producing pathway in the body, as it is used to fuel activity ranging from periods of sedentary activity right through to moderate intensity exercise. As the name suggests, this energy pathway is dependent on a constant and adequate supply of oxygen, so interplay with

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**Table 2.3 Characteristics of lactic acid system**

<table>
<thead>
<tr>
<th>Syllabus point</th>
<th>Characteristic of energy system</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Source of fuel</td>
<td>Glucose (stored as glycogen)</td>
<td>Stored glycogen from liver and muscles is quickly converted into glucose to be used as fuel.</td>
</tr>
<tr>
<td>Efficiency of ATP production (speed of production and amount of ATP resynthesised)</td>
<td>Fast 2 ATP</td>
<td>While not as fast as ATP-PC (due to a more complex set of chemical reactions), the cells are able to break down glucose quickly, with more glucose being made available from the muscle and liver glycogen stores if necessary. Compared with the amount of glucose used, only a few ATP are resynthesised when working anaerobically.</td>
</tr>
<tr>
<td>Duration for which the system can operate</td>
<td>10–75 seconds</td>
<td>While this system begins to operate after five seconds, it reaches full capacity at 10 seconds, taking over from the ATP-PC system for maximal activity. This can be sustained for up to 75 seconds before muscular fatigue and a reduction in power cause the athlete to slow down. At sub-maximal efforts above 85 per cent, activity can last up to three minutes, with anaerobic glycolysis providing most of the energy.</td>
</tr>
<tr>
<td>Cause of fatigue (what causes the system to either slow down or stop, and what effect this has on the athlete)</td>
<td>Increasing muscle acidosis</td>
<td>If the pyruvate is unable to remove the hydrogen at the same rate of accumulation, the pH inside the muscle leads to acidosis. This causes feelings of fatigue, as well as impairing the ability of the muscles to effectively contract at full power.</td>
</tr>
<tr>
<td>By-products of energy production (what else is produced as a result of this process)</td>
<td>Lactate</td>
<td>As pyruvate joins with hydrogen to form lactate, the muscle is able to buffer against the increasing acidity and remove the hydrogen atoms that are responsible for this. The lactate is then removed away from the muscle to be metabolised in the liver.</td>
</tr>
<tr>
<td>Process and rate of recovery (how the system recovers for subsequent efforts and how long it takes)</td>
<td>Lactate removal</td>
<td>During team sports, an athlete is able to use anaerobic glycolysis after two to five minutes' rest following a long and intense effort (e.g. sprinting the length of the field).</td>
</tr>
<tr>
<td></td>
<td>Repeated effort: two to five minutes</td>
<td>After intense exercise involving anaerobic glycolysis has stopped, the body must continue to transport the lactate to the liver to be converted back into glycogen and clear away all remaining hydrogen atoms.</td>
</tr>
<tr>
<td></td>
<td>Complete lactate removal: 30 minutes to two hours</td>
<td>To support both of these situations, an active recovery will help maintain blood flow to flush the lactate out of the muscle as quickly as possible (e.g. keep jogging and have a gradual cool-down).</td>
</tr>
</tbody>
</table>

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**lactate** a substance that is formed when pyruvate picks up hydrogen atoms, to help decrease muscle acidity; metabolised in the liver
an efficient cardiovascular and respiratory system is needed. Of the three energy pathways, it is also the most complex, requiring a range of intricate chemical processes to produce energy.

A range of fuels can be used to produce energy from the aerobic energy system, with each being used at various levels of intensity and duration.

Carbohydrates
In the form of glucose and glycogen, carbohydrates are the most efficient fuel, known as aerobic glycolysis. This is generally the focus of athletes, as glucose is the dominant and preferred source of fuel while exercising at a sustained level.

Fats
Fats, which are stored as lipids, can also be used as fuel. The lipids are broken down into free fatty acids, which can be metabolised aerobically. This is known as aerobic lipolysis. Generally, while someone is resting and sedentary, they use fats as their primary fuel source. However, a gram of fat contains more than twice as much energy as a gram of carbohydrate, and yields 10 times as much ATP. Therefore, sedentary activity tends to burn very few grams of fat because it is such an energy-rich reserve. The logical assumption is that lipids must therefore be a better fuel source than glycogen. However, the oxygen demands required to burn fat as a fuel render it totally ineffective for aerobic exercise, as the demands on the cardiovascular system to supply the increased oxygen would lead to a dramatic reduction in power output. The

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Figure 2.18 Tennis players must have a strong aerobic base in order to play matches over several hours

Figure 2.19 Sustained power output is required for a sport such as archery

Figure 2.20 Aerobic energy pathways are the predominant source of power for athletes participating in distance events like a marathon
only time that fats are used during exercise is if the intensity is kept to a light to moderate level, or if the glycogen stores have been completely exhausted and exercise continues (generally after two hours of constant activity).

Protein
The last fuel the body can use is protein, in the form of amino acids. However, this would only occur in an extreme situation, where both the glycogen and lipid reserves had been exhausted (such as in a famine). This is a potentially dangerous situation, as the amino acids are sourced from the breakdown of muscle tissue, including muscle. The leads to extreme weight loss and can cause harm to the body as toxins are released.

There is a coordinated interplay between the use of carbohydrates and fats as a fuel for exercise, which is stimulated by the intensity of exercise. The body will use fats for as long as it is more efficient, with the aim of preserving glycogen stores for as long as possible until they are needed. Elite endurance athletes aim to perform using fats for as long as possible in a race, to ensure they have sufficient glycogen stores as the intensity increases.

Sports that typically rely on the aerobic energy system either require very low physical exertion — such as archery — or a sustained and moderate level of power output. Typically, most team sports require a strong aerobic base to provide foundation to their anaerobic fitness. This is particularly true for sports such as tennis, soccer and AFL, where players are active for one to three hours, and can cover over 10 kilometres in a game. Of course, longer-distance events such as a marathon or ultra-ironman triathlons are powered predominantly by aerobic energy pathways.

The three components of the aerobic energy system
There are three significant components of the aerobic energy system:
• aerobic glycolysis
• Krebs cycle
• electron transport chain.
While using glucose, the aerobic energy system can resynthesise 38 ATP for each completed chemical pathway. If the athlete is using lipids because they have either run out of glycogen (commonly known as a ‘bonk’) or are at closer to resting levels, they can produce up to 460 ATP.

The body’s use of each energy system represents a complex interplay of fuel supply, as each energy system seamlessly draws energy from all three systems to varying degrees. At certain intensities and times of events, the body

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**Figure 2.21** Aerobic glycolysis operates in the same manner as anaerobic glycolysis. A glucose molecule is broken down, providing enough energy for the resynthesis of two ATP. However, because there is sufficient oxygen available, the pyruvate does not need to attach to pH-decreasing hydrogen atoms, and instead is used in the second component of the aerobic energy system.

**Figure 2.22** In the Krebs cycle, the pyruvate is converted into an enzyme called acetyl coenzyme A (acetyl CoA), which enters a complex set of reactions known as the Krebs cycle. The Krebs cycle itself resynthesises a further two molecules of ATP, and the resulting hydrogen electrons are then transported to the third component. In addition to this, carbon is another by-product of the Krebs cycle; it joins with oxygen to form carbon dioxide, which enters the bloodstream to eventually be breathed out.

**Figure 2.23** Diagram displaying the relevant contribution of the three energy systems in providing the fuel for ATP resynthesis during exercise: the hydrogen electrons from the Krebs cycle enter the electron transport chain, sometimes described as oxidative phosphorylation. These electrons undergo a series of reactions and are eventually reduced to water, which is removed as a waste product. The result of these reactions is a large amount of energy that is used to resynthesise 34 ATP molecules.
### Source of fuel

**Carbohydrates** (moderate intensity) and **fat** (rest to low intensity)

Carbohydrates, in the form of glucose, are used primarily for aerobic exercise, when the intensity increases towards and above 70 per cent of maximal heart rate \((220 - \text{age})\). At lower intensities, fat is the preferred fuel, as it is dense in energy. However, fat as a fuel does require more oxygen.

### Efficiency of ATP production

**Slow 38 ATP**

The time taken for energy to be produced aerobically is slow when compared with the other pathways. However, once functioning, the yield of ATP is far greater. This is even more so when fat is the fuel source, with over 400 ATP being produced. However, the excessive oxygen required means this is best used at rest.

### Duration for which the system can operate

**60 seconds +**

It takes at least 60 seconds for aerobic glycolysis to start providing energy, as the increased oxygen demand has to be delivered via the cardiovascular system. However, once these pathways are established, the aerobic energy system can continue working for hours as long as fuel sources are consistently replenished (such as a 24-hour mountain bike race).

### Cause of fatigue

**Depleted fuel sources**

A consistent level of moderate intensity can be sustained for up to two hours if glycogen stores are full. If these are not replenished regularly, then the athlete will switch to using fats, causing the athlete to quickly fatigue and have to slow down due to the increased oxygen demand. Other causes of fatigue are general neuromuscular and mental fatigue, as a result of the sustained activity.

### By-products of energy production

- **Carbon dioxide**
- **Water**
- **Heat**

These by-products do not have a negative effect upon performance, and are simply removed as waste products of the body. The heat produced will stimulate other changes in the body, such as vasodilation and sweating, to ensure body temperature is maintained at 37°C.

### Process and rate of recovery

- **Replenish fuel stores**
  - **24 hours**

Following a bout of sustained and intense exercise, athletes must ensure they eat adequate amounts of food to replenish depleted fuel stores. This primarily involves eating 50 to 100 grams of carbohydrates within 30 minutes of exercise. The process of restoring liver and muscle glycogen can take up to a full day.

### Table 2.4 Characteristics of the aerobic system

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</tr>
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<td>By-products of energy production</td>
<td>Carbon dioxide, Water, Heat</td>
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**Figure 2.24** Graph displaying the relevant contribution of the three energy systems in providing the fuel for ATP resynthesis during exercise.
relies more heavily on one energy system over the others; however, the other energy systems can be used almost instantly if required.

For example, if an athlete at rest instantly completes five tuck jumps, the ATP CP system will be dominant. A 30-second all-out effort will rely on mostly anaerobic glycolysis following the use of CP reserves. Steady state training at a moderate intensity of 60 per cent MHR will predominantly use the aerobic energy system to fuel the activity.

Table 2.5 Summary table

<table>
<thead>
<tr>
<th>Sport</th>
<th>ATP-PC/LA</th>
<th>Lactic acid system</th>
<th>Aerobic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Basketball</td>
<td>60</td>
<td>20</td>
<td>20</td>
</tr>
<tr>
<td>Fencing</td>
<td>90</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>Field events</td>
<td>90</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>Golf swing</td>
<td>95</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>Gymnastics</td>
<td>80</td>
<td>15</td>
<td>5</td>
</tr>
<tr>
<td>Hockey</td>
<td>50</td>
<td>20</td>
<td>10</td>
</tr>
<tr>
<td>Distance running</td>
<td>10</td>
<td>20</td>
<td>70</td>
</tr>
<tr>
<td>Rowing</td>
<td>20</td>
<td>30</td>
<td>50</td>
</tr>
<tr>
<td>Skiing</td>
<td>33</td>
<td>33</td>
<td>33</td>
</tr>
<tr>
<td>Soccer</td>
<td>50</td>
<td>20</td>
<td>30</td>
</tr>
<tr>
<td>Sprints</td>
<td>90</td>
<td></td>
<td>10</td>
</tr>
<tr>
<td>Swimming 1500 metres</td>
<td>10</td>
<td>20</td>
<td>70</td>
</tr>
<tr>
<td>Tennis</td>
<td>70</td>
<td>20</td>
<td>10</td>
</tr>
<tr>
<td>Volleyball</td>
<td>80</td>
<td></td>
<td>15</td>
</tr>
</tbody>
</table>

Table 2.6 Energy system contribution of a variety of sports

Source: ASC (see www.cambridge.edu.au/hscpdhpweblinks).
patterns and energy system of the game or sport is necessary.

The types of training movements utilised and the specific movement patterns adopted should mimic the demands of the sport. As an example, an explosive sprint athlete will prepare very differently from a marathon runner. Similarly, a Rugby League player’s training program will vary from that of a golfer. Examples of the energy system contribution of a variety of sports are provided in Table 2.6.

This demonstrates that while very few sports rely upon the contribution of one energy system to fuel the exercise, there are variations relating to the contribution of the energy systems to the sporting performance. The field events discus and hammer throw are fuelled almost entirely by the ATP-PC system. In contrast, distance running events are fuelled almost entirely by the aerobic energy system. Team sports like soccer are intermittent high-intensity sports that change constantly in speed and direction, so the energy system’s contribution varies, depending on the position. Due to the variations in many sports in relation to the energy system contributions required, differences also exist in the types of physical qualities that are required to meet the physical demands of the event. These physical qualities include:

- strength
- speed
- endurance
- flexibility.

The relationship between the physical qualities of strength, speed and endurance

Only a limited number of sports rely on the development of just one physical attribute, so the athletes’ physical preparation will vary significantly:

- Olympic power lifting relies on strength and speed.
- Team sports like soccer rely on speed, endurance, flexibility and some strength.
- Impact sports like Rugby League rely on all three physical qualities as well as flexibility.

There are many reasons why people choose to exercise, including to:

- improve health and well-being
- improve physical condition
- lose weight
- cope with daily stress
- feel better
- become an elite athlete
- overcome an injury.

Regardless of the reason people choose to exercise, there are basic training principles that must be understood and adhered to if the goals of the program are going to be met.

Aerobic training

Utilising the aerobic energy system, an athlete’s aerobic endurance levels are commonly developed using four traditional methods of training:

- continuous training
- fartlek intermittent training
- interval training
- circuit training.

**Figure 2.25** Distance running events are fuelled almost entirely by the aerobic energy system

**Figure 2.26** When the relationship between the physical qualities is shown as a triangle, strength is at the top of the triangle, speed is at the left corner and endurance is at the right corner

**Source:** Level 1 ASCA course notes, Module 2 – Training Theory, Planning Training and Periodisation Basics.
Continuous training
Continuous training is an extended, predominately steady-state training session that lasts no less than 15 to 20 minutes. Continuous training is the most commonly considered training method for aerobic development, and embodies what most people think of as training for the aerobic energy system. This form of training is most effective for lower level athletes and racing endurance sports like rowing, cycling, distance running and swimming, but it is much less common in sprints, power games, field events and court sports.

Fartlek
Fartlek means ‘speed play’, and was made popular by Emil Zatopek. It is an extended continuous training session with intermittent bursts of speed throughout the session. Due to the intermittent bursts of high-intensity effort during the session, both the aerobic and anaerobic energy systems can be targeted. Fartlek training sessions therefore resemble a combination of both continuous and interval training. Middle-distance track athletes often adopt ‘speed play’ sessions as part of their training programs.

Example of fartlek training
- Warm-up:
  - 10-minute walk
  - dynamic mobility exercises
- Fartlek session (30 minutes approximately):
  - two-lap (800 metres) jog at 70 per cent
  - 100-metre stride-through at 85 per cent
  - two-lap jog (800 metres) at 70 per cent
  - 200-metre intense run at sprint at 90 per cent
- repeat six times.

Continuous training guidelines
- **Duration**: Can be as short as 20 minutes, but will depend on the duration of the event for which the athlete is training. Endurance sports athletes will often need to do continuous training sessions much longer than an hour in length.
- **Mode**: Usually specific to the demands/nature of the sport (runners run, cyclists ride and swimmers swim); however, it can vary from the nature of the sport (cross-training effects).
- **Frequency**: Two to three times per week.
- **Type**: Continuous – ‘steady-state’ or ‘mixed intensity’ continuous.
- **Duration**: Generally >15–20 minutes in duration.
- **Volume**: Depends on mode, type, duration, intensity, age and experience of the athlete.
- **Intensity**: Generally sub-maximal (70–85 per cent of heart rate maximum) but mixed intensity continuous is effective.

Fartlek training guidelines
- **Mode**: Usually specific to the demands/nature of the sport. The sport will also determine the length of the speed bursts.
- **Frequency**: Generally two to three sessions per week.
- **Intensity**: Generally sub-maximal (75–80 per cent) interspersed with much higher (maximal intensity) bursts of varying durations during the course of the exercise.
- **Duration**: Can be as short as 15 minutes, but generally 20–30 minutes with bursts of intensity ranging from 10 seconds to several minutes. The duration will be dictated by the duration of the event for which the athlete is training.

Going further 2.5
Inquire
Provide an example of a sport that would benefit from continuous training. Assuming the athlete is relatively young, provide examples of the mode, frequency, type and duration of the training session that would be appropriate for this sport.

Going further 2.6
Create
Design a fartlek training session for a particular sporting event. When designing the training session, consider the mode, intensity and duration of the session.
Interval training

Interval training involves intermittent training at higher training intensities with defined work and rest periods to develop the aerobic energy system. Interval training is a common method of developing sport-specific endurance. High-level, experienced athletes are more likely to benefit from interval training methods than they are from continuous and fartlek training methods. There is no limit to the number of possible interval training methods.

<table>
<thead>
<tr>
<th>Type</th>
<th>Duration</th>
<th>Intensity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Short intervals</td>
<td>Less than 30 seconds</td>
<td>Greater than 100 per cent $V_O^2_{max}$</td>
</tr>
<tr>
<td>Medium intervals</td>
<td>Thirty seconds to one minute</td>
<td>Near 100 per cent</td>
</tr>
<tr>
<td>Long intervals</td>
<td>One minute or more</td>
<td>85–100 per cent</td>
</tr>
</tbody>
</table>

Table 2.7 Classifying interval training methods

Source: Level 2 ASCA course notes, Module 6 – Energy System Conditioning.

The large variety of training sessions that can be utilised in circuit training means that it is useful for both beginner and advanced athletes.

Example of a circuit training session for a soccer player

Nine stations, working in pairs, 30 seconds on, 30 seconds off for three minutes:

- sit-up header
- 10 line jumps then control pass
- 10-metre sideways movement then chest volley
- shuttle out and back with header
- length of field dribble (30-second run, 30-second juggle)
- loose ball chase, dribble back to start

Interval training guidelines

- **Intensity:** Varied, can be sub-maximal, maximal or super-maximal intensities with sub-maximal recovery periods.
- **Duration:** Short, medium and long intervals. The duration will be dictated by the duration of the event for which the athlete is training. To remain aerobic, recovery is generally 1:1 work to rest ratio or less.
- **Frequency:** Minimum one session per week if other training activities are taking place. Generally two to three sessions per week.
- **Mode:** Dictated by the sport. The sport will also determine the ideal length of speed bursts within the session.

Circuit training

Circuit training is an effective method of conditioning that develops strength and endurance (both aerobic and anaerobic), flexibility, coordination and game-specific skills within one exercise session. The main benefit of circuit training is that it effectively develops both strength and cardiovascular fitness in the same exercise session.

Circuit training describes how the workout is structured, not necessarily the type of exercises being performed. Typically, circuit training comprises a variety of exercises or stations that are completed within a given timeframe or for a prescribed number of repetitions with minimal rest in between.

While circuit training and interval training are somewhat similar in nature, there are some major differences. Interval training generally focuses on one type of exercise – such as running, cycling or swimming – during the session, and this may vary in intensity during the session. Circuit training consists of a large variety of exercises of shorter duration in one training session, and allows for an endless variety of training routines.

A well-designed circuit provides a balanced workout that targets all the muscle groups and builds cardiovascular endurance. Circuit training can also be used to correct the muscle imbalance that often occurs in athletes. In addition, it is used to provide a quick, time-efficient, high-intensity metabolic body fat-burning session for overweight athletes. Circuits also provide a high-intensity skills training session for athletes.

The large variety of training sessions that can be utilised in circuit training means that it is useful for both beginner and advanced athletes.
Example of a bodyweight circuit for a youth athlete

Ten stations, 30-second work period, 30-second rest period, two laps:
- wall squats
- push ups
- prone hold (hovers)
- side lunges
- Swiss ball crunches
- hands elevated push-ups
- bench step-ups
- side hold (side hover)
- reverse lunges
- bench dips.

As the athlete’s fitness improves, the difficulty of the exercise may be increased by increasing the exercise time, increasing the weights or resistance used, adding more difficult exercises or decreasing the amount of time spent resting between stations.

Circuit training guidelines

- **Mode**: Usually specific to the demands/nature of the sport. The sport will also determine the types of drills performed in the circuit.
- **Frequency**: Generally two to four sessions per week, depending on other components of training being performed. Allow 48 hours of rest for all muscle groups between sessions.
- **Type**: An endless variety of circuit options are available. Circuits typically consist of eight to 12 exercises or stations that target the entire body.
- **Intensity**: The resistance selected while challenging should allow the athlete to perform the exercise for the duration of the effort. For aerobic endurance, decrease the intensity of the exercise at each station, increase the length of time spent at each station and shorten the rest between stations to keep the heart rate continuously elevated. For a muscular strength focus, increase the intensity (resistance) of the exercise at each station and the rest time between stations to allow full muscular recovery between exercises.
- **Duration**: Generally, the activity at each station is performed for 30–90 seconds with 15 to 30 seconds of recovery between each station. Three to four sessions at least 20 minutes in duration may be performed per week.

Anaerobic training

Anaerobic training is used by athletes in non-endurance sports, and is effective in developing strength, speed and power. It is also used by body builders to build muscle mass. Anaerobic training leads to greater performance in short-duration, high-intensity activities, which last from mere seconds up to about two minutes. Activities lasting longer than two minutes are predominantly aerobic in nature.

Anaerobic energy system training comprises both:
- the alactic system – the predominant energy contribution for intense efforts up to 8–15 seconds, and
- the lactic system – the predominant energy contribution for intense efforts up to 40–60 seconds.

Examples of anaerobic alactic sports include 100-metre sprinting, Olympic lifting and the vault in gymnastics, while 100-metre and 200-metre swimming, 400-metre hurdles and sprint cycling are examples of anaerobic lactic sports.

The high-intensity nature of both anaerobic alactic and lactic sports means athletes
participating in these sports have a limited supply of energy, so they fatigue quickly and require extended recovery periods to allow the replenishment of the anaerobic energy supply.

Both the anaerobic alactic and lactic energy systems have two components:
• anaerobic power – the capacity to do the most work in the anaerobic energy system
• anaerobic endurance – the capacity to maintain work in the anaerobic energy system

All anaerobic training is performed using the interval method.

Flexibility training

Flexibility can be defined as the range of movement around a joint. The benefits of flexibility training for athletes include:
• enhanced movement performance
• reduced muscle soreness and tension
• reduced injury risk – both in the short and long term
• improved muscular coordination
• enhanced physical and mental relaxation.

Note: In physical preparation for professional team sports, there has been a significant shift away from prolonged static stretching prior to training sessions and games. Evidence suggests that prolonged static stretching prior to explosive intermittent team sports may suppress the firing rate of the muscles. Instead, warm-ups comprise dynamic mobility and skill drills that progressively increase in speed and intensity, and warm the athlete up dynamically. Static stretching is, however, an important component of recovery and the cool-down.

The four most commonly used methods of developing joint flexibility include:
• static stretching
• ballistic stretching
• proprioceptive neuromuscular facilitation (PNF)
• dynamic stretching.

### Table 2.8 Anaerobic training guidelines

<table>
<thead>
<tr>
<th></th>
<th>Intensity (%)</th>
<th>Duration of repetitions</th>
<th>Work</th>
<th>Rest</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alactic power</td>
<td>95–100</td>
<td>5 seconds</td>
<td>4–8 repetitions</td>
<td>1&gt;10</td>
</tr>
<tr>
<td>Alactic endurance</td>
<td>90–95</td>
<td>10 seconds</td>
<td>3–5 repetitions</td>
<td>1:08</td>
</tr>
<tr>
<td>Lactic power</td>
<td>95–100</td>
<td>10–15 seconds</td>
<td>3–5 repetitions</td>
<td>1:06</td>
</tr>
<tr>
<td>Lactic endurance</td>
<td>90–95</td>
<td>30–60 seconds</td>
<td>3–5 repetitions</td>
<td>1:03</td>
</tr>
</tbody>
</table>

Source: Level 1 ASCA course notes, Module 7 – Energy System and Endurance Conditioning.

Static stretching

Static stretching is a method used to gradually lengthen the muscle while the body is at rest. The stretch position is held for a minimum of 30 seconds to two minutes in order to achieve the muscle-lengthening benefits of the stretch. Athletes often experience a warm sensation or some mild discomfort, either during or directly after the stretch. Correct methods of static stretching lessen the sensitivity of tension receptors within the muscle, relaxing the muscle and resulting in increased muscle length.

Ballistic stretching

Ballistic stretching is a form of dynamic stretching that consists of repeated movements that bounce, jerk or swing through the end-range of motion. Ballistic stretching uses the momentum of a moving body or a limb in an attempt to repeatedly force it beyond its normal range of motion – for example, bouncing down repeatedly to touch your toes.

Figure 2.30 Stretching to promote flexibility can offer many benefits for athletes.
type of stretching is not considered useful, and can lead to injury. It does not allow your muscles to adjust to, and relax in, the stretched position. It may instead cause them to tighten up by repeatedly activating the stretch reflex.

It is extremely important to be careful when incorporating ballistic methods into a warm-up routine. Some speed, power and gymnastics athletes do incorporate ballistic movements after a controlled dynamic warm-up.

PNF stretching
Proprioceptive neuromuscular facilitation (PNF) is usually a partnered form of stretching that involves lengthening the muscle against resistance; it is often referred to as the ‘contract’, ‘hold’ and ‘relax’ method of PNF stretching.

While there are a variety of forms of PNF stretching, it is one of the most effective methods of increasing the range of motion of a muscle, and is best employed following training sessions or games. Using the lying hamstring stretch as an example, the common variations in PNF stretch methods are provided below.

**Hold–relax PNF stretching**

- **Step 1:** This is a partnered method of PNF hamstring stretch where a partner moves the athlete’s extended leg to a point of mild discomfort (see Figure 2.31). The athlete relaxes and holds the stretch for a period of 10 seconds.
- **Step 2:** The partner instructs the athlete to gently contract the hamstring isometrically by pushing the extended leg against the partner for a period of six seconds.
- **Step 3:** The athlete is then instructed to ‘relax’ while the partner gently takes the extended leg through a slightly greater range of motion.
- **Step 4:** A second passive stretch is held for 30 seconds.

**Contract–relax PNF stretching**

- **Step 1:** The same as the hold–relax PNF stretch.
- **Step 2:** The partner instructs the athlete to contract the hamstring concentrically by pushing their extended leg against the partner’s hand. Enough force and resistance is applied by the partner to the athlete’s leg to allow the athlete to push the extended leg through the full range of motion. This is referred to the ‘contract’ phase.
- **Step 3:** The same as the hold–relax PNF method.
- **Step 4:** The same as the hold–relax PNF method.

**Hold–relax with opposing muscle contraction**

- **Step 1:** The same as the hold–relax and contract–relax PNF stretch.
- **Step 2:** The partner instructs the athlete to gently contract the hamstring isometrically by pushing the extended leg against the partner for a period of six seconds (same as the hold–relax method).
- **Step 3:** The partner completes a second passive stretch by taking the extended leg through a greater range of motion. Unlike the hold–relax and contract–relax methods, the athlete is instructed to pull the extended leg in the same direction in which the partner is pushing the leg.
- **Step 4:** Same as the hold–relax and contract–relax methods.

**PNF stretching guidelines**

- PNF stretching is a strenuous form of stretching, so 48 hours of rest should be allowed between PNF stretching routines.
- Only one exercise is necessary per muscle group.
- Two to five sets of a particular exercise should be chosen for each muscle group.
- Following the isometric or concentric contraction phase, ensure that the passive stretch is held for 30 seconds.
- PNF stretching methods should not be employed for children.
- If the PNF session is performed cold, allow for a five- to 10-minute light aerobic warm-up incorporating light dynamic movements prior to the PNF session.
- Do not PNF stretch prior to competition or training sessions.
Dynamic stretching
Dynamic stretching has become the most popular and widely used method of actively stretching muscles among many professional soccer, Rugby League, AFL and Rugby Union athletes. Dynamic stretching involves moving parts of the body in a controlled manner, with movements gradually progressing in speed and range of motion. It should be the dominant form of stretching in a warm-up. Examples of dynamic stretching include walking lunges that gradually take longer and longer strides with each rep, or shoulder circles with larger diameters of movements each rep.

Types of muscle contraction
Muscle contractions can be divided into:
• isotonic
• isometric
• isokinetic.
Isotonic contractions
Isotonic contractions involve muscular movement, and comprise two important muscular contractions. The concentric phase occurs when the muscle shortens in length (see Figure 2.36). The eccentric muscular contraction occurs as the muscle lengthens (see Figure 2.37).

Concentric muscular contractions are not only common to many sporting activities, but occur in everyday life.

While eccentric movements are not as common as concentric movements, eccentric muscular strength contractions play an important role in controlling the deceleration of movements.

As the soccer player kicks the football, the quadriceps muscle contracts concentrically as the leg straightens. At the same time, the hamstring muscle contracts eccentrically to control the deceleration of the leg.

Isometric contractions
The working muscle does not change in length during isometric contractions – for example, pushing both hands against the sides of an immovable object like a doorway. While the muscles of the arms are contracting forcefully, there is no movement.

Isokinetic contractions
Isokinetic muscular contractions are similar to isotonic muscular contractions in that both promote a change in muscular length during the contraction. Unlike isotonic movements, isokinetic muscular contractions occur at a constant speed, making them less relevant to many sporting activities.
activities. Isokinetic equipment is also extremely expensive.

Strength training methods
A variety of strength training methods are commonly employed by both professional athletes, and there is debate around which method is best for strength development. Generally speaking, the answer depends on many factors, such as the age, experience and specific goals of the program.

Strength training methods include:

Free weights
Free-weight equipment includes barbells, dumbbells, kettlebells, medicine balls and sandbags. It is the most commonly utilised equipment in the strength training of many professional team and individual sport athletes, as it is versatile and inexpensive. Free weights are generally preferred over weight machines for strength and conditioning in the development of sport-specific strength training programs, as free weights better simulate sport-specific lifting situations and promote whole-body stabilisation as athletes are required to recruit many stabilising muscles in order to control the weight by maintaining correct postural form and lifting techniques. Weight machines, on the other hand, limit the athlete to specific movements that are fixed in direction.

Weight machines
Weight machines offer a large variety of exercises that guide the client through the movement in a controlled, supported fashion, so less attention needs to be paid to technique, form, balance, coordination and muscle stabilisation. Machine weights are more commonly used for inexperienced strength trainers, the elderly and those recovering from injury. Machines are also useful if circuit training is performed. Circuit training involves going from one machine to the next with little rest in between. Machines allow quick movement from one exercise to the next without having to change dumbbells or add weight to the bar.

Resistance bands
Resistance bands have a variety of uses and benefits in the application of strength training among both professional athletes and general clients. Bands are portable, light and inexpensive compared with free weights and weight machines. Band work also provides a constant tension on the muscle through a movement similar to that...
provided by cable machines. Like free weights, bands require the recruitment of more stabiliser muscle in order to control the movement and offer a large variety of movements in many directions. The downside to band training is that they are not as demanding as free or machine weights. It is also impossible to determine the weight being lifted on the bands.

Strength and conditioning trainers often use light resistance bands as part of rehab training where light band work is used to strengthen the rotator cuffs, knees, glutes and groin muscles prior to training.

Heavy resistance bands are also used during maximal strength and explosive strength training movements in the gym. By applying bands to the bar during the bench press (see picture below), there is an increase in resistance through the range of motion – this is called accommodating resistance. Heavy chains are also often used to provide accommodated resistance among experienced strength athletes.

Hydraulic machines
Unlike weight machines, hydraulic machines do not require any selection of weight or resistance. By simply pushing or pulling against the lever using your arms or legs, the hydraulic cylinders provide counter-resistance to the movement. The harder

Figure 2.42 A pin-loaded inclined chest press is a common example of a weight machine

Figure 2.43 By adding chains to the barbell squat, the exercise becomes an accommodated resistance exercise. The movement becomes heavier as the athlete stands.

Figure 2.44 The hydraulic seated chest press

Figure 2.45 The band is attached to the bar during the bench press to provide accommodated resistance. The weight gets heavier as the bar reaches the top of the movement.
and faster you push or pull, the more resistance you create within the machine. One of the main benefits of hydraulic machines is that they offer the ability to do two movements at the same time. For example, during the hydraulic seated chest press (see Figure 2.44), the client works the pec muscles as the levers are pushed out, while the back muscles (lats) are worked as the levers are pulled back towards the chest. The downside is that hydraulic machines do not provide an eccentric contraction, which is the lowering phase of an exercise.

**Principles of training**

**Progressive overload**

Progressive overload is one of the most commonly used training techniques, and is recognised across the fitness industry as critical to the success of fitness programs. Progressive overload refers to training becoming gradually harder the fitter or stronger you become. Progressive overload is most commonly used in strength-based programs; however, the principle can be applied to cardio programs as well. For example, in a gym program, a participant may bench press 40 kilograms in Week 1, 42.5 kilograms in Week 2, 45 kilograms in Week 3 and so on. As the body adapts, the training becomes harder and this increases the capacity of the body to perform.

This technique encourages constant improvement, and is great for those in the early stages of a training program. The principle is also an effective way for individuals with very little base fitness. Over time, however, the improvement and the ability to continuously overload the body will begin to plateau. At this stage, the participant and their coach and/or trainer will need to reassess their training goals and consider a program that focuses on maintenance and/or including some variety.

**Specificity**

The principle of specificity refers to the training being targeted towards the goals and objectives of the athlete and/or the demands of the chosen sport. When designing a program that incorporates specificity, the athlete and coach should consider the following questions:

- Which energy system is to be targeted?
- Which muscle groups will be targeted?
- Which components of fitness will be targeted?

If these questions were applied to the training program of a 100-metre sprint athlete, the training should be targeted at enhancing the ATP-PC energy system. Strength training would target the large upper leg, lower back and core muscles, while components of fitness critical to a training program that upholds the integrity of specificity would...
include strength, power and reaction time. It would be counter-productive for this athlete to participate in long-distance road runs, as this style of training would do little to enhance the energy system required or fitness components involved.

Specificity in training programs is now present in team sports, depending on the position of play for each athlete. A close analysis of Rugby League and a comparison between the positions of prop and halfback is a good example. Visually, these two athletes will typically have a very different body composition. The positional requirements and responsibilities are also quite different, which means the components of fitness these positions utilise will not be the same. A front rower must be strong and powerful, while the halfback will require greater speed, agility and cardiovascular fitness. Hence their respective training programs should be specific to those demands.

Reversibility

Reversibility can colloquially be explained as ‘use it or lose it’. The effects of training will begin to diminish if training stops. Within two weeks of ceasing to train, muscle density will decrease and the positive effects of cardio training will begin to diminish. While an athlete does not need to continuously improve throughout their training schedule, it is important to have a maintenance program in place to ensure that the improvements gained are not subsequently lost because training stops or slows.

Variety

Premierships, gold medals, green jackets and yellow jerseys take many years of hard, strenuous and often repetitive training to achieve. This is where the principle of variety is important. A coach who can provide their athlete with variety in their training will be able to maintain the concentration and motivation of their athlete longer. The principle of variety simply affords the athlete with an opportunity to continue training without necessarily doing something that is specific to their regular sport. A good time to include some variety in an athlete’s training could be during the off-season and/or when the athlete is recovering from injury. It might be as simple as including some boxing as part of a cardio routine for a netball squad or encouraging a surfer to do yoga.

Yoga is a popular form of cross-training for athletes. While it provides variety in a training program, it also has proven benefits for breathing, flexibility, core strength and relaxation.

Training thresholds

Thresholds refer to specific points of measurement that, when passed, take someone or something to another level. When it comes to training thresholds, there are two specific points of measurement that are very important: the aerobic threshold and the anaerobic threshold. For an athlete to be able to use these thresholds successfully within training, they must be able to measure when their body reaches the thresholds. Athletes and coaches now use more tools and resources to measure performance during training and competition than ever before. Heart rate, however, remains one of the most accurate indicators of intensity, and it is intensity that determines the threshold at which someone is training.

Heart rate can be measured both quickly and accurately with basic equipment. To understand heart rate, it is first necessary to calculate a person’s maximal heart rate. This is calculated by subtracting their age from 220. This would mean somebody who is 20 years of age would have a maximal heart rate of 200 beats per minute – that is, 220 – 20 = 200. The intensity at which an athlete must be training to break the aerobic threshold is 70 per cent of their maximal heart rate. If the above example were applied, then the 20-year-old athlete would need to have a heart rate of 140 beats per minute to gain aerobic improvement. The second anaerobic threshold would be passed when the athlete’s heart rate surpassed 80 per cent of their maximal heart rate or 160 beats per minute. The passing of the anaerobic threshold
is also characterised by a sharp increase in the production of blood lactate. This is referred to as the lactate inflection point. Blood lactate and maximal oxygen uptake (VO₂ max) provide a very accurate measurement of when thresholds are crossed and the intensity of exercise. To measure blood lactate and VO₂ max, laboratory-grade equipment is required. However, heart rate can be measured using an unobtrusive heart rate monitor or simply by finding a pulse and counting the number of beats per minute.

An athlete can perform in the aerobic zone for considerably longer than they can in the anaerobic zone. As a by-product of training on or above the anaerobic threshold, the body will produce lactic acid, which causes fatigue and minimises the length of time at which that level of intensity can be maintained. The more an athlete can train above the anaerobic threshold, the more tolerant they will become of the lactic acid, and the longer they will be able to sustain the increased effort.

Warm-up and cool-down

The warm-up and cool-down are two very important components of any training session or competition. The warm-up should precede any form of training or competition. A good warm-up prepares the body for the rigours of training or competition by increasing the range of movement around joints, elevating the heart rate, allowing for skill rehearsal, and honing the focus and concentration of the athlete. By doing this, athletes minimise their risk of injury, and physically and psychologically prepare themselves. A warm-up should include the following components:

- **Aerobic activity.** A light jog is a good way to start. This gradually increases the exercise intensity and the body temperature.
- **Specific flexibility exercises.** Stretching should not be done until there has been some movement in the muscles. Stretching cold muscles can cause injury. The value of stretching is often debated, but the stretching of muscles specific to the activity is advisable. Keep the static stretching components reasonably short, focusing more specifically on dynamic exercises that are related to the upcoming activity.
- **Skill rehearsal.** The warm-up should also include some skills applicable to the upcoming activity – for example, basketball players should dribble, pass, catch or shoot.

The cool-down immediately follows the main body of exercise. The cool-down phase is often overlooked, but is particularly important for those athletes who must quickly return to training and/or who have their next competition shortly afterwards. While exercising, the body creates by-products like blood lactate, and sustains many small tears in the muscle fibres. By engaging in an active recovery or cool-down, the fresh, oxygen-rich blood can circulate more easily, helping to flush out the by-products and repair the small tears. A cool-down should involve aerobic movement (light jog and/or brisk walk) and some gentle static stretching.

<table>
<thead>
<tr>
<th>Exercise zones</th>
<th>VO₂ max (maximum effort)</th>
<th>Anaerobic (hard-core training)</th>
<th>Aerobic (cardio training/endurance)</th>
<th>Weight control (fitness/fat burn)</th>
<th>Moderate activity (maintenance/warm-up)</th>
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</thead>
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<tr>
<td>Beams per minute</td>
<td></td>
<td></td>
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<td>100%</td>
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Figure 2.48 Aerobic and anaerobic heart rate zones
Physiological adaptations in response to training

Chapter 2    Factors Affecting Performance

Physiological adaptations in response to training

At the heart of physical activity is the desire to reap the many benefits that are associated with it. These benefits can have a positive impact on all facets of a person's individual health.

For people wanting to improve their physical conditioning and performance in competitive sporting events, training enables them to positively impact their body in a range of unique ways.

These broad performance goals rely on unique physiological changes or adaptations that occur within the related systems of the human body, such as the cardiovascular, nervous and muscular systems. These adaptations are the result of a training stimulus that causes the human body to adapt, change and become more efficient. In doing so, the body is responding to the stimulus in a way that ensures it is better able to endure or cope with the physical stress being asked of it.

Obviously, there is a close relationship between the principle of training, progressive overload and the physiological adaptations that occur in response to training. For such an adaptation to occur, the stimulus must be greater than what the body is already accustomed to, otherwise the human body will remain largely unchanged.

To achieve these changes and adaptations, a specific, focused and individually tailored training program is required. As greater amounts of scientific data and more training innovations are developed in the areas of strength and conditioning, it can be a complex task to develop a training program that will safely and effectively help a person reach their desired performance goals. The most relevant physiological adaptations are:

- **resting heart rate**
- **stroke volume**
- **cardiac output**

**Checklist 2.11**

1. How can the principles of training be applied to aerobic training?
2. How can the principles of training be applied to resistance training?

**Summary 2.10**

1. Define progressive overload.
2. What is specificity?
3. What is the principle of reversibility?
4. How can a coach provide variety while maintaining all other principles of training?
5. What is the aerobic threshold and what occurs if you exceed it?
6. What is the anaerobic threshold and what are the benefits of training around this mark?
7. Discuss the importance of a warm-up and cool-down.

**Driving questions 2.12**

1. When a person undertakes a thorough and regular training program, what are some of the major changes that occur to the body?
2. Why do these changes occur and what is the benefit of them?
- oxygen uptake and lung capacity
- haemoglobin level
- muscle hypertrophy
- effect on fast/slow-twitch muscle fibres.

As each physiological adaptation is studied, links should be made with appropriate training activities and programs that will contribute to its development, as well as the principles of training.

**Resting heart rate**

A person’s resting heart rate (RHR) is a commonly used indicator of their general physical fitness. A lower RHR indicates a strong heart, capable of pumping a greater amount of blood in fewer beats. This is the preferred condition for the human heart, and regular aerobic and anaerobic training designed to appropriately stress the cardiovascular system will lead to a decrease in resting heart rate.

Typically, an untrained adult will have a RHR of between 72 and 80 beats per minute (bpm). However, a trained adult is more likely to have a RHR of closer to 60 bpm. As cardiovascular fitness increases, RHR can become as low as 30 bpm in extremely fit athletes such as ultra-triathletes. These figures are based on averages, as some healthy people have heart rate measurements that naturally fall outside of these norms.

One of the most important measurements for heart health is not the actual RHR of a person, but the time it takes for someone’s heart to return to resting values following exercise. This is known as their rate of recovery, and doctors often use this stress test on heart patients to check the health of their cardiovascular system. As their aerobic endurance improves and the heart strengthens, recovery is much faster. This is evident in elite athletes playing team sports, who are able to quickly recover following high-intensity maximal efforts.

In addition to this, athletes with greater aerobic conditioning will be able to maintain a lower working heart rate at all levels of intensity compared with an untrained athlete, except when the heart is pushed to its maximal capacity. Trained adults are able to achieve a higher maximum heart rate than untrained adults. All of these factors are evident in Figure 2.51.

**Stroke volume and cardiac output**

Endurance training involves exercising for a sustained period with an elevated heart rate. Over time, this type of training has a direct training effect upon the heart muscle itself, including both an increase in size (thicker wall of the left
ventricle) and contractility (ability to efficiently contract repeatedly and forcefully). In addition to this, trained adults have more blood volume, to accommodate an increase in the number of oxygen-carrying red blood cells. These changes allow the heart a greater capacity to pump more blood per beat around the body by more fully ejecting the blood that has filled into the left ventricle. This is known as an increase in stroke volume. These changes all increase the body’s ability to pump oxygen-rich blood to the working muscles of the body, allowing them to continue to produce energy aerobically.

Cardiovascular development through aerobic and anaerobic training results in an increase in stroke volume at all levels of work intensity. Even though stroke volume plateaus at moderate intensities, a trained adult will always have a greater stroke volume than an untrained adult. This allows the heart to beat less often to deliver oxygen to the required muscles, leading to reduced levels of fatigue. This can be seen in the graph above.

Regular aerobic training leads to a significant increase in the efficiency and capabilities of the entire cardiovascular system. Greater stroke volumes combine with a greater capacity to work at higher heart rates to produce an increase in the product of the two: cardiac output.

To calculate a person’s cardiac output, their heart rate should be multiplied by their stroke volume:

\[
\text{heart rate (HR) x stroke volume (SV) = cardiac output (CO)}
\]

To determine the cardiac output of a healthy adult with a resting heart rate of 60 bpm and a stroke volume of 75 mL/beat, the calculation would be:

\[
60 \text{ bpm} \times 75 \text{ mL/beat} = 4500 \text{ mL/min}
\]

However, it is while exercising that these measurements take on greater significance, with the cardiac output increasing by four to five times.
During exercise, the majority of this increased blood flow is directed towards the working muscles and away from less essential body systems, such as the digestive system. Because the trained adult has a lower working heart rate compared with an untrained athlete at a set intensity level, the increase in cardiac output is largely attributed to an increased stroke volume. The difference in cardiac output between an untrained adult and an elite athlete can be as much as double, with extremely fit adults being able to pump 30 to 40 litres of blood out of the heart per minute.

Apart from decreasing fitness levels through reversibility, another factor that leads to a decrease in the functioning of the cardiovascular system is age. As people get older, their heart rate, stroke
volumes and therefore cardiac output all gradually decrease in capacity. For this reason, older athletes should take extra precautions when exercising at moderate to high intensities.

**Oxygen uptake and lung capacity**

Aerobic and anaerobic training lead to the development of both the cardiovascular and respiratory systems. The combined system is often referred to as the cardiorespiratory system, which incorporates the lungs, heart, and all blood vessels. The primary role of these body organs during exercise is to provide as much oxygen as is needed or is possible to the working muscles, to ensure that they continue to work aerobically for as long as possible. If the intensity of training is high, and more anaerobic in nature – that is, short- to medium-interval training – the oxygen required is used primarily for recovery, as the body is unable to supply enough oxygen to maintain consistent work intensity due to increasing fatigue from lactate build-up. In both cases, increased oxygen uptake and lung capacity will benefit the athlete, and are a natural physiological adaptation in response to training.

Regular aerobic training results in a variety of changes to the respiratory system. The actual lung capacity may increase slightly for some adults; however, this is more likely to occur in elite endurance athletes such as road cyclists. The most significant change is in the actual amount of air that can be moved in and out of the lungs with each breath. As with the heart’s stroke volume and heart rate, the lungs also develop in their capacity to draw in more air and increase the ventilation rate without necessarily getting larger. The manner in which the air is moved in and out of the lungs is more noticeable, as the lungs prefer to breathe more deeply and forcefully than to increase the

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Table 2.9 Increased performance with training
ventilation rate (in a similar manner to the heart and the increase in stroke volume at submaximal intensities). The muscles that contribute to the process of breathing in and out increase in efficiency and strength, which equally contributes to increased lung capacity. Some athletes use specific breathing exercises and equipment to enhance their lung capacity.

To test lung capacity, athletes use medical-type equipment that can measure both the depth and force of breathing.

It is interesting to note that the lungs are more than capable of breathing in adequate oxygen to supply the working muscles. It is actually the efficiency of the cardiovascular system that is often the limiting factor with regard to cardiorespiratory endurance. Development in this system will contribute to greater oxygen uptake, a key physiological adaptation to regular aerobic training.

From deep sleep to high-intensity activity, our bodies have an oxygen demand that needs to be met. As the body's ability to draw oxygen into the muscle cells is increased through regular training, the athlete will be able to sustain a higher average power output over an extended period, whether it is through running, swimming, cycling or rowing. Testing oxygen uptake can be difficult without the use of technical equipment capable of measuring the amount of oxygen and carbon dioxide being inhaled and exhaled with each breath. However, maximal tests, where the athlete works to absolute exhaustion, can be a reliable measure of the maximum amount of oxygen that an athlete is able to draw into the working muscles per minute. This is commonly referred to as VO₂ max, which is measured in millilitres of oxygen per kilogram of body weight per minute. The popular multi-stage fitness test (also known as the beep test) and yo-yo test both have prediction tables of maximal oxygen uptake, which is a respected measurement of aerobic fitness.

The health benefits of an effective and efficient cardiorespiratory system are just as important as the performance benefits for athletes. Reduced risk of cardiovascular disease, type 2 diabetes and being overweight are all positive outcomes of regular training that stimulates the aerobic system to adapt to a suitably difficult training load.

However, all sportspersons benefit in some way from being aerobically fit. Archers with a lower resting heart rate can calmly shoot between heartbeats; netball centres are able to recover faster after successive and intense bursts of activity; marathon runners can sustain a greater pace over the course of the entire race. The training principles of progressive overload and specificity are essential to ensure that these adaptations continue. Training at the appropriate threshold of intensity, as well as using the type of training needed, will specifically develop the required energy systems for a particular sport. Also, reversibility is very relevant with regard to oxygen uptake. An athlete who stops or slows their volume and intensity of training will quickly notice a decrease in aerobic and anaerobic performance. Consider an athlete following an injury, and the noticeable loss of reported fitness and endurance.

Figure 2.59 Regular aerobic and anaerobic training leads to greater oxygen uptake, which helps athletes, such as football players, sustain a high power output over an extended period.

Figure 2.60 Male and female elite athletes have significantly higher maximal oxygen uptake values than average individuals.
Nick Walshaw puts himself through the rigours of a VO₂ max test

By NICK WALSHAW
16 July 2012

Sports boffins simply refer to it as the sheet.

An unassuming slip of A4 paper which, for the best part of 18 years, has stuck to a wall here among the white coats, red lights and ping-pong machines that comprise the Australian Institute of Sport physiology department.

According to senior physiologist Hamilton Lee, present that glorious day the sheet came into being, it’s something like a sports science version of Picasso’s ‘Weeping Woman’. Or a Monet. The greatest VO₂ max test ever completed.

‘And I can still remember Cadel Evans setting it,’ he says, looking down at me collapsed in a rancid mix of my own perspiration and failure. ‘Back then, Cadel was an unknown mountain biker on scholarship here.

‘But from the moment he hopped on to this same bike, yeah, he lit it up. Produced a printout that’s never been beat. But as for yours ... ahh ... has the editor insisted you publish this?’ Sadly, he has.

He’s convinced the best way for The Daily Telegraph to unveil our 2012 Olympic team – a mob of 410 athletes which includes our reigning Tour De France champion – is to have this overweight muppet join them in final preparations.

Spending more than a month coping punches, pulling hamstrings, sweating rivers. Kicked so badly by taekwondo fighter Safwan Khalil, my beloved beer belly will stay bruised for 12 days.

But before all this, a fitness check. Which is how, after signing a declaration waiving the AIS of all responsibility should I die, this hack finds himself inside a laboratory – pedalling harder than an Indian street hawker while breathing through a snorkel-like mouthpiece.

Blood taken from my left hand every three minutes, too.

The VO₂ max test is the ultimate way of determining your motor. And it’s done by keeping an exercise bike, which increases in resistance every three minutes, around 80 revs until the point of exhaustion.

‘Like red-lining a car,’ Lee explains as, with only minutes gone, my breathing already sounds like Darth Vader’s.

‘This test, there’s none better for determining aerobic capabilities, cardiovascular fitness and ...’

Pausing, he then turns to The Daily Telegraph’s photographer, setting up a light stand nearby.

“You’d better hurry up with that,” he says. ‘I can’t see this going long.’

It doesn’t.

When Evans did this same test over 30 minutes back in 1995, he recorded that record result of 87.

‘And a quick look tells me it’s not going today,’ Lee says. ‘Although, to be fair, you are the first journalist we’ve ever allowed on this machine ... and the first I know of who’s done it in boardies.’

Not that Billabong can be blamed for what follows.

According to data, an untrained young man’s VO₂ max reading should be 45. Young untrained female, 38. Yet when I almost fall from the bike with just 16 minutes done ... well, the result is an embarrassing 35.

‘Which is good for a woman in her 30s who doesn’t get outside a lot,’ Lee laughs. ‘Of course, the other thing with Cadel was the phenomenal way he recovered. Even moments after the test was done he looked better than ... well, certainly better than you down there.’

Source: The Daily Telegraph (see www.cambridge.edu.au/icspdhe1weblinks)
Haemoglobin levels

The red blood cells (RBC) are the formed component of blood responsible for transporting oxygen. Each RBC is comprised of over 200 million molecules of haemoglobin, making up 97 per cent of its volume. Oxygen diffuses across the semi-permeable membrane in the lung’s alveoli, to be picked up by the haemoglobin in the RBC. This oxygen-rich blood is then transported to the heart, to be pumped all around the body for use in aerobic respiration.

Aerobic or endurance training leads to an increase in RBC count, and therefore total haemoglobin levels in the body. This increased oxygen-carrying capacity will enable the athlete to maintain a higher average pace and power output, as the body can increase its oxygen uptake. Haemoglobin levels can be increased by over 20 per cent as a response to training.

Such is the advantage of increased haemoglobin levels that athletes and sports scientists have spent considerable time, effort and money to discover ways of naturally and artificially increasing an athlete’s RBC count. The illegal use of artificial erythropoietin (EPO), which is derived from a naturally occurring hormone in the body that stimulates RBC production, has received much media attention over the last decade, particularly in the Tour de France. Blood doping, using either the athlete’s own or donor’s blood to temporarily increase RBC count, is another illegal method used in endurance sports. Legal methods include training in a hypoxic environment, where oxygen concentration in the air is low. This stimulates the body to increase RBC production to account for the lower levels of oxygen available in the air. This can be achieved by either training and living in a high-altitude location, or by spending time in an enclosed hypoxic tent that mimics these conditions.

While the effect is temporary, the effect can provide a distinct short-term advantage to an endurance athlete.

Generally, aerobic training can increase haemoglobin levels by over 15 per cent. However, increased blood viscosity (thickness or density) from higher concentrations of red blood cells...
is offset by an increase in total blood volume – particularly blood plasma, which is the liquid component of blood.

**Muscle hypertrophy**

Many athletes and non-athletes desire bigger bodies and increased musculature. Maintaining strong muscles is also an important contributor towards healthy ageing, and many older adults are encouraged to participate in regular and safe resistance training. However, increasing the actual size of a person’s body requires a very disciplined, demanding and regular training program, aimed at stimulating the muscles in such a way that they are forced to grow in order to cope with the training stimulus. Many people participate in forms of resistance training that do not necessarily lead to increased muscle size, but do increase the tone of their muscles and improve muscular endurance. Similarly, aerobic or endurance training, which may increase the tone of muscles and their definition by decreasing body fat and increasing the appearance of lean body tissue, will not have a hypertrophic effect on the body.

Specific resistance or weight training targeted towards increased muscular bulk and strength leads to specific changes within a muscle’s structure, as well as other related body systems:

- The stimulation of the nerves that innervate a particular muscle increases their ability to quickly stimulate a muscle to contract, which is known as their excitability.
- Connective tissues, such as the tendons and bone attachments that enable a muscle to move a particular limb, are thickened and strengthened to prevent injury. This also leads to increased bone strength and density, which is why strength training is so important for adults of all ages.
- Within the actual muscle, increased size and amount of muscle cells relate to increased cross-sectional thickness, not length. Actin and myosin filaments, which produce the sliding or contracting action of muscles, increase their mass, leading to the hypertrophy of the muscle fibres.
myofibrils, the elongated contractile threads that make up skeletal muscle and give it its striated (or striped) appearance.

A number of principles of training stand out as being essential for muscle hypertrophy:

- **Progressive overload.** This is a fundamental requirement for hypertrophy. The muscles must work harder than they are accustomed to doing. This means training has to be sufficiently challenging to force the muscles to have to adapt to the increased load being placed upon them. For example, if an athlete could comfortably bench press a set weight eight times, the load should be increased slightly until it is very challenging to complete eight reps without some minor assistance in the last rep. This process must occur gradually to prevent injury. Also, training must maintain regularity, with each major muscle group exercised at least once or twice each week.

- **Specificity.** If an athlete is training for a particular sport, the movements and muscles trained should relate to the sport. For example, a shot putter must have significant development around the shoulder girdle, leading to variations of bench and shoulder presses being important movements. Specificity also relates to the design of training programs. In short, training should consist of heavier weights and lower repetitions. If the load is too light, muscular endurance will be increased without noticeable increases in the size of muscle.

- **Variety.** Muscles quickly become accustomed to a particular training regime, and gains will slow or plateau if a variety is not evident within a training program. Athletes should use a variety of exercises that stress a muscle from different angles. For example, bench presses should be completed on inclined, flat and decline benches, as well as the athlete doing flies and dumbbell presses to more fully develop the pectorals. Programs should be gradually altered every four to six weeks to produce continued growth.

- In addition to this, thorough **warm-ups** are necessary and **reversibility** will quickly set in, as evidenced by muscle **atrophy** and loss of strength. It is worth noting that an athlete’s ability to increase muscle size is largely genetically determined. A higher degree of fast-twitch muscle fibres, which are more suited to power based sports, will enable increased growth as they have a greater capacity to increase in size than slow-twitch muscle fibres. Also, higher levels of testosterone produce an androgenic effect on the body, where it has a greater capacity to grow. This is why males who have higher rates of testosterone are able to build more muscle. A person’s body shape, known as their somatotype, will also determine the degree to which a person is able to increase muscle bulk. A mesomorphic body shape, which has a strong genetic disposition, will enable greater gains from heavy resistance training.

### Effect on fast/slow-twitch muscle fibres

There are **TWO** major types of muscle fibres found in muscle tissue:

- **slow-twitch muscle fibres (ST)** – also known as type I or red muscle fibres
- **fast-twitch muscle fibres (FT)** – also known as type II or white muscle fibres.

It is now commonly recognised that FT or type II can be further categorised into:
Background information on muscle fibres

The muscle fibres that make up a single muscle – for example, the biceps – are individually stimulated to contract by a particular neuron or nerve, which is known as a motor unit. The number of motor units fired depends upon the actual movement and the intensity of the activity. The motor unit recruitment theory suggests that for low-intensity work, ST fibres are recruited first, followed by FT as the stimulation increases due to a greater intensity of effort. Therefore, the human body has a complex ability to switch on and utilise only the minimum amount of muscle fibres needed to produce a set movement. It can therefore distinguish which particular muscle fibres should be used, depending upon the intensity of the effort.

Because each type of muscle fibre has unique characteristics and capabilities, this makes them more advantageous or useful in specific situations or at particular intensities of activity, as the body can utilise the fibre type that is best suited to the particular activity. However, it is recognised that the composition or individual makeup and percentage of each muscle fibre type is predominantly genetic – a hereditary and non-modifiable individual characteristic. The most accurate way to assess an individual’s muscle fibre composition is to take an invasive muscle biopsy to be examined under a microscope. Some tests have been developed that can be used as a predictor of muscle fibre composition. One such test is described below.

Establish the 1RM (the greatest weight that they can lift just once) of an athlete performing a particular movement (extreme caution should be exercised here due to the high exertion required). They should then perform as many repetitions at 80% of 1RM as possible.

- If more than 12 repetitions can be performed, then the muscle group has more than 50% Type I ST fibres.
- If less than 7 repetitions is all that is possible, the muscle group is likely composed of greater than 50% Type II FT fibres.
- If the athlete can perform between 7 and 12 repetitions, the muscle group most likely has an equal proportion of fibres. (Pipes, 1994).

Karp, J.R, Muscle Fiber Types and Training, Track Coach #155.

Another way to indirectly determine a person’s muscle fibre makeup (especially a younger person) is to review the range of sports at which they excel, comparing activities of varying activities from longer distance endurance events to more explosive maximal events. Strengths in a particular area will possibly indicate the person’s compositional makeup.

- **type IIa** – an intermediate fibre, displaying characteristics of both slow- and fast-twitch muscle fibres, where specific training can make it seem more like either ST or FT fibre
- **type IIb** – a more pure or classic fast-twitch fibre suited to maximal power production.

Slow-twitch muscle fibres

These are also described as red muscle fibres because of their high blood supply, being provided by the increased number of blood capillaries present (which can be seen in Figure 2.73, where the ST fibres are darker in colour). This increased...
surface area allows for greater gaseous exchange – primarily oxygen into the working muscle and carbon dioxide removal. As a result, type I ST muscle fibres are adapted to use oxygen more efficiently and work aerobically. They contract slowly and release energy gradually as required during endurance activities over a longer duration, such as jogging, cycling or swimming. They are more efficient in the use of fats as a fuel source during exercise at a comfortable steady pace. This promotes glycogen sparing and conservation, in preparation for periods of higher intensity efforts. They are fatigue resistant at submaximal intensities; however, overall power output is low.

Sports that are better suited to athletes with higher percentages of ST fibres include:
- marathon running
- long-distance swimming
- ultra-ironman triathlons.

Key characteristics of type I ST muscle fibres (in comparison to type II FT muscle fibres) are:
- a greater number of capillaries and therefore blood supply, promoting greater oxygen supply
- the metabolisation of ATP at a slower rate
- increased amounts of mitochondria, the organelle in muscle cells responsible for aerobic energy production
- increased amounts of myoglobin, which plays a similar role to haemoglobin in storing and transporting oxygen within the cell to the mitochondria for aerobic respiration and energy production
- increased amounts of oxidative enzymes to assist with aerobic energy production.

Obviously, aerobic-based endurance training will have the greatest impact upon type I ST fibres.

Specific physiological adaptations in response to aerobic training include:
- an increase of over 15 per cent in the number of muscle capillaries
- increased myoglobin stores to support the increased oxygen supply
- increased size, efficiency and amount of mitochondria, accounting for greater aerobic capacity
- some increase in hypertrophy, often seen as an increase in lean muscle mass and tone.

Fast-twitch muscle fibres

These are often described as white muscle fibres. Because type II FT fibres largely rely on anaerobic pathways – that is, without the need for oxygen – the body does not need to supply these fibres with a rich source of blood and oxygen – hence the difference in colour between the two types:

FT fibres have significantly greater power and force production, with greater resistance to short-term fatigue during anaerobic activities. However, if the activity lasts for more than a minute or so, these fibres fatigue quickly due to the decreased oxygen supply.

Sports that are better suited to athletes with higher percentages of FT fibres include:
- sprints (100 to 400 metres)
- shot put
- weightlifting.

Key characteristics of type II FT muscle fibres (in comparison to type I ST muscle fibres) include:
- fewer capillaries (therefore blood and oxygen supply) and fewer mitochondria
- more fuel for anaerobic energy pathways, namely creatine phosphate and ATP
- the metabolisation of ATP at a faster rate
- increased amounts of glycogen
- larger motor units and neurons that stimulate FT fibres, capable of faster and more powerful stimulation, described as increased excitability and contractility.

**Going further 2.14**

**Communicate**

There are two major types of muscle fibres – red and white.
1. Why do you think they are described in this way?
2. Based on this answer, make some assumptions about each type of muscle fibre’s possible features, characteristics and capabilities.
3. Share your thoughts with another person, and then with the rest of the class.
• increased glycolytic enzymes to assist with the fast metabolism or breakdown of glycogen in the absence of oxygen. Training methods that target FT fibres depend upon the specific nature of the sport. Medium to heavy resistance training, aimed at increasing power, strength or muscle bulk, will lead to specific adaptations. Likewise, anaerobic training, using short intervals where anaerobic pathways are utilised, will also lead to development of type II FT fibres.

Specific physiological adaptations in response to anaerobic training (either resistance or short intervals) include:

• increased stores of ATP, creatine phosphate, glycogen and glycolytic enzymes, all leading to increased production of ATP from anaerobic energy pathways 
• increased synchronisation and coordination of motor unit recruitment, leading to increased neural activation, and therefore greater force and power production
• considerable potential for muscle hypertrophy with specific training programs, focusing on heavy resistance training
• greater tolerance to increased muscle acidity and more efficient lactate clearance
• some increase in hypertrophy, often seen as an increase in lean muscle mass and tone.

As mentioned earlier, type II FT fibres can be categorised into either type IIa or type IIb. Type IIb is a purer or more classic version of fast-twitch muscle fibres, and the previous description is very accurate for these. However, type IIa requires some further explanation.

These are often described as intermediate fibres, because they contain characteristics of both fast- and slow-twitch muscle fibres. They have increased capillary supply and mitochondrial function compared with type IIb fibres, but also an increased amount of anaerobic capacity compared with type I fibres. They can produce higher power outputs over a longer period, and can recover in shorter amounts of time due to their increased oxygen supply. From a training perspective, type IIa fibres will respond specifically to the type of training being performed. Therefore, they take on characteristics and capacities of either type I ST or type IIb FT, depending upon the training stimulus. For this reason, they can be described as being interchangeable, capable of enhancing either the aerobic or anaerobic power of the athlete. People with higher percentages of type IIa fibres are very adaptable athletes, who succeed in sports that require a mix of both energy systems, such as AFL, netball and general classification cycling, where riders must have endurance to climb mountains as well as ride fast in a time trial.

Another interesting feature of the human body’s muscle fibre composition is the difference in the various muscle groups in the body. Postural and supportive muscles that are consistently used in everyday activities are more ST in profile – for example, core abdominal muscles (transverse

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**Going further 2.15**

**Communicate**

Review the article on building a Tour de France-winning body on the SBS website (see [www.cambridge.edu.au/hscpdhpe1weblinks](http://www.cambridge.edu.au/hscpdhpe1weblinks)) and summarise the ideal muscle fibre composition of a Tour de France rider. Then, for a selected sport, describe the ideal muscle fibre composition.

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**Going further 2.16**

**Collaborate**

In small groups and on a large piece of paper, select a sport or famous athlete. Make links between this sport or athlete and the syllabus dot points. Use the mind map in the figure below as a guide. Some research may be required. Aim to include as much information and examples as possible to make your understanding of the syllabus content visible.

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abdominus) and calf muscles (soleus). Leg muscles such as the quadriceps (rectus femoris) and shoulder muscles (deltoid) are typically used for more powerful movements, so are more FT dominant.

See the following articles on athletes who are particularly well suited to their sports:
- ‘Butterfly king: Michael Phelps’ reign explained’, The Telegraph, (see www.cambridge.edu.au/hscpdhpe1weblinks)

**Summary 2.17**

Outline the physiological adaptations that occur to the following in response to training:
- resting heart rate
- stroke volume
- cardiac output
- oxygen uptake
- lung capacity
- haemoglobin level
- muscle hypertrophy
- fast-twitch muscle fibres
- slow-twitch muscle fibres.

**Checklist 2.18**

Describe the relationship between the principles of training, physiological adaptations and improved performance.
2.2 The impact of psychology on performance

**Driving questions 2.19**

‘Make sure your worst enemy doesn’t live between your own two ears.’ Laird Hamilton

1. How important do you think a player’s psychological state is in determining success?
2. Identify examples of when mental strength either won or lost a game. Do you think you can ever win without being mentally strong?

**Motivation**

A unique feature of the sporting environment is the high degree of competitiveness and public exposure – something with which most people do not have to deal on a day-to-day basis. Highly motivated athletes train more intensely and are more driven to succeed when competing. The critical nature of motivation is most clearly evident when an athlete is suffering from a lack of motivation, where they may:

- seem generally unhappy, distracted and less interested in training or competing
- be unable to push themselves to the same degree during high-intensity training
- experience a decrease in performance level
- be experiencing strained relationships with those around them
- be experiencing higher degrees of anxiety and stress.

Sometimes athletes are unaware of declining motivation levels until their performance starts to suffer. They may find it difficult to measure, assess and increase their own motivation. Coaches and sports psychologists can play a significant role in helping to establish healthy thought patterns and motivational factors that can lead to increased motivation.

A wide variety of incentives and disincentives can lead to increased motivation of an athlete. All athletes have unique personalities, and therefore respond in a different manner to these. Coaches need to be sensitive to the individual athlete, and to ensure the motivational factors driving the athlete will have the greatest impact. This can be particularly challenging in a team situation, where different personalities exist. This can be a source of frustration for athletes, even prompting them to seek a different coach or team they feel will be more beneficial for their development.

**Positive and negative motivation**

There are two broad types of motivational factors: **positive** and **negative motivation**. Positive factors instil a sense of drive in an athlete to achieve their goals, because of the variety of positive outcomes that could result from success. These could include:

- financial rewards
- representative team selection
- the desire to win the gold medal or grand final
- the adoration of fans
- a renewed and improved contract
- a competitive desire to beat all others and win for personal satisfaction
- a drive to achieve a personal best and to fulfil their potential.

Negative factors act as a deterrent, and often will compel an athlete to greater efforts for fear of the negative outcome. These could include:

- being dropped from the team or losing a contract
- losing and suffering the perceived humiliation or embarrassment of defeat
- not achieving what they believe to be their full potential
- threats by the coach to do extra or more intense training sessions.

Like most people, athletes generally respond more favourably to positive motivation throughout life. However, there are times where negative motivation can be used as a powerful force to drive an athlete towards success. This can vary between individuals, and coaches must be aware of the situation so motivational factors can be used most appropriately.
Summary 2.20

1 Write some examples of self-talk mantras that an athlete could habitually repeat to themselves to positively increase motivation.

2 Classify the following examples into the categories below:
   - praise from coach, offer of a bigger contract
   - fear of not getting a renewed contract
   - fear of being dropped from the team
   - winning gold
   - worried about disappointing family
   - desire to win
   - satisfaction of achieving personal best
   - fear of not living up to expectations of supporters
   - fame and popularity.

   **Positive/intrinsic**
   - praise from coach, offer of a bigger contract
   - winning gold
   - satisfaction of achieving personal best
   - fame and popularity.

   **Negative/intrinsic**
   - fear of not getting a renewed contract
   - fear of being dropped from the team
   - worried about disappointing family
   - desire to win

   **Positive/extrinsic**
   - satisfaction of achieving personal best
   - fame and popularity.

   **Negative/extrinsic**

3 Analyse your current motivations for your efforts in the Higher School Certificate. What types and source of motivation could you take on board that would drive increased commitment and efforts in your studies?

Checklist 2.21

Evaluate performance scenarios to determine the appropriate forms of motivation – for example, golf versus boxing.

Intrinsic and extrinsic motivation

There are also two sources of motivation: **intrinsic motivation** and **extrinsic motivation**. The internally (or intrinsically) motivated athlete is almost self-propelled towards success and hard work. They have personal goals, expectations and fears that drive their efforts and commitment. These motivating factors are intensely personal, and are often driven by an athlete’s high level of competitiveness and desire to succeed and win.

Extrinsic goals can be either positive or negative in nature. It is advised that athletes should focus more on extrinsic goals from a reliable and controlled source, such as a coach. While playing for the adoration of a crowd can be a powerful influence to play hard, negative feelings of embarrassment may follow if the support stops or turns negative. This can lead to other psychological barriers to successful sporting performance, such as increased anxiety.

Sports psychologists generally aim to empower athletes to be able to monitor and positively influence their own levels of motivation. By setting personal goals and positive incentives, the athlete is able to remain focused and is driven to work hard. A key aspect of developing this power is for the athlete to closely observe and control their self-talk, to ensure their thought patterns are positive and beneficial.

Anxiety and arousal

Trait and state anxiety

The immense pressure an athlete faces during elite competition can challenge the athlete’s mind almost as much as the physical demands of the sport. Even as spectators and fans watch their favourite athletes and teams compete, they can feel the pressure, with increased feelings of anxiousness and nervousness, as well as increased heart rate, breathing and body temperature. However, these
Chapter 2

Fact ors Affecting Performance

state anxiety
feelings of anxiety related to a specific game or event

trait anxiety
the genetic predisposition and proclivity an athlete has towards increased anxiousness and nervousness

challenges can extend beyond the game, as the athlete may have to deal with feelings of anxiety outside of competition. If dealing with anxiety becomes a daily struggle, then athletes are as exposed to mental health disorders, such as anxiety and depression, as any other person.

Increased anxiety levels can be detrimental to the performance of all athletes. There are two categories of anxiety that athletes will need to learn to handle: state anxiety and trait anxiety.

All people have unique and individual personality characteristics. Some people may carry greater levels of anxiety throughout life, over any number of daily events. For athletes with higher levels of trait anxiety, the increased pressure of elite competition can present an even greater mental obstacle to success.

The nature of competition inherently leads to increased pressure on the athlete to perform to the best of their ability. Some sports place a great deal of pressure on an athlete to perform very precise movements with only a small degree of error allowed, such as shooting and archery. In other sports, there are certain aspects where the pressure on the athlete increases, such as a free throw in basketball. Success is entirely reliant on the athlete being able to control their nerves and execute the skill accurately. In all sports, state anxiety will increase as the level of competition rises, eventually culminating in either a grand final or a gold medal match. In a situation where an athlete has to execute a single skill that they have practised for four years leading up to the Olympics, only the most controlled and focused athletes will be able to prevent state anxiety from impacting upon their performance.

Both state and trait anxiety can negatively impact upon performance. Some of the signs that athletes report when suffering from increased anxiety include:

• feelings of ‘stomach butterflies’, even to the point of vomiting prior to competition
• constant feelings of tension and being unable to relax, which can lead to increased feelings of fatigue

Going further 2.22

Communicate
Is anxiety something with which all elite athletes have to deal, or is it more likely that elite athletes have reached such a high level of success because of an innate or natural ability to deflect or even not suffer from anxiety? Discuss this as a group.

Going further 2.23

Create

1 Reflect on the times you have felt the most nervous and anxious. Share with the class how this felt, and describe the impact it had on your state of well-being and ability to perform under pressure.

2 Watch some sports footage, where an athlete had to remain focused and the pressure to perform was immense, but ultimately they failed (in colloquial terms, choked). Write a mock journal entry about the thoughts this athlete may have been having prior to executing the unsuccessful skill, and the thoughts immediately after. Discuss the impact that this may have on similar situations in the future, and make some suggestions about how these could be minimised.
prior to a game, feeling very twitchy – their legs may seem uncontrollably shaky or they may pace around the room
• muscles becoming tense, leading to increased errors. This can happen during the match as the competition increases. This is particularly evident in tennis, as a player struggles to serve out a match, or during a penalty shootout in soccer.
• having more negative thoughts and doubts about their own ability, leading to decreased confidence and self-belief.

All athletes – particularly those who suffer more from trait anxiety – identify factors that lead to increased anxiety, become skilled in recognising the signs and feelings of increased anxiety (both in and out of competition) and develop strategies and techniques to help manage these (which are discussed below).

Sources of stress

Stress is a natural part of human existence, and is closely linked to the pressures associated with the competitive sporting environment. All athletes respond to stressful situations in unique and individual ways, which are associated with their level of trait anxiety. Positive stress caused by exciting circumstances, such as bungy jumping, is called eustress. However, stress caused by undesirable threats is called distress. Excessively elevated levels of cortisol, the hormone released in response to stress, are linked with a range of health conditions such as heart disease. Often people will say that they perform best when there is a small amount of stress, as it compels them to action. An example of this is an upcoming exam, which will motivate a student to study. There are many internal and external sources of stress.

Handling stress is a normal part of everyday life. However, experiencing excessive and long-term stress can have many negative personal and performance effects on an athlete. Because of
the nature of the competitive environment and professional sport, athletes must develop skills in recognising and dealing with stress. Internal sources of stress relate to a person’s personality. Some people tend to stress and worry more about everyday events, whereas others are more relaxed and calm. Feeling threatened – such as the fear of being dropped from a team – can increase stress. External sources of stress could include threats by coaches about the negative consequences of a poor performance, or losing sponsorship, or not having a contract renewed. The fear of losing and performing in front of large crowds is another source of stress with which athletes must be able to deal. There are many strategies and techniques that an athlete can practise and utilise to help them handle the stress of a situation. These skills empower an athlete to take more control during high-pressure events. These are discussed in the next section.

Optimum arousal

All sports require athletes to be in a certain mental state and condition prior to competing. This differs between sports, and athletes also present with individual differences in their mental state during the final moments prior to competing. Research has found that different tasks require different levels of arousal for optimal performance. For example, difficult or intellectually demanding tasks may require a lower level of arousal (to facilitate concentration), whereas tasks demanding stamina or persistence may be performed better with higher levels of arousal (to increase motivation).

Going further 2.24

Inquire

‘Prior to the event, the athlete was so pumped up – totally psyched and buzzing around the room – ready to take on and conquer all. They seemed so confident, almost to the point of arrogance.’

1 What images came to mind when reading this?
2 What sport did you associate with it?
3 Do all elite athletes have to be in such a state to ensure success?
4 If you answered no to the previous question, what is different about the sport that would indicate this?

The arousal level of an athlete can play a significant role in determining success. Adequate preparation of the athlete for the impending event involves physically preparing the athlete, as well as achieving this specific level of arousal. This relationship is demonstrated in the theory commonly known as the inverted U hypothesis. Yerkes and Dodson (1908) originally considered the relationship between arousal and performance. The Hebbian version of this suggested a specific point of arousal where performance was optimised. Later developments of the theory in relation to sport suggested that, rather than a precise point of optimum arousal, a broader zone exists that takes into account individual differences and natural fluctuations of this optimal arousal to suit the task ahead. This is demonstrated in Figure 2.80.

When an athlete who is about to compete is suffering from arousal levels that are either too high or too low, they are less likely to be able to reach their full potential. They must be able to assess and adjust their arousal levels both leading up to an event and during the event. Specific psychological skills can be employed at this point to either increase or decrease arousal (discussed in the next section).
High levels of arousal are suitable for sports that are either very physical or combative in nature, such as Rugby Union, boxing and weightlifting. Sports that generally demand lower levels of arousal, such as shooting and archery, require greater levels of control and concentration. It is also recognised that athletes actively learning the basic skills and tactics of a sport require lower levels of arousal. Being over-aroused in this situation can lead to decreased concentration and attention. As the athlete develops towards being elite, they are able to effectively use higher levels of arousal to their advantage. This is described in Figure 2.83.

**Psychological strategies to enhance motivation and manage anxiety**

The importance of a strong and focused mind in sport is now widely recognised. Many professional coaches and athletes believe that the awareness of one’s state of mind, as well as a range of effective strategies to mentally prepare for competition and maintain self-belief, can be the difference between winning and losing. This is most clearly evident in the case when the world’s best are in the heat of battle, where the physical characteristics and skill levels are evenly matched. Consider a play-off in golf between the world’s number 1 and 2 ranked players at a major tournament such as the US Open, or a penalty shootout at soccer’s World Cup.

To ensure athletes are adequately prepared for elite competition, coaches and managers will employ the expertise of a sports psychologist, to develop a close relationship with athletes and to help individual athletes recognise potential problems with their current level of motivation, arousal levels, anxiety and stress, especially while competing. Once these are identified, a range of psychological skills can be developed and practised, to help achieve even greater performances in competition. By helping the athlete enhance their motivation and manage anxiety, they increase the likelihood of improved performance.

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**Going further 2.25**

**Inquire**
Imagine a coach asking an athlete whether they are ‘switched on and ready’. They are essentially asking them whether they are in the right state of mind to rise to the occasion and compete.

1. Are their arousal levels at the optimum level?
2. Imagine the response of a Rugby League player compared with an archer. How would each of these athletes feel if they said ‘no’?
3. What advice would you give to each athlete to either increase or decrease their arousal level?

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*Figure 2.82* Archery demands a lower level of arousal

*Figure 2.83* Sport-specific optimal levels of arousal

*Figure 2.84* An athlete’s mental preparation strategy can be the difference between winning and losing
Concentration/attention skills (focusing)

The ability to maintain concentration for an extended period of time can be challenging. A range of external and internal factors can distract someone from the task on which they are currently focusing. All physical skills require cognitive processing. This could be to:

- read and filter cues received through the five senses into relevant and irrelevant categories
- read and interpret the movement and tactics of opposing players
- be able to make correct decisions that complement the execution of a particular game plan.

Athletes are able to execute many routine skills automatically, with minimal concentration and specific thought. This is achieved through years of training to practise and refine motor patterns. However, the basketballer who executes a technically correct pass that is intercepted because of a poor read of the opposition’s movements has failed to accurately focus on the relevant cues and make a correct decision. Athletes must maintain their concentration and attention on relevant cues, and be able to ignore cues that are largely irrelevant. All sporting scenarios present a unique challenge to the athlete when it comes to maintaining the correct focus.

Generally, successful athletes are able to focus more on the process and actual movement skill or team tactic to be executed, and ignore the factors that do not have a direct impact or relevance to the actual execution. This is particularly important prior to executing skills performed in a more stable and static environment, such as a penalty shot, free throw or conversion. However, in these moments the athletes will be more acutely aware of their thought processes, and are more likely to have to combat thoughts of doubt, fear and anxiety. The athlete must be able to stay positive and confident, focus only on the relevant cues and information, and be able to block and ignore the factors that are irrelevant to the impending skill to be performed.

Another aspect of concentration and attention is the unique situation where an athlete enters a state of total immersion and focus on the play around them. This is a very satisfying experience that is unique to experienced athletes, where the skill execution itself is second nature. While analysing and moving in a very dynamic and competitive environment, they make decisions and execute skills with little conscious thought. This is evident in soccer, when a team makes a number of quick and successive passes through opponents to score.

**Summary 2.26**

1. What are trait and state anxiety?
2. What are some sources of stress?
3. What is the optimal arousal zone?
4. What are indicators of under-arousal?
5. What are indicators of over-arousal?

**Going further 2.28**

**Inquire**

Reflect upon your level of concentration right now, in class.

1. Is it adequate to learn?
2. How does it compare with another lesson from today?
3. What are some of the factors that support your concentration and act as barriers to staying focused?
4. How much responsibility do you take for the level of concentration and focus you have in class?
5. How could you increase this to enhance learning?

**Checklist 2.27**

1. Explain the difference between anxiety and arousal.
2. How does this affect performance?

**Going further 2.29**

**Collaborate**

In small groups, identify a range of common sporting scenarios that demonstrate each of these aspects of an athlete’s focus.
Players involved are reading the movements of both opponents and team-mates, and making instantaneous and complex decisions on their next move, then executing them with amazing timing and accuracy.

Mental rehearsal/visualisation/imagery

Most professional athletes and coaches recognise the value and power of being mentally strong, even in sports that primarily seem to be physically based, such as weightlifting. Being able to control doubt, fear and anxiety while remaining centred and focused can provide the edge required for victory. Both real and fictitious imagery created in the mind can help athletes achieve both these goals. Athletes can use their imagination and visual memory to improve performance. Two major types of imagery used are mental rehearsal and visualisation. If practised and properly performed, mental rehearsal is a powerful psychological skill and phenomenon that can be used to a player’s advantage, increasing the likelihood of success. It allows the athlete to experience the skill before it has actually occurred. It is most useful for self-paced skills that are under the total control of the athlete. Such sports include golf, archery, long jump, shot put, diving and gymnastics vault. These opportunities also exist within dynamic sports such as a free throw in basketball or a conversion kick in Rugby League.

Athletes should practise this skill in training, to ensure they are able to effectively execute it in the competitive environment. Some key guidelines are:

- The skill should be performed from the athlete’s point of view, as in the first person.
- They should always be successful.
- The skill should be visualised in real time, from start to finish.
- Once rehearsed, the athlete should attempt the skill without delay for maximum effect.

Athletes who routinely use mental rehearsal report decreased anxiety and greater confidence. It also assists them to focus on the skill while ignoring distractions such as their own negative thoughts and heckling from the crowd. One of the greatest benefits of mental rehearsal is the effect it has on the neuromuscular system. Elite athletes have highly refined motor patterns, which helps account for their incredible consistency in skill execution. Effective mental rehearsal stimulates this precise motor pattern, without resulting in the actual movement being rehearsed. Athletes report being able to almost ‘feel’ this sensation throughout their bodies as they prepare to perform.

While also involving role-play and imagining specific mental scenarios, visualisation differs from mental rehearsal primarily through the lack of reality that can exist in the mental image. This depends upon the desired psychological outcome the athlete desires in preparation for competition.

If an athlete were trying to relax, decrease anxiety or arousal levels and trying not to think too much about the impending intensity or stress of competition, they could focus on an image or scenario that calmed them down and allowed them to focus on something unrelated – for example, imagining relaxing on a secluded island in the warm sun and the smell of the sea.

Going further 2.30

Create

Watch video footage of athletes executing set skills under relatively controlled circumstances, while having to handle intense mental pressure.

1. What are the relevant cues that demand attention, and what are the irrelevant cues that need to be ignored and blocked from the athlete’s immediate attention?

2. What strategies are employed to assist these athletes in such circumstances?

3. Famous last words: What are the ‘top five worst thoughts’ a coach wants their athlete to think of prior to taking the final set shot to win the grand final? Replace these with thoughts that complement and enhance the concentration of the athlete.

Going further 2.31

Communicate

Reflect on and share personal anecdotes where you have experienced this ‘Zen’-like state of flow, as you achieved your most memorable feats in sport. These are as common in the playground as they are in the Olympics.
sun. Anything that promotes feelings of calm and relaxation could be used for this.

However, if the athlete were seeking to increase confidence and arousal levels, a more stimulating visualisation would achieve this – for example, imagining performing incredible feats such as winning gold, scoring a miracle goal or making a ‘crunching’ tackle would allow an athlete to feel almost invincible. While this may seem to lead to an ‘inflated ego’, a positive impact can be found in the increased confidence and arousal for intense and combative competition.

A unique feature of visualisation is that it can be used while actually performing or training to increase the intensity of effort. An athlete running on a treadmill could imagine that they are running in front of their home spectators in an Olympic Games final. By creating a scenario and role-playing it to ensure incredible success, the athlete can push their body to greater heights as they ignore feelings of pain and fatigue. Some key guidelines for visualisation include:

• It should be practised and rehearsed away from actual competition, prior to using it before or during competition.
• Most images should be from the perspective of a spectator – that is, in the third person.
• Success should always be evident in sporting visualisations.

Athletes should become aware of the specific physiological impact of certain visualisation techniques, and ensure that they do not over-compensate for the desired effect. For example, relaxing too much could lead to feelings of tiredness or lack of focus, whereas an athlete may become over-aroused, leading to decreased performance. Athletes need to be aware of anxiety levels, emotional levels, heart and breathing rates as well as feelings of nerves, sweating, or tiredness and lethargy.

Relaxation techniques

The ongoing and intense stress of elite competition can lead to decreased performance, burn-out and the loss of desire to compete. It could possibly even contribute to the development of a mental health condition, such as depression, if left unchecked. Specific relaxation techniques play a major role both in and away from the competitive environment. Generally, methods of relaxation are used while the athlete is sensing increased feelings of stress, anxiety and arousal prior to or during competition.

The use of calming and relaxing music can take the athlete’s mental attention away from distracting and negative thoughts that could be flooding their mind. It can also help them to zone away from outside distractions and noise, allowing them to focus their thoughts on the upcoming performance. The chosen music should lead to feelings of relaxation and focus. If music is used while an athlete is training, such as on a long training ride, the athlete should not develop an over-reliance on this mental distraction, as it is most likely not permitted during actual competition, where the athlete will not be able to use music to distract them from feelings of fatigue.

The conscious use of controlled and rhythmic breathing is an effective way of calming an anxious athlete, especially if they are physically reacting to high levels of state anxiety. It can provide a single point of focus and concentration. An athlete could be mindful of the feelings of the cool air rushing in and warm air being exhaled through the nose and mouth. When coupled with visualisation, the athlete is able to directly affect their levels of anxiety and arousal. Some athletes may even use a specific aromatic smell, such as the menthol in a warm muscle rub, to increase arousal and alertness, by stimulating the limbic system of the brain. Alternatively, smelling certain essential elements such as lavender can help calm and relax an athlete.

Meditation based on Oriental practices such as yoga and tai chi, or more sensory-based meditations focused on the feelings of warmth and heaviness of the body, can help athletes relax and escape from the stressors of training and competition. These can be done privately by listening to a podcast or in a group led by a trained instructor. These are often accompanied by music and aromatherapy, and some athletes describe these sessions as essential for helping them maintain good mental health and well-being.

Going further 2.32

Collaborate

Students need to be divided into three groups:
• practical practice-only group
• mental rehearsal-only group
• combined practical and mental rehearsal group.

Students are to spend a set amount of time engaged in practice of a common sporting skill using their given practice method. Discuss the experiences of each group following five executions of the skill following the practice period.

Students are to spend a set amount of time engaged in practice of a common sporting skill using their given practice method. Discuss the experiences of each group following five executions of the skill following the practice period.
A popular method of relaxing both the mind and body is Jacobson’s progressive muscle relaxation technique (PMR), first devised in the 1920s. This is a proven method to decrease an athlete’s perceived levels of anxiety, and has even been reported to help decrease the effects of certain physical ailments. Biofeedback research demonstrates the positive effect of PMR in decreasing heart and ventilation rate, as well as brain activity and stress. Similar to meditation, it helps provide a narrow focus point, concentrating on feelings of relaxation. In a quiet environment, the athlete closes their eyes and follows a two-step process:

1. Increase the tension of a specific muscle by performing a gentle isometric contraction.
2. After a few seconds, release the tension and contraction and focus on the feeling of relaxation in the muscle.

This is repeated throughout the body on different muscles. PMR can be performed both in and outside of competition.

Goal-setting

Elite athletes are highly driven individuals, who aim to be the absolute best that they can be. The commitment and efforts made during training to fully prepare themselves for competition are arduous and highly taxing, both physically and mentally. Only the most dedicated and self-disciplined of athletes generally go on to achieve greatness.

Consider the following example of a typical training day for an ultra-triathlete:

- Wake up at 4:30 am every morning.
- Each Monday, Wednesday and Friday, swim from 5 am until 7 am.
- On Tuesdays, Thursdays and Saturdays, bike ride instead.
- Each week, swim around 30 kilometres, ride about 800 kilometres and run about 120 kilometres.
- Have a midday sleep before going for an hour’s run in the afternoon.
- Go to sleep by 9:30 pm.

An athlete’s drive, motivation and enthusiasm for training naturally vary; however, it is evident that such training requires the strictest self-discipline and commitment. To assist with this, effective goal-setting can be invaluable in helping athletes stick to strict training regimes and continue to produce the physical efforts required to achieve success and improved performances. Goals are important to help keep athletes accountable to a previously established expectation or standard, and the athlete may have several goals in place at any one time in relation to a range of lifestyle, training and performance factors. These could include the following:

- **Nutritional goal** – adhering to a set nutritional plan as established by a dietician
- **Lifestyle goal** – avoiding alcohol or ensuring that the athlete is asleep by a set time on most nights
- **Training goal** – completing a set volume of training in a set time, such as 40 kilometres of swimming per week
- **Performance goal** – winning gold or finishing the season in the top four

Going further 2.33

**Inquire**

1. What is the difference between attitude and behaviour? Which factor drives the other? How could athletes use this to their advantage? How could a student use this to their advantage? How does a person change their attitude?

2. Reflect on the current goals you have in your life.
   - If you do have a current goal established, what influence does it have on your behaviours and attitude?
   - If you don’t have any identifiable goals, to what extent do you think this could be influencing your current attitude and behaviours?

3. Discuss these reflections and consider the role of goal-setting in helping to guide attitudes and behaviours.

Going further 2.34

**Communicate**

Interview or invite a former or current elite athlete as a guest speaker, to discuss the strategies they use to enhance their motivation and manage anxiety. Students should establish set questions based on the PDHPE syllabus, to identify specific examples of these psychological principles in action.
A number of people should be aware of an athlete’s particular goals, such as their sports psychologist, coach and family. This increases the accountability and likelihood of success. Also, goals should be kept visible, to act as a constant reminder of the intended aim. For example, a poster on a wall, an image as a screen-saver on a phone or writing something on a piece of tape wrapped around the wrist can all serve as such reminders.

A common acronym to help establish effective goals is to use the principles of SMARTER:

- **Is the goal** specific? Goals should be explicit and clearly defined. There should be no doubt about the standard that the athlete is aiming to achieve. An athlete who says ‘I aim to do well’ is not establishing a definitive level of performance or achievement.

- **Is the goal** measurable? Generally, goals that are quantifiable (able to be measured in numbers) are more effective in setting a clear expectation of success – for example, decreasing an athlete’s personal best in the 400-metre sprint to below 45 seconds or their weight to 85 kilograms. Performance-based goals are not always able to be expressed using statistics; however, honest reflections from either the athlete or an educated observer such as a coach can still track progress and improvement.

- **Is there an action plan to help achieve the goal?** Athletes generally set longer-term goals (anywhere from three months to four years in the case of the Olympics). It is hard to connect such distant goals to the short-term demands of today’s arduous training program. Therefore, a range of related short-term and mid-term goals need to be identified and established that will help track the athlete towards their ultimate long-term goal. Often these goals are more training and behaviour based, as the long-term goal is likely to be performance based, such as winning the grand final. Short-term goals could include:
  - increasing training intensity by decreasing a weekly 5-kilometre test run by 15 seconds per week
  - for this week’s Rugby League game, aiming for a completion rate of 75 per cent
  - sticking to an established nutritional plan
  - sleeping at least eight hours per night.

- **Is the goal** realistic? Goals need to be something for which to strive. If the set goal is too easily achieved, then the athlete is not driven to work harder and push themselves. However, goals can be too hard and somewhat unlikely to be achieved because they are outside the athlete’s current level of potential achievement or improvement. When setting a performance goal, athletes must be honest with their current level of development and the level that they could see themselves achieving in a set time. Goals that find this delicate balance between being too easy or difficult to achieve are most effective in helping the athlete reach their potential without disheartening them.

- **What is the timeframe of the goal?** All goals, whether they are short term (days to weeks), mid-term (weeks to months) or long term (months to years), should have a defined timeframe within which the athlete intends to achieve the goal. This imposes finality on the athlete, and will increase the chances of success.

- Goals should be routinely evaluated using a suitable tool or test. This could be a questionnaire, training log or statistical data...
Checklist 2.37

Research the case study of a particular athlete. What do they use as motivation? What psychological strategies do they employ?

At this point, athletes must be very aware of their self-talk (the internal self-conversation and thoughts). This can lead to further anxiety if uncontrolled and unhelpful, whereas positive self-talk can be beneficial in helping to control feelings of anxiety and increasing motivation.

Going further 2.38

Create

Students should establish and set an actual goal for themselves to achieve. This could relate to a set standard of academic achievement, a fitness or sporting goal, or even a goal to save a set amount of money. Ensure that the goal reflects the principles of SMARTER, and has a very clear action plan set to help achieve the goal.

The goal should then be signed by someone else (such as a parent, friend or teacher) as a means of accountability; this person should also be given a copy of the goal. In addition, a visual reminder of the goal itself should be put somewhere to act as a reminder.

Regularly review progress and make necessary adjustments. Once established, students should reflect on what it feels like to specify a desired goal, and how they think this may influence their attitude and behaviours.

from a GPS device. This process should occur at regular intervals throughout the timeframe (such as fortnightly), and should involve the athlete and a coach or trainer who can provide independent assessment. This can allow progressive modifications to the goal to be made if the athlete is either tracking below or above the expected progress level. This ensures the goal stays realistic and achievable.

• When establishing a goal, the athlete should identify potential or set rewards that will be realised if the goal is achieved. These could be the inherent effect of a particular goal, such as personal glory and satisfaction, prizemoney or achieving a number one ranking. However, it could be a personal reward put in place by the athlete, coach or even their family for a particular goal that may not relate to a competitive performance outcome. This could be a holiday, contract extension or monetary reward for a specific achievement. Extrinsic and material rewards are less effective. Athletes being driven by internal factors generally show more resilience, perseverance and commitment.
2.3 The effects of nutrition and recovery strategies on performance

Nutritional considerations

**Driving questions 2.39**

1. What specific changes do you make to your dietary intake to account for increased physical activity?
2. What are the specific reasons for each of these changes?
3. If an elite athlete were to regularly neglect their diet, in what ways would this be detrimental to their performance?

**Pre-performance**

The training diet

The aim of the training diet is to achieve nutritional adequacy (providing the body with recommended intake of vitamins and minerals) and provide appropriate amounts of energy to support training and body composition goals. It is important that nutritional targets for athletes (such as total energy, protein and carbohydrate requirements) are based on an individual athlete’s goal body weight and muscle mass, as this provides more specific targets. Carbohydrates (starches and sugars) are a key fuel source for exercise, especially during...
prolonged and high-intensity exercise. The body stores carbohydrate as glycogen in the skeletal muscles and liver; however, its storage capacity is limited. If athletes are not able to consistently provide adequate energy and carbohydrates in their training diet, this can lead to fatigue, inability to improve in training, poor concentration during training sessions, reduced immune system functioning and increased susceptibility to injury.

The amount of carbohydrate needed depends on the fuel needs of the athlete’s training program, including the frequency, duration and intensity of the training. Training sessions and activity levels change from day to day, and carbohydrate intake needs to be adjusted to reflect this. On high-activity days, carbohydrate intake should be increased to provide the required fuel for the extra activity and promote recovery between sessions. Alternatively, on low- or no-training days, carbohydrate intake should be reduced to reflect the decreased training load.

### Situation Carbohydrate targets

<table>
<thead>
<tr>
<th>Situation</th>
<th>Carbohydrate targets</th>
</tr>
</thead>
<tbody>
<tr>
<td>Light</td>
<td>Low-intensity or skill-based activities 3–5 g per kg BM</td>
</tr>
<tr>
<td>Moderate</td>
<td>Moderate exercise programme (~1 hour/day) 5–7 g per kg BM</td>
</tr>
<tr>
<td>High</td>
<td>Endurance program (i.e. moderate- to high-intensity exercise of 1–3 hours/day) 6–10 g per kg BM</td>
</tr>
<tr>
<td>Very high</td>
<td>Extreme commitment (i.e. moderate- to high-intensity exercise of &gt;4–5 hours/day) 8–12 g per kg BM</td>
</tr>
</tbody>
</table>

BM = body mass

### Table 2.10 Daily needs for fuel and recovery

The pre-event meal

The aim of the pre-event meal is to ensure the athlete’s glycogen stores are topped up and they are well hydrated. Establishing a good pre-event meal, which provides the right nutrients and fluids, provides psychological benefits for athletes as they know they have prepared well. This meal should be high in carbohydrates, moderate in protein and low in fibre and fats. Meals high in fibre and fat take longer to digest, and therefore can lead to stomach discomfort during exercise.

Key considerations for the pre-event meal include:

- What is the duration and intensity of the event?
- How long has it been since the last meal or snack?
- How long is it until the event starts?

The following foods are suitable to eat three to four hours before exercise:

- crumpets with jam or honey + flavoured milk
- Pancakes with honey or maple syrup
- baked potato + cottage cheese filling + glass of milk
- baked beans on toast
- breakfast cereal with milk
- bread roll with cheese/meat filling + banana
- fruit salad with fruit-flavoured yoghurt
- pasta or rice with a sauce based on low-fat ingredients (e.g. tomato, vegetables, lean meat).

The following snacks are suitable to eat one to two hours before exercise:

- liquid meal supplement
- milkshake or fruit smoothie
- sports bars (check labels for carbohydrate and protein content)
- low-fibre breakfast cereal (rice bubbles/cornflakes) with milk
- cereal bars
- fruit-flavoured yoghurt
- fruit.

Source: Adapted from AIS, ‘Eating before exercise fact sheet’ (see www.cambridge.edu.au/hscpdhpe1weblinks).

Some of the glycogen stores in the liver are released overnight to provide glucose for the brain, as the brain remains quite active during sleep. Athletes who compete in events that have early morning starts (such as some triathlons or endurance events) need to be aware of this, and develop a nutritional plan such as getting up extra early to ensure they have time for an adequate breakfast or planning a high-carbohydrate snack within one to two hours of the event starting time. This enables them to top up the glycogen losses in the liver that occur during an overnight fast.

Hydration before the event needs to be planned carefully, and should start many hours...
before the event commences. As a guide, athletes should include 300–600 millilitres of fluid with the pre-event meal and another 300–400 millilitres approximately 20 minutes before the event, allowing enough time for a toilet stop if needed. Fluids should also be sipped regularly between the pre-event meal and the starting time, and using fluids that contain sodium will help fluid absorption. It is important for athletes to keep a drink bottle with them to help prompt them to consume enough fluid, as many athletes forget to hydrate well due to nerves, organising equipment or going over tactics/race strategy with coaches.

Carbohydrate loading

Carbohydrate loading refers to strategies that aim to maximise muscle glycogen stores prior to a competitive event (high carbohydrate intake combined with light training or rest). For events lasting for less than 60 minutes, there is no performance benefit associated with carbohydrate loading, and it may actually have a negative effect on performance in short-duration events at high intensity. Provided the athlete has only engaged in light exercise or rested for the 24–36 hours prior to the event, adequate glycogen stores will be achieved with an intake of around 5 grams of carbohydrate per kilogram of body weight over this period.

For endurance events lasting more than 90 minutes, such as marathons, triathlons, long-distance swimming, cross-country skiing and road race cycling, effective carbohydrate loading can improve overall performance by 2–3 per cent.

Traditional carbohydrate loading protocols consisted of a three- to four-day ‘depletion phase’ involving hard training and a low-carbohydrate diet, followed by a three- to four-day ‘loading phase’, which involved tapered training and a high-carbohydrate diet. More recent studies have shown that glycogen stores can be increased to the same levels by following a high-carbohydrate diet for 36–48 hours while the athlete is rested. The recommended carbohydrate intake to achieve effective carbohydrate loading is 8–12 grams per kilogram of body weight.

| Breakfast          | 3 cups of low-fibre breakfast cereal with 1.5 cups of reduced fat milk |
|                   | 1 medium banana                                                      |
|                   | 250 mL orange juice                                                  |
| Snack             | Toasted muffin with honey                                            |
|                   | 500 mL sports drink                                                  |
| Lunch             | 2 sandwiches (4 slices of bread) with filling as desired             |
|                   | 200 g tub of low-fat fruit yoghurt                                   |
|                   | 375 mL can of soft drink                                            |
| Snack             | Banana smoothie made with low-fat milk, banana and honey             |
|                   | Cereal bar                                                          |
| Dinner            | 1 cup of pasta sauce with 2 cups of cooked pasta                     |
|                   | 3 slices of garlic bread                                             |
|                   | 2 glasses of cordial                                                 |
| Late snack        | toasted muffin and jam                                               |
|                   | 500 mL sports drink                                                  |

Table 2.11 Example of a carbohydrate loading meal plan based on a 70 kg athlete

Source: Adapted from AIS, ‘Carbohydrate loading fact sheet’ (see www.cambridge.edu.au/hscphpsweblinks).

This sample plan provides about 14 800 kJ, 630 g carbohydrate (9 g/kg body weight), 125 g protein and 60 g fat.

If athletes have followed an effective carbohydrate loading plan, they typically experience weight gain (usually about 1 kilogram). This is due to the increased glycogen in the muscle and also extra water, which is stored with the
glycogen. Athletes need to be informed that this weight gain is a sign that they have effectively increased their glycogen stores and is not an increase in body fat. The fear of weight gain may prevent some athletes from carbohydrate loading.

During performance
The most important factor when considering whether carbohydrate intake during exercise will improve performance is the duration of the exercise. The following table summarises the amount of carbohydrate recommended during exercise.

<table>
<thead>
<tr>
<th>Duration</th>
<th>Carbohydrate targets</th>
</tr>
</thead>
<tbody>
<tr>
<td>During brief exercise</td>
<td>&lt;45 min</td>
</tr>
<tr>
<td>During sustained high-intensity exercise</td>
<td>45–75 min</td>
</tr>
<tr>
<td>During endurance exercise</td>
<td>1–2.5 hours</td>
</tr>
<tr>
<td>During ultra-endurance exercise</td>
<td>&gt;2.5–3 hours</td>
</tr>
<tr>
<td>Speedy refuelling</td>
<td>&lt;8 hour recovery</td>
</tr>
</tbody>
</table>

Table 2.12 Carbohydrate recommendations during exercise
Source: AIS, ‘Carbohydrate – the facts’ (see www.cambridge.edu.au/hscpdhpe1weblinks).

It is important that athletes plan their food and fluid intake carefully to meet these carbohydrate targets during exercise. In endurance events, where a consistent carbohydrate intake is needed over many hours, it is important to think about the type of carbohydrate the athlete is going to consume. Repeatedly having the same type of sugars from sports drinks or energy gels can cause athletes to experience symptoms such as stomach cramps, bloating, the need to go to the toilet and potentially diarrhoea. A combination of ‘sports foods’ (such as gels and sports drinks) and real foods (fruit, muesli/sports bars, low-fibre sandwiches) is best tolerated. Another benefit of using a mix of sports foods and real foods is that the foods the athlete eats during the event can also be a good source of key electrolytes such as sodium, potassium and magnesium to help with hydration.

It is important that athletes carefully plan their food and fluid intake according to the event, and identify where their opportunities to eat and drink will occur. Consider a triathlon, for example. There is no opportunity for athletes to carry or consume food during the swim leg. There is also a better opportunity for athletes to carry more food and eat on the bike than during the run leg.

Fluid
It is important that athletes are educated about hydration, and that any fluids provided to athletes are cool, palatable and conveniently available, or they will not be consumed. Research has shown that athletes typically only replace 30–70 per cent of sweat lost during exercise.

Fluid requirements vary significantly between athletes and between exercise situations. Fluid losses are affected by:
- genetics – some people sweat more than others
- body size – larger athletes tend to sweat more than smaller athletes
- fitness – fitter people sweat earlier in exercise and in larger volumes
- environment – sweat losses are higher in hot, humid conditions
- exercise intensity – sweat losses increase as exercise intensity increases.

When planning for an endurance event, athletes should carefully monitor their fluid intake during training and try to simulate race conditions (intensity, duration and environmental conditions) where possible. Negative effects on performance start to occur at just 2 per cent dehydration, so athletes should aim to keep their fluid losses to less than this. The potential effects of mild dehydration include:
- reduced mental function leading to poor concentration
- increased ratings of perceived exertion leading to feelings of fatigue at lower intensity
- delayed gastric emptying from the stomach leading to stomach discomfort
- poor aerobic performance
- impaired heat regulation.

By recording body weight immediately before and after exercise (with minimal clothing, if any) athletes will get a reasonably accurate idea of their fluid losses as 1 kilogram loss in weight reflects approximately 1 litre fluid loss.

For example, if an athlete weighs 70 kilograms before exercise and 68 kilograms after, the 2 kilogram loss of weight reflects their overall fluid losses over that exercise session (a 2.9 per cent
loss). It is also important to record any fluid the athlete has consumed over that session in order to calculate the overall sweat rate and develop a hydration plan according to this.

**Over-hydrating**
Consuming fluid in excess of requirements may cause some gastrointestinal discomfort, and can lead to hyponatraemia (low blood sodium levels), which causes symptoms similar to dehydration and is potentially life threatening. Hyponatraemia is unlikely to occur in events of less than two or three hours’ duration, and athletes are at risk when large volumes of low-sodium drinks (such as water) are consumed when sweat losses are small. Those most susceptible to hyponatraemia are small females who have long race times (more than three or four hours), as these athletes tend to have relatively small sweat losses and plenty of time to consume large amounts of fluid during the event. As a result, structured hydration plans are often not advisable for these athletes. The best way to prevent hyponatraemia is to focus on consuming sodium-containing fluids such as sports drink and sodium-containing foods such as vegemite sandwiches, as well as limiting fluid intake to no more than sweat loss.

It is very important that athletes train their diets to make sure the foods and drinks they plan to have during the event are well tolerated and don’t result in any stomach upset, as this can significantly affect performance and may result in the athlete not even finishing the race. The general advice is not to try anything new on event day.

**Post-performance**
Recovery nutrition has received much attention, and has been heavily researched in recent decades. Immediately following exercise, the activity of enzymes involved in refuelling (synthesis and storing glycogen) and repairing (repair of damaged muscle tissue and building of new muscle tissue) is increased significantly. Therefore, the aim of the recovery meal/snack is to provide carbohydrate to refuel and protein to repair muscle tissue as well as fluid to correct any dehydration.

Athletes are encouraged to consume foods and drinks that provide 1–1.2 grams of carbohydrate per kilogram of body weight within the first hour of finishing, as this is when rates of glycogen synthesis are greatest. This is especially important if the time between prolonged training sessions is less than eight hours. High glycaemic index carbohydrate foods have been shown to refuel muscle and liver glycogen stores more quickly, and these should be the basis of the carbohydrate consumed within the first hour. This meal should also be low in fibre, as this will slow the digestion and absorption of carbohydrate. Conveniently, the majority of high glycaemic carbohydrates are low in fibre.

Search for the glycaemic index of different carbohydrates on the University of Sydney website (see www.cambridge.edu.au/hscpdhpe1weblinks).

A small amount of protein is also important for muscle recovery, especially after high-intensity sports and strength training. Athletes should aim to have approximately 15 grams of protein following high-intensity exercise, and recent research suggests that the optimal amount following strength training and power-based sports is about 300 milligrams of protein per kilogram of ideal body weight (21 grams of protein based on a 70 kilogram athlete).

Examples of low-fibre recovery meals that provide carbohydrate and protein include:
- milkshakes/smoothies
- liquid meal supplements based on milk
- yoghurt and fruit salad
- crumpets/muffins/toast with jam or honey with 300 millilitres of milk
- bowl of low fibre cereal with milk.

After high-intensity exercise, the immune system can be suppressed for many hours. Consuming a suitable recovery meal has been shown to improve the functioning of the immune system, which is important to help prevent athletes catching infectious illnesses.

**Do athletes need a post-performance meal?**
Athletes need to think practically about their day-to-day training schedules and plan recovery meals accordingly. If athletes have only completed a short training session or trained at a low intensity, then it is highly unlikely that they have completely used their glycogen stores and therefore do not require such a high-carbohydrate recovery meal. If athletes routinely consume more carbohydrate than they need, it may lead to unwanted weight gain, which will hamper performance.

**Dietary requirements of athletes in different sports**
Different sporting events vary significantly in their intensity and duration, and so do athletes’ nutritional needs in different sports. To highlight the extent of the different fuel needs of different sports, compare cyclists competing in the Tour de France with athletes in low-intensity and short-duration sports such as archery. The energy needs of cyclists in the Tour de France can be as high as 30 000 kilojoules a day on the longer-duration and higher-intensity stages, and average 20 000–25 000 kilojoules a day on the shorter-duration and lower-intensity stages.
Going further 2.40

Inquire
Consider the sports in Table 2.13 and tick or cross the boxes appropriate for each sport.

<table>
<thead>
<tr>
<th>Sport</th>
<th>Do they need a high-carbohydrate pre-event meal?</th>
<th>Will carbohydrate during the event improve performance?</th>
<th>Do they need a specific recovery meal after performance?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Elite ironman triathlon (9–10 hours’ duration)</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Midfield player in soccer match (90 minutes’ duration)</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sprinter (100 metre and only one race in a day)</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>A competitive surfer in a 35-minute heat (only surfing one heat that day)</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Elite rower (competing in two heats and a final in one day)</td>
<td>X</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 2.13 Dietary requirements

1. Explain why you have ticked the boxes you have.
2. What sorts of foods and drinks would you use for each of the boxes you have selected for the different sports? (Make sure you consider the opportunities the athlete has to eat and drink during each event.)

Figure 2.89 The energy needs of cyclists in the Tour de France vary greatly from athletes competing in a sport such as archery.

Summary 2.41

1. What is carbohydrate loading?
2. Outline the pre-performance nutritional needs of athletes.
3. Outline the nutritional and hydration needs of athletes while competing.
4. Outline the post-performance nutritional needs of athletes.

Checklist 2.42

Compare the dietary requirements of a power athlete and an endurance athlete.
**Supplementation**

**Vitamins/minerals**

Vitamins are a group of micronutrients that are only required in small amounts, and do not provide any energy in the form of kilojoules or calories. Although vitamins don’t directly provide any energy, many vitamins play essential roles in the breakdown and metabolism of macronutrients (fats, carbohydrates, protein and alcohol) to produce energy. As well as their involvement in energy-production pathways, vitamins also play a key role in the building and repair of tissue and immune function.

The majority of vitamins are essential, as they are unable to be synthesised by the body, and therefore must be provided through a balanced diet. There are two groups of vitamins: fat-soluble vitamins (vitamins A, D, E and K) and water-soluble vitamins (all B vitamins and vitamin C).

Minerals are also essential micronutrients for optimal health and sports performance. Like vitamins, minerals do not provide energy. Key minerals include calcium, iron, magnesium, sodium, potassium, zinc, iodine and selenium. Iron and calcium are two key minerals that are often deficient among certain athlete groups.

Calcium is integral for bone structure, and also plays a role in muscle contraction. The development of strong bones occurs during childhood and adolescence. An adequate calcium intake, vitamin D status and regular weight-bearing exercise all contribute to the development of healthy bones. If these factors are not accounted for, the risk of fractures, osteopenia and osteoporosis is significantly increased in later life. The quality (density) of bone tissue gradually declines from the mid-twenties in both males and females, and even greater losses occur after menopause in females. Recent national surveys in Australia have identified that calcium intakes of children and adolescents are well below the recommended dietary intake (RDI) levels. Among this age group, there are also decreasing rates of physical activity; combined with a low calcium intake, this is a key risk factor for poor bone health later in life.

Calcium-rich foods include dairy products, green, leafy vegetables and fish with edible bones such as sardines and canned salmon.

Iron is a key component of haemoglobin, which is responsible for the transport of oxygen around the body. As well as having a significant impact on general health, low iron will negatively affect sports performance due to reduced oxygen delivery to working muscle. As a result, the muscle cells are unable to produce energy and eliminate acidic by-products effectively. Those most at risk of iron deficiency are females, vegetarians and endurance athletes (they have higher sweat losses). Athletes competing in low-weight category events (such as lightweight boxing and rowing), or events where having a low body weight is an advantage, are also at risk due to restricted food intake among these athletes.

Foods high in iron include lean meats, green leafy vegetables, legumes, wholegrain products and fortified products such as breakfast cereals.

**Vitamin and mineral supplementation**

Many athletes choose to supplement their diet with additional vitamins and minerals on top of their dietary intake, believing it will aid performance and recovery. Despite their widespread use, there are no scientific studies to confirm these claims. Vitamin and mineral supplements are best used as a last resort if dietary intakes are inadequate. However, it is important to note that excess consumption of some vitamins and minerals can have harmful effects on health. It is always best to consult a registered dietitian or sports scientist before starting a supplementation program.
is no clear evidence that general multivitamin
supplements improve performance, and the
absorption of these vitamins and minerals from
a supplement is generally much lower than from
eating the foods that contain them. Some research
has indicated that these supplements may even
prevent the development of certain training
adaptations, and therefore may have a negative
effect on performance.

Recent research indicates that certain nutrients
may improve performance – for example, specific
nutrients in beetroot may improve performance in
sprint cycling events and power-based sports and
magnesium may aid muscle recovery; however,
more research is needed to confirm this and
identify what the optimal dosage is to achieve these
benefits.

Figure 2.92 Many athletes choose to supplement their
diets with additional vitamins and minerals

Protein

Protein is important for the building and repair of
new tissue, and as a result many athletes competing
in strength and power sports take additional
protein supplements as they believe it will help
increase their muscle mass. Proteins are made up
of a range of different amino acids, and a range
of different supplements are available in liquid
or powder form. It is important that athletes are
educated about protein, as it is not used to fuel
exercise performance (this only occurs under
extreme conditions when carbohydrate and fat
stores are exhausted). As protein is not a fuel,
the majority of athletes easily meet their protein
requirements through their food intake without
needing additional supplements. Despite this,
many athletes still consume excess amounts
of protein, and intakes of around 3 grams per
kilogram of body weight are not uncommon among
certain athlete groups – especially in male team
sport environments. Historically, there has been
concern that high-protein diets may have a negative
effect on kidney function; however, there is no
widespread evidence among healthy athletes to
support this.

An important consideration regarding an
athlete’s protein intake is how they spread it out
over the day. Recent studies have shown that
strength gains, muscle hypertrophy and recovery
are improved with small amounts of protein
(15–25 grams) consumed regularly throughout the
day. Many athletes do not evenly distribute their
protein intakes, and typically have small amounts
at breakfast and snacks and large amounts at the
evening meal. Protein supplements/shakes can
be attractive to athletes as they are portable and
convenient to consume in between meals and after
training sessions. The recommended serving size on
many of the protein powders available may be as
high as 50–60 grams of protein per serving, which is
significantly more than required.

Caffeine

Caffeine is a substance found naturally in the
leaves, beans and fruits of a variety of plants,
and is regularly consumed by some 90 per cent
of adults. The most common dietary source of
caffeine is coffee, but cola drinks, energy drinks
and specialised sports foods and supplements also
contribute to regular intake.
Caffeine is rapidly absorbed and transported to all body tissues and organs, where it has a large variety of effects. These may vary between individuals, and can be both positive and negative responses, including the mobilisation of fats to the muscle cells, changes to muscle contractility, alterations to the central nervous system to change perceptions of effort or fatigue, stimulation of the release and activity of adrenaline, and effects on cardiac muscle.

The major benefits of caffeine on exercise capacity and performance appear to be achieved by central nervous system effects. These effects reduce the perception of fatigue and allow for optimal pacing and performance to be maintained for a longer period. This is most likely to benefit endurance sports such as long-distance running, cycling, triathlons and cross-country skiing.

In the past, caffeine has not been recommended among athletes due to its potential to act as a diuretic and contribute to dehydration. More recent studies have shown that small to moderate doses of caffeine have minor effects on overall hydration in people who are regular caffeine users. In addition, caffeine-containing drinks such as tea, coffee and cola drinks provide a significant source of fluid in the everyday diets of many people, including athletes.

Sports supplements and ‘pre-workout’ supplements are not required to list their caffeine content on the label. For example, several of the supplements in Table 2.16 (page 134) have not listed their caffeine content; however, caffeine (methylxanthine) or guarana – which contains caffeine – are listed as ingredients.

Supplements are not subject to the same criteria as foods, and therefore they may contain significantly more caffeine per serve than common foods and drinks. This is a concern, as many of the ‘pre-workout’ supplements are popular among young athletes who may not be habitual caffeine users.

These sources also show that there are a variety of protocols of caffeine intake that can enhance performance. These include the consumption of caffeine:
- before the exercise bout
- spread throughout exercise
- taken late in long-duration exercise as fatigue is beginning to occur.

Different protocols may achieve optimal performance outcomes, even in the same sport or individual. Suitable or optimal protocols may be dictated by the specific characteristics of the event, the practical considerations of consuming a caffeine-containing product and the individual characteristics/preferences of the athlete. The athlete who is intending to use caffeine to enhance

<table>
<thead>
<tr>
<th>Product</th>
<th>Serve</th>
<th>Caffeine content (mg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Powerade Fuel+ sports drink</td>
<td>300 mL can</td>
<td>96</td>
</tr>
<tr>
<td>PowerBar caffeinated sports gel</td>
<td>40 g sachet</td>
<td>25</td>
</tr>
<tr>
<td>PowerBar double caffeinated sports gel</td>
<td>40 g sachet</td>
<td>50</td>
</tr>
<tr>
<td>PowerBar caffeinated gel blasts</td>
<td>60 g pouch (~9 lollies)</td>
<td>75</td>
</tr>
<tr>
<td>Gu caffeinated sports gel</td>
<td>32 g sachet</td>
<td>20–40</td>
</tr>
<tr>
<td>Carboshotz caffeinated sports gel</td>
<td>50 g sachet</td>
<td>80</td>
</tr>
<tr>
<td>PB speed sports gels</td>
<td>35 g sachet</td>
<td>40</td>
</tr>
<tr>
<td>PowerBar Performance bar with Acticaf</td>
<td>65 g bar</td>
<td>50</td>
</tr>
</tbody>
</table>

Table 2.14 Caffeine content of common sports foods and supplements (Australia)
<table>
<thead>
<tr>
<th>Food or drink</th>
<th>Serve#</th>
<th>Caffeine content (mg) average and range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Instant coffee</td>
<td>250 mL cup</td>
<td>60 (12–169)</td>
</tr>
<tr>
<td>Brewed coffee</td>
<td>250 mL cup</td>
<td>80 (40–110)</td>
</tr>
<tr>
<td>Brewed coffee (same outlet on different days)</td>
<td>250 mL cup</td>
<td>130–282</td>
</tr>
<tr>
<td>Short black coffee/espresso from variety of outlets</td>
<td>1 standard serve</td>
<td>107 (25–214)</td>
</tr>
<tr>
<td>Starbucks Breakfast Blend brewed coffee</td>
<td>600 mL (Venti size)</td>
<td>415 (300–564)</td>
</tr>
<tr>
<td>Iced coffee – commercial brands</td>
<td>500 mL bottle</td>
<td>30–200 depending on brand</td>
</tr>
<tr>
<td>Frappuccino</td>
<td>375 mL cup</td>
<td>90</td>
</tr>
<tr>
<td>Tea</td>
<td>250 mL cup</td>
<td>27 (9–51)</td>
</tr>
<tr>
<td>Black tea</td>
<td>250 mL cup</td>
<td>25–110</td>
</tr>
<tr>
<td>Green tea</td>
<td>250 mL cup</td>
<td>30–50</td>
</tr>
<tr>
<td>Iced tea</td>
<td>600 mL bottle</td>
<td>20–40</td>
</tr>
<tr>
<td>Hot chocolate</td>
<td>250 mL cup</td>
<td>5–10</td>
</tr>
<tr>
<td>Chocolate – milk</td>
<td>60 g</td>
<td>5–15</td>
</tr>
<tr>
<td>Chocolate – dark</td>
<td>60 g</td>
<td>10–50</td>
</tr>
<tr>
<td>Viking chocolate bar</td>
<td>60 g</td>
<td>58</td>
</tr>
<tr>
<td>Coca-Cola</td>
<td>375 mL can/600 mL bottle</td>
<td>36/58</td>
</tr>
<tr>
<td>Diet Coke</td>
<td>375 mL can/600 mL bottle</td>
<td>48/77</td>
</tr>
<tr>
<td>Pepsi</td>
<td>375 mL can/600 mL bottle</td>
<td>40/64</td>
</tr>
<tr>
<td>Red Bull energy drink</td>
<td>250 mL /330 mL/500 mL can</td>
<td>80/106/160</td>
</tr>
<tr>
<td>V energy drink</td>
<td>250 mL/350 mL/500 mL can</td>
<td>78/109/155</td>
</tr>
<tr>
<td>Mother energy drink</td>
<td>150/300 mL/500 mL can</td>
<td>48/96/160</td>
</tr>
<tr>
<td>Monster energy drink</td>
<td>340 mL/500 mL can</td>
<td>109/160</td>
</tr>
<tr>
<td>Lipovitan energy drink</td>
<td>250 mL can</td>
<td>50</td>
</tr>
<tr>
<td>Rockstar</td>
<td>500 mL can</td>
<td>160</td>
</tr>
<tr>
<td>Vitamin water – energy</td>
<td>500 mL bottle</td>
<td>82</td>
</tr>
<tr>
<td>No Doz (Australia)</td>
<td>1 tablet</td>
<td>100</td>
</tr>
</tbody>
</table>

**Table 2.15** Caffeine content of common foods, drinks and therapeutic products (Australia)

*Source: Adapted from Burke et al., Caffeine for Sports Performance, 2013.*

<table>
<thead>
<tr>
<th>Product</th>
<th>Serve</th>
<th>Caffeine content (mg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Musashi Re-activate Hard Core</td>
<td>15 g powder serve</td>
<td>120</td>
</tr>
<tr>
<td>Body Science (BSc) K-OS</td>
<td>13 g powder</td>
<td>150</td>
</tr>
<tr>
<td>Jack 3D</td>
<td>5 g powder</td>
<td>? [ingredients: ‘caffeine’]</td>
</tr>
<tr>
<td>No-Xplode</td>
<td>18 g</td>
<td>? [ingredients: ‘methylxanthine (caffeine)’]</td>
</tr>
<tr>
<td>Assault</td>
<td>20 g</td>
<td>? [ingredients: ‘caffeine’]</td>
</tr>
<tr>
<td>1 MR</td>
<td>8 g</td>
<td>300</td>
</tr>
<tr>
<td>No-Shotgun</td>
<td>22 g</td>
<td>? [ingredients: ‘caffeine’]</td>
</tr>
<tr>
<td>Amped NOS</td>
<td>40 g</td>
<td>? [ingredients: ‘caffeine’]</td>
</tr>
<tr>
<td>Animal Rage</td>
<td>1 stick</td>
<td>? (ingredients note caffeine/coffee bean extract)</td>
</tr>
<tr>
<td>Code Red</td>
<td>10 g powder</td>
<td>? [ingredients: ‘caffeine’]</td>
</tr>
</tbody>
</table>

**Table 2.16** Pre-workout supplements

*Source: Adapted from Burke et al., Caffeine for Sports Performance, 2013.*
Chapter 2  Factors Affecting Performance

<table>
<thead>
<tr>
<th>Product</th>
<th>Serve</th>
<th>Caffeine content (mg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oxyelite pro</td>
<td>1 capsule</td>
<td>100</td>
</tr>
<tr>
<td>Body Science (BSc) Hydroxyburn Pro</td>
<td>40 g</td>
<td>(? (24 mg guarana listed on label))</td>
</tr>
<tr>
<td>Body Science (BSc) Hydroxyburn Hardcore</td>
<td>3 capsules</td>
<td>210 (70 mg per capsule)</td>
</tr>
<tr>
<td>Muscle Tech Hydroxycut Hardcore pro</td>
<td>40 g sachet</td>
<td>? [ingredients: ‘caffeine’]</td>
</tr>
<tr>
<td>Shred Matrix</td>
<td>1 capsule</td>
<td>? [ingredients: ‘caffeine, guarana, yerba mate’]</td>
</tr>
<tr>
<td>Animal Cuts</td>
<td>10 g</td>
<td>? [ingredients: ‘caffeine’]</td>
</tr>
</tbody>
</table>

Table 2.17 Fat-loss supplements

Sports performance should experiment in training or less important events to determine the timing and dosages of caffeine that best suit their individual needs.

Creatine products

Creatine is a naturally occurring compound found in large amounts in skeletal muscle and the brain. Creatine is provided from dietary intake and synthesis from amino acids. The major source of creatine in the diet is from animal muscle – such as meat or fish – which typically provides 1–2 grams per day, or half the daily turnover.

As vegetarians do not consume any significant creatine in their diets, they are reliant on the body making creatine from amino acids, and typically have lower creatine levels in their muscles.

Creatine provides a number of important functions related to fuel supply in the muscle. The best-known role is as a source of phosphate to regenerate ATP, which is the most important fuel source for sprints or bouts of high-intensity exercise lasting up to 10 seconds.

Studies in the early 1990s showed that muscle creatine and phosphocreatine in skeletal muscle could be increased by around 20 per cent. These results are significant in terms of improving the exercise capacity of the phosphocreatine energy system, and have led to the widespread use and popularity of creatine among a range of athletes. Since then, further studies have shown that there is considerable variability in different athletes’ responses to creatine supplementation. Individuals with the lowest initial levels, such as vegetarians, may show the greatest responses, while individuals with higher resting creatine levels may not significantly benefit from supplementation. Strategies that enhance creatine uptake into the muscle cells include taking creatine with a carbohydrate-rich meal or snack (around 50 grams of carbohydrate).

Creatine supplementation has been shown to enhance the performance of exercise involving repeated sprints or bouts of high-intensity activity, separated by short recovery intervals. Therefore, competition or training programs involving intermittent high-intensity work patterns with brief recovery periods (less than 1 minute) or resistance training programs are most likely to benefit from creatine supplementation. Performance enhancements may be seen as the result of an acute loading protocol, but chronic creatine use may offer the greatest benefits.

The best-researched dietary creatine supplement is creatine monohydrate, with a number of protocols of loading being established:

- Rapid loading may be achieved by five days of repeated doses (e.g. five doses of 5 grams) of creatine.
- Slow loading will occur over a longer period (28 days) with a daily dose of 3 grams.
- A maintenance dose of 3 grams per day will allow elevated levels to be sustained.
- Unloading: once the muscle creatine content has been saturated, it will take at least four weeks to return to resting levels.

A weight gain of 600–1000 grams is typically associated with acute loading, and is due mostly to water retention.

Creatine monohydrate is the common source of creatine in commercially available supplements, and the experience of 20 years of research indicates it is safe and effective in the recommended dosages. A number of other forms of creatine have been included in newer supplements, with claims of being a superior form of creatine; these include creatine serums, creatine malate and creatine ethyl esters. There is little to no evidence supporting marketing claims that these alternative creatine sources are more effective in increasing muscle creatine levels and achieving performance outcomes, or that they are associated with fewer side-effects.

Creatine supplementation should be limited to experienced and well-developed athletes. Young athletes are able to make substantial gains in performance through maturation and skill/technique improvements without supplementation.
Recovery strategies

Driving questions 2.46

Think back to a time when you were extremely sore and feeling fatigued after strenuous exercise.
1. What did you do to alleviate this and promote faster recovery?
2. What else do you think could have helped?
3. Consider a sport such as football or basketball and make a list of the reasons why athletic recovery is now given so much emphasis.

Recovery is the time required for the repair of damage to the body caused by training or competition, and is crucial to optimal sports performance for many reasons: some are physiological and some are psychological. Most coaches and athletes are aware that getting enough rest and recovery after exercise is essential to high-level performance; however, many are still prone to over-train and feel guilty or weak when a day off training is taken. The result is usually a loss of enjoyment and interest in training and competition, a decline in performance and eventually a state of over-training, from which it is very difficult to recover.

Clearly, athletes must work hard in order to increase the appropriate fitness qualities required to meet the demands of the sport, however, training is associated with both physiological and psychological fatigue. Well-designed training programs balance suitable training loads with strategically planned recovery strategies in order to optimise the performance potential of athletes. Peak athletic performance will only be achieved when the athlete’s fatigue levels are less than...
their fitness level. Recovery strategies comprise physiological, neurological, psychological and muscle damage strategies.

Training programs that fail to balance appropriate training load and recovery strategies generally follow four distinct stages, leading to over-training:

- **Stage 1: Acute fatigue.** This initial fatigue is normal when training.
- **Stage 2: Training stimulus overload.** The overload principle states that loads greater than normal must be placed on the body in order for training adaptations to take place. With appropriate periodisation of training and recovery, training adaptation will take place. Stimulus overload that is too great will result in over-reaching and, in the worst case scenario, over-training.
- **Stage 3: Over-reaching.** The accumulation of either training or non-training stress can result in a short-term decrement in the athlete’s performance capacity, with or without related physiological and psychological signs and symptoms of over-training, in which restoration of performance capacity may take several days to several weeks.
- **Stage 4: Over-training.** This involves the accumulation of either training or non-training stress that results in a long-term decrement in the athlete’s performance capacity, with or without related physiological and psychological signs and symptoms of over-training, in which restoration of performance capacity may take several weeks or months.

Basic indicators of over-training and under-recovering

- increased muscle tension and or tenderness
- increased heart rate at rest, during the workout or during the recovery period between bouts of exercise
- negative change in aerobic and anaerobic levels
- decreased appetite
- increased susceptibility to illness
- sleep disturbances
- loss of enjoyment and performance.

Causes of overtraining

- a sharp and dramatic increase in training volume and intensity
- training that is performed too often and too intensely
- a lack of rest and recovery between sessions
- a lack of variety in sessions, resulting in boredom.

In response to training (stress), the human body attempts to maintain a state of homeostasis (internal stability), and will constantly attempt to...
adapt to the training stress. Training is simply the manipulation of the application of stress (training load), and the body’s subsequent adaptation to that stress in order to maintain homeostasis. Training programs that balance load and appropriate recovery ensure that a desired adaptive response to training is achieved. This process is called supercompensation (see Figure 2.100), and was first proposed by Hungarian scientist Nikolai Jakowlew in 1976.

The human body’s fitness levels are broken down into four periods: initial fitness, training, recovery and supercompensation. During initial training, the athlete has a base level of fitness (shown in the first time sector of the graph). Initially, when a training stimulus is implemented, the athlete’s fitness level decreases (shown by the second time sector in the graph). Following training, the athlete’s body enters the recovery period, during which the athlete’s fitness level will increase up to the initial fitness level (shown by the third time sector in the graph). The adjustable nature of the athlete’s body means it will take itself to a higher level of fitness in anticipation of the next training session. It is at this point that the athlete’s body commences the supercompensation period (shown by the fourth time sector in the graph). If the next training session is applied during the supercompensation period, the athlete’s body has a greater chance of progressing to a higher level of fitness. However, if the next training session is applied too soon during the recovery period, the athlete has a far greater chance of over-training. Conversely, if the next training session is applied too late after the supercompensation period, the athlete’s fitness level will decline back towards the initial fitness level (shown by the last time sector in the graph).

The supercompensation period varies, depending on the type of training being undertaken and the volume and intensity at which it is performed. As a general rule, high-intensity explosive anaerobic sessions such as speed and strength training will require 48 to 72 hours of recovery between intense workouts in order to allow the supercompensation process to occur. Submaximal aerobic training (75 per cent intensity and lower) will require only 24 hours of recovery. High-intensity anaerobic training and moderate-intensity aerobic training require different recovery times in order to allow the supercompensation process to occur.

Long-term recovery

Long-term recovery methods provide both physiological and psychological recovery, and refer to periods of rest and recovery that are built into the annual periodised training program. A well-designed periodised plan will include recovery days and or weeks within the annual training schedule. Coaches often add rest periods, cross-training days, social events, variations in training sessions, venues, loads and intensities – all of which are designed to promote recovery and avoid
Chapter 2  Factors Affecting Performance

the pitfalls of staleness, boredom and over-training (see example above of a weekly program showing recovery cycles).

Physiological strategies

Cool-down
Training and competition cause changes in the body, such as muscle tissue breakdown and the depletion of energy stores (muscle glycogen), as well as fluid loss. Without sufficient time to repair and replenish, the body will continue to break down from intensive exercise. While many coaches and athletes understand the benefits of an appropriate warm-up prior to training and competition, the cool-down and its benefits are often overlooked. The cool-down provides a number of physiological benefits to the athlete to help reverse the damage caused by exercise. These include:

- gradually lowering the athlete’s heart rate, body temperature and metabolism
- removal of waste products
- replenishment of energy stores and the repair of damaged tissues
- a reduction in muscle stiffness and soreness
- replenishment of fluid loss.

Table 2.18 Example of long-term recovery implementation within an in-season weekly training plan for a team sport athlete

<table>
<thead>
<tr>
<th>Monday</th>
<th>Tuesday</th>
<th>Wednesday</th>
<th>Thursday</th>
<th>Friday</th>
<th>Saturday</th>
<th>Sunday</th>
</tr>
</thead>
<tbody>
<tr>
<td>AM:</td>
<td>AM:</td>
<td>AM:</td>
<td>Rest day</td>
<td>AM:</td>
<td>AM:</td>
<td>AM:</td>
</tr>
<tr>
<td>Pool recovery</td>
<td>Train</td>
<td>Train</td>
<td>Massage</td>
<td>Train</td>
<td>Rest</td>
<td>Ocean recovery</td>
</tr>
<tr>
<td>Static stretch</td>
<td>Ice baths</td>
<td>Ice baths</td>
<td>Ice baths</td>
<td>Ice baths</td>
<td>Ice baths</td>
<td>Ice baths</td>
</tr>
<tr>
<td>PM:</td>
<td>PM:</td>
<td>PM:</td>
<td>PM:</td>
<td>PM:</td>
<td>PM:</td>
<td>PM:</td>
</tr>
<tr>
<td>Massage</td>
<td>Gym</td>
<td>Yoga class</td>
<td>Rest</td>
<td>Game</td>
<td>Stretch</td>
<td>Relaxation</td>
</tr>
</tbody>
</table>

Figure 2.102 Marathon running requires a different recovery time to sprint running

Hydration
The replenishment of lost fluids and muscle fuel replacement are the two most critical components of recovery following training and competition. A body weight fluid loss of 2 per cent or more during exercise may result in a drop in aerobic endurance, an increased risk of soft tissue injury, losses in concentration and reduced reaction time. It is essential that athletes are educated in relation to hydration. Regular urine hydration checks and pre- and post-session weighing in order to monitor individual athlete sweat rates are essential. A loss of 1 kilogram equates to 1 litre of fluid loss. It is generally recommended that, in order to replenish 1 litre of lost fluid, it is necessary to consume 1.5 litres of fluid.

Figure 2.103 Hydration is a crucial component of recovery

Nutrition
Appropriate nutritional replenishment following training requires planning, and must balance the demands of the exercise. Muscle glycogen supplies within the muscles and liver not only fuel energy demands, but are critical in the recovery process following training and competition.

When food and/or sports drinks containing CHO are consumed, blood glucose levels in the blood elevate quickly and peak at about 20–30 minutes. The glycaemic index (GI) of a food or sports drink is determined by the rate at which CHO is available.
The higher the GI, the more rapid the absorption (see Table 2.19). Athletes should aim to consume 1 gram of high glycaemic index carbohydrate per kilogram of body mass immediately after exercise. This process should be repeated after one hour of completing the exercise. Snacks or sports drinks containing a moderate level of protein and carbohydrates are recommended, especially after hard training. For strength, speed, power and impact, team sport athletes’ post-session snacks should contain 10–20 grams of protein (6–12 grams of amino acids) in addition to high GI carbohydrate, to have a substantial effect on net protein synthesis. As a general rule, a 4:1 ratio of carbohydrate to protein is recommended (see box below for carbohydrate and protein snacks, and carbohydrate snacks).

### Carbohydrate and protein snacks

**50 g carbohydrate snacks providing at least 10 g protein**
- 250–350 mL liquid meal supplement
- 250–350 mL milkshake or fruit smoothie
- 500 mL flavoured low-fat milk
- Many sports bars (check labels for protein and carbohydrate content)
- 60 g (1.5–2 cups) breakfast cereal with half a cup of milk
- 1 round of sandwiches, including cheese/meat/chicken filling, and 1 large piece of fruit or 300 mL sports drink
- 1 cup fruit salad with 200 g carton fruit-flavoured yoghurt or custard
- 200 g flavoured yoghurt or 300 mL flavoured milk and 30–35 g cereal bar
- 2 crumpets or English muffins with thick spread of peanut butter
- 250 g baked beans on 2 slices of toast
- 250 g (large) baked potato with cottage cheese or grated cheese filling
- 150 g thick-crust pizza

**Carbohydrate snacks**

**50 g carbohydrate snacks**
- 800–1000 mL sports drink
- 800 mL cordial
- 500 mL fruit juice, soft drink or flavoured mineral water
- 60–70 g jelly beans or jube sweets
- 2 sports gels
- 3 medium pieces fruit or 2 bananas
- 2 sports gels
- 1 large chocolate bar (70–80 g)
- 3 thick rice cakes with jam or honey
- 1 cup thick vegetable soup with large bread roll
- 1 jaffle/toasted sandwich with banana filling
- 100 g (1 medium or 2 small) American muffins, fruit bun or scones
- 250 g (1 cup) creamed rice
- 250 g (large) baked potato with salsa filling
- 100 g pancakes (1–2 large) + 30 g syrup

*Source: Australian Institute of Sport, Nutrition for optimal recovery after training and competition.*

<table>
<thead>
<tr>
<th>High (GI &gt;85)</th>
<th>Moderate (GI = 60–85)</th>
<th>Low (GI &lt;60)</th>
</tr>
</thead>
<tbody>
<tr>
<td>White bread</td>
<td>Pasta/noodles</td>
<td>Apples/pears</td>
</tr>
<tr>
<td>Wholemeal bread</td>
<td>Popcorn</td>
<td>Cherries</td>
</tr>
<tr>
<td>Nutrigrain</td>
<td>Porridge</td>
<td>Peaches</td>
</tr>
<tr>
<td>Cornflakes</td>
<td>Potato chips</td>
<td>Apple juice</td>
</tr>
<tr>
<td>Weetbix</td>
<td>Special K</td>
<td>All Bran</td>
</tr>
<tr>
<td>Potato</td>
<td>White rice (boiled)</td>
<td>Baked beans</td>
</tr>
<tr>
<td>Rockmelon</td>
<td>Sweet corn</td>
<td>Lentils</td>
</tr>
<tr>
<td>Raisins</td>
<td>Sponge cake</td>
<td>Ice cream</td>
</tr>
<tr>
<td>Bananas</td>
<td>Oranges</td>
<td>Yoghurt</td>
</tr>
<tr>
<td>Corn chips</td>
<td>Orange juice</td>
<td>Fructose</td>
</tr>
<tr>
<td>Sugar/honey</td>
<td>Chocolate</td>
<td>Brown rice</td>
</tr>
<tr>
<td>Cordial/sports drinks</td>
<td>Milk (all types)</td>
<td></td>
</tr>
<tr>
<td>Glucose</td>
<td>Peanuts</td>
<td></td>
</tr>
</tbody>
</table>

**Table 2.19 Glycaemic index of various foods**

Neural strategies

Hydrotherapy and massage promote relaxation of muscles that may have sustained damage or fatigue during high-intensity exercise. The integration of neural recovery strategies into the recovery program is common in many contact team sports (see NRL example later in this chapter).

**Going further 2.47**

**Create**

Select a team sport or individual athlete and design an appropriate recovery session by utilising the physiological recovery methods discussed above. Discuss the physiological benefits of each recovery method for the team or athlete.
Hydrotherapy

Hydrotherapy uses water to assist recovery, remove waste products, soothe aching muscles, promote metabolic recovery and provide the perfect environment to eliminate joint load and jarring. Water hydrotherapy includes showers, jets, spas, baths, flotation tanks, underwater massage, pools and plunge pools (hot and cold). Many contact team sports in Australia utilise the gravity-assisted advantages of hydrotherapy in the post-game recovery program.

Contrasting hot and cold water immersion provides neural stimulation within the central nervous system, increasing the sensation of arousal and alertness in an athlete and minimising the effect of delayed-onset muscle soreness. Athletes need to be reminded to drink water before, during and after hydrotherapy treatments, as sweating tends to go unnoticed in hot-water environments. Athletes tend to spend too long in a warm environment. In extreme cases, prolonged immersion in hot water can be detrimental, as it can lead to dehydration and neural fatigue. Following hydrotherapy, athletes should feel relaxed and alert, not sleepy and lethargic.

Massage

The physiological benefits of sports massage include increased blood flow, oxygen and nutrient transfer to the fatigued muscles, and the removal of metabolic waste products such as lactic acid. Massage also provides temporary flexibility gains by warming and stretching the muscles. Psychologically, massage allows athletes to feel less fatigued and more relaxed. Massage also provides feedback for the athletes in relation to the areas of the body that are fatigued, tight and sore.

While massage can be expensive for many athletes, simple self-massage techniques are free, quick and easy to administer, yet can be an effective way to minimise shin splints and repetitive strain problems.

Inquire

Weigh yourself on the scales. Using the recommended post-session nutritional requirements provided, give examples and discuss the amount of CHO and protein required following a resistance training session.

Going further 2.48

**Spa or bath, with contrast shower or cold plunge pool**

Alternate hot (39–40°C) and cold (10–12°C)

Spend three to four minutes in the hot, then spend 30–60 seconds in cold

Repeat 3 times

**Showers**

Can be used at any time

30 seconds warm to hot, then 30 seconds cold

Repeat 3 times

Always take a bottle of water or sports drink

*Source: Angela Calder, Recovery training, Australian Institute of Sport.*

Sports massage techniques

There are a variety of massage techniques that can be incorporated into sports massage, including:

- vibration (shaking)
- tapotement (percussion)
- petrissage (kneading)
- effleurage (stroking)
- friction (small-range intensive stroking).

Sports massage incorporates varying combinations of massage techniques, and can be administered during all phases of training.

Massage performed 15 to 20 minutes prior to the session or competition can either relax or stimulate the athlete, depending on the methods adopted. Within the training session, short periods of massage can help athletes cope with the training loads and increase their performance potential. Restorative massage helps reduce muscle tension, fatigue and stress levels.

Injury-prevention massage is generally performed two days after competition, and helps to promote muscle relaxation and return muscles to their ‘normal’ resting state.
Foam roller (an alternative to massage)
Foam rollers have become extremely popular among professional athletes over the last few years. They provide a cheap and effective alternative ‘self-massage’ for athletes who are unable to pay for daily massage. Self-foam rolling, either before or after training, allows athletes to focus on tight, sore muscles and assist in ensuring that muscles remain supple.

Tissue-damage strategies
Cryotherapy, or cold therapy, involves the use of low water temperatures to dissipate body heat from the body, and is extremely effective in reducing pain and inflammation, and removing waste products from the muscle. Cryotherapy may enhance recovery by restricting the inflammatory process. Cryotherapy methods include:

- cold-water immersion
- contrast bathing
- local ice application.

Cold-water immersion
Cold-water immersion involves athletes entering a cold-water bath (4–12°C) for a short interval of one to two minutes followed by 30 seconds’ rest; this process is repeated three to four times. While the physiological benefits of cold-water immersion are not well understood, it may be useful for reducing swelling, soreness and bruising, and is often used in the acute treatment of muscle injuries. Athletes generally report feeling better, with reduced stiffness and tightness, following cold-water immersion.

Cryogenic chamber therapy
Wearing only a bathing suit, socks, gloves, mouth and ear protection, the athlete is placed in a cryogenic chamber that is cooled using liquid nitrogen to a temperature of −110°C. While exposure does not exceed three minutes, the athlete’s skin temperature may drop to 5–12°C; however, the athlete’s core temperature remains relatively unchanged. Such exposure to extreme cold for short durations releases endorphins, providing instant pain relief.

Ice pack therapy
An ice pack is placed over the injured area, promoting immediate vasoconstriction (decreased blood vessel diameter), reducing heat, and decreasing metabolism and blood circulation. Upon removal of the ice pack, blood vessels vasodilate (expand), resulting in fresh oxygen-rich blood full of nutrients flowing to the muscle, thus stimulating recovery and removing lactic acid.
Psychological strategies

While many coaches apply physiological methods of recovery within the training program, the importance of psychological recovery is often overlooked. The psychological benefits of sound recovery practices include increased motivation, a sense of well-being and the reduction of training and/or life stress. Psychological recovery methods include the following:

Meditation
Meditation trains the athlete’s ability to relax the mind, and is a useful tool for helping athletes to control the stress of training, competition and over-arousal. This is achieved by relaxing the parasympathetic (calming) nervous system. Meditation has a number of benefits, including:

• lower heart rate
• lower breathing rate
• lower blood pressure
• relaxation of the muscles
• calming of the sympathetic (excitatory) nervous system.

Like training, meditation is a learned skill that takes time to master.

Progressive muscle relaxation
Progressive muscle relaxation (PMR) is a technique that involves tightening and holding a specific muscle for five seconds before relaxing. Generally, PMR commences from either the feet or the head, and gradually works its way up or down the body. PMR is best adopted either following training or prior to going to bed. Like any skill, PMR requires practice, but once the athlete becomes familiar with PMR training, they will be able to identify the difference between muscle tension and relaxation.

Mental imagery and visualisation
Mental imagery and visualisation involve the athlete using the senses of sight, sound, smell and touch to visualise a state of relaxation, enjoyment, escapism and comfort. Mental imagery and visualisation can be used prior to going to bed in order to switch off and relax. Alternatively, the athlete can use mental imagery to visualise a positive performance or the perfect execution of skills prior to games or training.

Breathing exercises
Breathing exercises are used frequently in the martial arts. They help to relax tight muscles, the result of which is more efficient movement, technique and improved posture. Focusing on breathing during stretching also assists in relaxing both the mind and body. Breathing in through the nose and expanding the rib cage is the most effective method during inhalation, while breathing out through the nose during exhalation is also important.
Flotation for rest and relaxation
Relaxing in a flotation tank or using buoyancy vests in a pool can be useful for promoting a state of weightlessness and relaxation. Flotation takes time to feel completely comfortable; however, it is an excellent method for reducing stress and burn-out. By minimising brain stimulation, the athlete is able to focus more effectively on relaxing and becoming emotionally calm.

Musical
Many athletes enjoy listening to music; however, very few use it effectively as a method of recovery. While it is often used to ‘pump up’ athletes prior to an event, music can be just as effective in promoting relaxation if the appropriate music is selected. By compiling a variety of music to promote either relaxation or arousal, the athlete can manipulate its use. Used prior to going to bed, light, relaxing music is useful in promoting a deep, sound sleep.

Compression garments
Compression garments are increasingly being used as a mode of recovery among many professional team sport athletes. Very few research studies have examined the efficacy of these garments in improving recovery; however, compression garments may:
- enhance blood circulation to peripheral limbs
- reduce blood lactate concentration during maximal exercise bouts
- enhance warm-up via increases in skin temperature
- aid the removal of blood lactate and improve subsequent exercise performance
- reduce the effects of delayed-onset muscle soreness.

While there are many methods of recovery available, sleep, nutrition and hydration are the big three that are necessary for all athletes.

Summary 2.49
1. Outline physiological recovery strategies, providing examples.
2. Outline neural recovery strategies, providing examples.
3. Outline tissue damage recovery strategies, providing examples.
4. Outline psychological recovery strategies, providing examples.
5. Create and evaluate a post-game recovery protocol for a professional team sport athlete.

Checklist 2.50
Research the main features and proposed benefits of a range of recovery strategies.

Other recovery methods often implemented among professional athletes

Wellness monitoring
Many professional strength and conditioning coaches working with team sport athletes require the athlete to provide information relating to body weight, sleep quality, stress levels, fatigue, training enjoyment and muscle soreness. Wellness monitoring encourages an athlete to monitor and recognise the body’s physiological and psychological responses to training, competition and general lifestyle. Data also allow the coach to monitor how the athlete is responding to the demands of training and competition, and to individualise training loads accordingly.
NRL recovery

The following is an example of a recovery protocol implemented among National Rugby League players following an NRL game.

During an NRL game, players cover upwards of 8 kilometres at an average heart rate of around 165 bpm. Following the game, the players are in a state of muscle catabolism (muscle breakdown), so it is imperative that active recovery methods are implemented as soon as possible in order to promote muscle recovery (anabolism) and the replenishment of fluids and muscle glycogen stores as quickly as possible.

Step 1: Replenish lost fluids and energy stores lost during the game

When the players return to the dressing room following the game, they weigh in to assess the amount of fluid lost during a game. It is not uncommon for players to lose in excess of 3 litres of fluid during the course of a game. Players commence fluid intake in order to replenish hydration stores. Within 15 minutes of the players finishing the game, they consume a liquid post-exercise sports drink that contains both carbohydrates and amino acids.

Step 2: Low-intensity aerobic exercise and flexibility (cool-down)

The players commence 5 to 10 minutes of light aerobic exercise on stationary bikes. Low-intensity aerobic exercise promotes blood flow to the muscles and assists in the removal of lactic acid and waste products that build up as a result of exercise. Low-intensity aerobic exercise also promotes the transfer of nutrients to the muscle to assist recovery. Light static stretching follows the light aerobic exercise, and helps to restore muscle length to normal. Players’ muscles become extremely tight following games. Each static stretch is held for around 15 seconds.

Step 3: Contrast baths

The players perform three to four cycles of 30 seconds of cold (10–12ºC) and two to three minutes of hot (39–40ºC). The process of vasodilation (expanding) and vasoconstriction (constriction) of the blood vessels sends oxygen to the muscles, and assists in nutrient transfer and the removal of waste products.

Step 4: Nutritious meal and continued hydration

The players sit down with family and friends, and consume a meal containing high carbohydrates and moderate protein food options in order to further promote the replenishment of muscle glycogen and protein synthesis. Players continue the process of rehydration during this time. Rehydration may take 24 to 48 hours, depending on the level of dehydration. Psychologically, sitting down with family and friends allows the players to mentally unwind and relax following the game.

Step 5: Sleep

Getting quality sleep – at least eight hours – is also an important part of short-term recovery. Sleep and rest are necessary for soft-tissue (muscles, tendons, ligaments) repair and the removal of chemicals that build up as a result of cell activity during exercise.

Figure 2.111 In Step 2, players cool down by doing 5 to 10 minutes of low-intensity aerobic exercise on stationary bikes
2.4 The impact of the acquisition of skills on performance

Driving questions 2.51

1. What was the last physical skill you learned?
2. How long was it until you felt confident performing the skill?
3. What factors made learning this skill easier or more difficult?

Stages of skill acquisition

Cognitive

The cognitive stage is the initial stage of learning a new skill. It is essential the athlete gains an understanding of the skill and how it can be applied to their sport. The process might begin by watching the skill performed by someone who is proficient and then breaking it down into smaller components for teaching. The stimulus given to the athlete in the form of videos and demonstrations must be balanced so as not to overload the athlete with information that may cause confusion and anxiety.

The physical practice of the skill is critical to this stage. The complexity of the skill will determine how many steps the teaching and practice is broken into, and how long it will take to move to the next stage. A coach will use drills as a way of breaking the skill into smaller components. As these drills are mastered, the athlete can start linking the entire skill together. While practising in the cognitive stage, athletes will typically make errors and require external feedback from the coach/teacher to help guide them. In most cases, positive reinforcement when something is done well must be a feature of the coach’s feedback. The use of negative and defamatory language is usually of little assistance to the athlete.

The two biggest factors dictating how quickly it takes an athlete to move beyond the cognitive stage are the coach and the complexity of the skill. Some athletes may take as little as a few minutes or as long as many weeks to learn a new skill. Visualisation, or mental rehearsal, is a sound coaching strategy during this stage. Visualising the successful execution of the skill can be quite beneficial.

Associative

The second stage of skill acquisition is referred to as the associative stage. This stage is characterised by less tuition from the coach and more practice from the athlete. During this stage, the athlete is doing less of the drills and is more focused on practising the entire movement involved in the new skill. Errors still occur, but with frequent practice these will be reduced and the athlete will begin to gain some fluency in the execution of the skill. Feedback from the coach is still important, but through greater understanding the athlete will begin to be able to provide some of their own feedback as well. This is an important point in the acquisition of the new skill because, as the athlete begins to feel more proficient, their confidence also increases. The increased sense of confidence is a critical step in the psychology of the athlete, as it represents the point at which the athlete feels comfortable performing the skill. With confidence and ability, the athlete can move to the third stage of skill acquisition. Some athletes, however, remain at this stage, and never get to a level where the skill can be performed automatically.

Autonomous

The third and final stage of skill acquisition is the autonomous stage. As the name suggests, at this stage the athlete performs the skill automatically. They need not consider and plan the skill’s implementation – it can simply be performed consistently and accurately when required. They are able to link the sub-routines together easily and in the correct order. Although there may be some errors, these are very occasional and are generally corrected quickly without external feedback. The skill is executed efficiently, effectively and in a way that is visually attractive. When this level of execution is practised, the athlete can be in a state of physical and psychological harmony. This state is referred to as ‘flow’.

When athletes perform skills autonomously, they have great ability to attend to all the other

Summary 2.52

Outline the three stages of skill acquisition.
Chapter 2  Factors Affecting Performance

Chapter 2  Facts Affecting Performance

demands of their sport. For example, when a skill is autonomous, the athlete can pay greater attention to reading the play and making the correct decisions as far as who to pass the ball to or which weakness in the opposition to exploit.

Characteristics of the learner

Personality

Personality represents the common characteristics that shape an individual’s pattern of behaviour. Personality is developed over a lifetime as a result of our ongoing social interactions; however, common behaviours form what is referred to as one’s character. The personality traits of an athlete will determine the rate at which they acquire new skills and how well they can apply them. For example, athletes who are enthusiastic, reliable and determined will be more likely to apply themselves to training and preparation than those who are lazy and unmotivated. Even at elite levels of sport, coaches target athletes for their positive attitude as well as their raw talent.

Heredity

The heredity of an athlete is the major factor that determines their potential to succeed. These are the psychological characteristics, physical attributes and biology that are passed on from the athlete’s parents. It is not uncommon for elite athletes to have parents and/or siblings who have also been highly successful at their sports. Such characteristics as height, body shape, limb length, personality, intellect, games sense and much more are directly impacted upon by one’s genetics. However, while the athlete can inherit many wonderful qualities from their parents, it is important for these qualities to be nurtured. Simply being born with natural sporting talent is no guarantee of sporting success. The environment in which the athlete grows up, the access the child has to skill development and the hard work the athlete is willing to put in can all either help or hinder what genetics has provided.

Confidence

Confidence develops through prior success, and represents the belief that a person will succeed. To be confident, an athlete must strike a balance. An athlete who believes they can achieve something difficult is far more likely to succeed than the athlete with self-doubt. For this reason, confidence is critical to the acquisition of new skills. Athletes must believe they can complete the skill autonomously, even before they actually can. It takes supreme confidence to believe in one's ability even when things like learning a new skill are difficult and seem unattainable.

Prior experience

Prior experience is another factor that will influence an athlete when learning a new skill. It involves a transfer of learning. An athlete who has already sampled something similar will have physical skills that may be transferable, and confidence that they can use their prior experience to accelerate their learning curve. A good example of prior experience and its influence on learning new skills is diving. Many Olympic-level divers have been gymnasts for many years. Gymnasts already possess a mastery of their movement, and can easily flip, tumble, turn and contort their bodies into the necessary positions for success in diving. There are many examples of elite athletes who have changed sports and succeeded in transferring their skill base. Prior to winning the Tour de France, a road cycling event, Cadel Evans was a world champion cross-country mountain biker.

Ability

Ability represents the athlete's performance. How well can the athlete take all the different

Summary 2.54

Outline the characteristics of the learner that impact on skill acquisition.

Checklist 2.55

How do the characteristics of the learner influence skill acquisition?
skills and apply them in a competitive arena? An athlete with high levels of ability (often inherited) can consistently acquire the new skills faster. An athlete who does not possess the natural ability will need to work harder and demonstrate greater determination if they wish to succeed. For example, cricketer Sir Donald Bradman not only attained the established skills of batting more easily than most, but revolutionised new skills that his contemporaries tried to emulate.

The learning environment

The learning environment refers to all the external influences on athletes while they are learning new skills. Elements like the weather, the playing surface and the coach’s feedback are examples of the learning environment.

Nature of the skill

The first area to consider in the learning environment is the nature of the skill. Skills can be defined and categorised. Most are classified into one or more of the following categories:

- open or closed skills
- gross motor or fine motor skills
- discrete, serial or continuous skills
- self-paced or externally paced skills.

Open and closed skills

Closed skills are those that are executed in a controlled and stable environment, or one that is the same every time the skill is repeated. A closed environment is difficult to create, and is not seen in many competitive sports. An open skill refers to skills performed in a dynamic environment. The open skill is performed accurately in spite of the environmental influences. Closed skills are often useful when learning. This allows the athlete to concentrate on the skill; however, as they become more proficient, the coach will introduce other elements to make it an open skill.

For example, if a batsman in cricket wants to learn the square cut, the athlete may begin by setting a bowling machine to bowl the ball in the perfect position every time for a square cut. The athlete would also train in the indoor net on the same surface every time, as this would create a more closed environment. As the batsman becomes more proficient at the shot, the coach can introduce different bowling speeds, varying bowling lines and lengths as well different surfaces and outside pitches, thereby making the skill more open. Defining a skill as open or closed is difficult because most skills tend to lie on a continuum. Some are more open than closed while others progress back and forth on the continuum, depending on the environment.

Gross and fine motor skills

Gross motor skills are those that require large muscle groups to execute them – for example, run, hop, skip, jump. Alternatively, fine motor skills require only small muscles to execute the skill. Fine motor skills are more delicate, and the most

Going further 2.56

Inquire

1. Place the following sports onto a continuum from closed to open skills:
   - ten-pin bowling
   - lawn bowls
   - basketball
   - surfing.

2. Place the following skills (all during a game) onto a continuum:
   - basketball free throw
   - basketball lay-up
   - basketball dribble
   - basketball pass to restart play.
common examples are things like writing, cutting and drawing. Fine motor skills in sports are more difficult to identify, as most sporting performance uses gross motor skills. Sporting examples come from more sedentary activities like chess, darts and putting.

**Going further 2.57**

**Inquire**

Place the following sports onto a continuum from gross to fine motor skills:
- kicking a ball
- swimming
- dart throwing
- weightlifting.

Discrete, serial and continuous skills

Skills can also be classified based on the process or steps it takes to complete them. The simplest classification is of a discrete skill, which can be defined by having a clear starting and finishing point — for example, catching a ball in basketball.

A serial skill is one that links together several discrete skills. A lay-up in basketball is an example of a serial skill; the athlete must dribble, jump and shoot, all as one skill. The next classification is a continuous skill, which is repetitive and ongoing — for example, dribbling or running in basketball.

Self-paced and externally paced skills

Pacing is another classification factor when considering the nature of the skill. Specifically, the skill is defined as either self-paced or externally paced. In sport, this often involves the athlete’s proficiency at a skill coming to the fore when they participate in competition.
paced. Self-paced skills are those in which the athlete controls the timing – for example, a tennis serve. An externally paced skill is controlled by factors outside of the athlete’s control – for example, returning the tennis serve. Another example in cricket is where the bowler is self-paced while the batsman is externally paced.

### Going further 2.59

**Inquire**

Place the following skills onto a continuum from self-paced to externally paced skills:

- swimming
- javelin throw
- kicking a goal in Rugby Union
- surfing.

The performance elements

The performance elements are critical for the athlete’s success in a competitive environment. While athletes may demonstrate proficiency at a skill during practice, they must also be able to apply it during competition. In addition to building the skill, the coach must develop performance elements like decision-making, and strategic and tactical awareness. While skill development is fundamental to any training session, as the athlete progresses the coach should use techniques that develop the skills through competitive games. This is referred to as the game-centred approach. A soccer coach who gets their players to practise passing through small-sided games is applying this principle. In this scenario, the soccer players enhance their passing game while in an open environment in which they have to balance all the uncontrolled environmental factors like surface and defence.

Decision-making is a skill that can only be learnt through experience. Knowing when to pass the ball or draw a player, or which opposition weakness to target, is a crucial performance element that needs to be developed. Presenting athletes with scenarios that are both theoretical and practical is a good way to develop decision-making skills. Taking time out after training and competition to debrief specific decisions and their level of success can ensure continuous improvement.

The athlete who can manipulate a game to their advantage is said to have strategic and tactical

### Going further 2.60

**Inquire**

1. Research TGfU or the Game Sense Model. What does the model involve? What are its advantages and disadvantages?
2. Research the advantages and disadvantages of other instructional methods.
awareness. The knowledge and confidence to take leadership of a situation so as to ensure the best possible result for the athlete, and possibly the team, is immensely powerful in sport. More often than not, opponents can possess similar skills and ability: it is strategy alone that makes the difference between winning and losing. In soccer, coaches and players implement formations targeted at guaranteeing their team’s strengths and exposing the opposition’s weaknesses.

Practice method

Massed and distributed practice
Massed practice is when the session is all blocked together and no break is taken. This is ideal if the training schedule does not allow for multiple days of practice or the athlete is highly motivated. A coach may assign an hour of training time to a particular skill. Massed practice is suitable for discrete and simple skills. This type of training is beneficial for beginners, as they can consolidate their learning.

Distributed practice is when the rehearsal session is broken into smaller parts, or is interspersed with small breaks. This is a good way to learn complex skills as the athlete can remain free from fatigue and apply their concentration. In a distributed form of practice, the coach would implement the skill rehearsal in four 15-minute blocks across four days. Distributed practice is suited to continuous and complex skills, as well as skills that may result in injury.

Whole and part practice
Whole practice is a method in which the whole skill is practised in its entirety. This type of practice allows the athlete to get a sense of the skill while also developing their kinaesthetic sense.
Part practice involves breaking a skill down into its components and rehearsing each component separately before combining them into the whole skill. This is suitable for complex skills.

Feedback
Feedback is a process by which information about a past or present event is provided. The information may come internally or externally, during or after the event, and/or as result within a game. Feedback is very important as part of the learning process.

Summary 2.61
1 Outline the nature of skills and provide examples.
2 Outline the performance elements and provide examples.
3 Outline the various practice methods and determine which method would suit beginners versus advanced performers.
4 Outline the various forms and feedback and determine which would be suited to beginners and advanced learners.
because it helps to shape improvement and development.

Internal and external feedback
Internal feedback is received from signals within the body. These are sometimes referred to as proprioceptive signals. The skill is performed, and during the execution the athlete can judge the success by the way it feels. For example, an AFL player kicking a goal knows when their foot strikes the ball whether they did so in a manner that was appropriate and in line with what they should feel if they are going to score a goal. Quite often, players indicate that they know a goal will be successful a long time before it goes between the posts simply because it ‘felt good off the boot’. External feedback is when the information comes from a source outside the body. The type of external feedback can vary from a crowd’s applause at their approval to video analysis with a coach. Scoreboards, stopwatches, team-mates, parents and coaches all provide external feedback.

Concurrent and delayed feedback
The moment at which feedback is received will also play a part in the learning process. Feedback that is received at the time when the skill and or movement is performed is referred to as concurrent (continuous) feedback. This feedback occurs simultaneously with the skill being performed. Concurrent feedback is always internal. The AFL kicker in the above example also experiences concurrent feedback.

Delayed feedback occurs after the event. An example would be when a golfer hits the ball. The feedback comes in the form of where it lands on the fairway.

Knowledge of results and performance
Feedback can also be classified in terms of results and performance. An athlete’s knowledge of results represents one variety of this feedback. Knowledge of results comes after the skill has been executed, and takes its form in how many goals were scored, the time it took and so on. For example, a netball shooter may take 36 shots in a game and score 34 goals. This knowledge of the result helps to provide feedback.

Knowledge of performance also provides feedback through more specific skills-based indicators. For example, after the netball game in which the shooter scored 15 goals from 36 attempts, the coach may talk through with the athlete technical points such as hand position on the ball, position to the net and the angle of release.

The knowledge of performance provides direct information about the quality of execution. The kinaesthetic sense of an athlete can also provide knowledge of performance. Often athletes can be happy with their performance despite the result, due to the quality of the performance. The opposite is also true, with an athlete achieving victory despite playing badly. Both situations still provide the athlete with useful feedback.

**Checklist 2.62**

Design a plan for teaching beginners to learn a skill of your choice. They should learn the skill to mastery. In your plan, consider:
- practice methods
- performance elements
- characteristics of the learner
- feedback.

**Assessment of skill and performance**

Gathering information about the athlete’s performance is important, and will be used to shape future training programs, highlight weaknesses and

**Driving questions 2.63**

Reflect on the last competitive game you watched.
1. Who won?
2. How was this decided?
3. If you described the game to a friend, would you use any other information to describe the quality of the performances?
suggest areas for development. The gathering and assessment of performance data is popular across professional sports, with many software products available to help analyse an athlete’s performance.

Characteristics of skilled performers
Close observation of an athlete who demonstrates not only proficiency but mastery of a skill will highlight key characteristics. The characteristics of a skilled performer include kinaesthetic sense, anticipation, consistency and technique, as well as their mental approach.

Kinaesthetic sense
This is considered the ‘sixth sense’ for athletes. The ability to feel and sense their movements is part of their autonomous performance. Thus they can correct and tweak their performance mid-movement or game. The kinaesthetic sense of a highly skilled athlete is one of their greatest weapons. This is demonstrated when an athlete is able to ‘feel’ what is happening, and know how they need to adjust even the smallest of movements to adapt to and conquer the situation. Former surfing world champion Kelly Slater showed tremendous kinaesthetic sense at the height of his career. He would regularly make small adjustments to his movements while surfing, depending on the prevailing conditions. His kinaesthetic sense presented itself as a fluid, technical and entertaining form of surfing never seen before.

Anticipation
Anticipation is the ability of someone to predict an outcome and act accordingly. A skilled performer with anticipation is able to stay ahead of their opponent using their instinctive awareness to counter them. In field hockey, an athlete with good anticipation is able to predict the direction of a pass, which space to manoeuvre towards and which way an opponent may strike the ball for a shot. This player tends to be ahead of the game, and therefore has greater time to respond. Through time and experience comes greater capacity for the athlete to outplay their opponent.

Consistency
Consistency is the ability to do something repeatedly and achieve the same result. A skilled performer is said to consistently perform at a high level. This simply means that they can perform their chosen skill under the pressure of competition and achieve great results. For example, the best basketballers consistently make their shots. An unskilled performer will fail to make the majority of their shots – sometimes they get a couple of good shots but on other occasions they miss badly. Most people can execute a particular skill reasonably well; however, the skilled performer can execute the same skill to a higher standard repeatedly. This consistency is very important in maintaining form across long seasons or during a game that requires constant attention and focus.

Technique
The technique of a skilled performer is an important characteristic. Technique is the procedure and method of executing the skill. The athlete with a superior technique has absolute control over their body and how it delivers the desired outcome. With well-developed technique comes efficiency and economy of movement, less chance of injury, greater kinaesthetic sense and, most importantly, a greater chance of performing the skill successfully.

Mental approach
The mental approach is often said to make the difference between champions. Many athletes are physically gifted and train exceptionally hard, yet never succeed. Therefore, the mental aspect of an athlete must play a role in success at the elite level.
Objective and subjective performance measures

To measure performance enables the coach and athlete to study and analyse their performance and that of an opponent more closely. Measurement normally involves gathering information and data. There are two styles of measurement:

- **objective measurement**
- **subjective measurement**.

To objectively assess something, the judge must use a concrete measuring tool like a tape measure. When a long jumper lands in the sand, the judge measures the distance of the jump with the tape measure. The distance they have jumped cannot be disputed. This is an objective measure, and is said to be more reliable.

A subjective assessment is based more on opinion. For example, while long jump, high jump and sprint races all have objective measurement tools, a gymnast or a diver is judged on the basis of someone’s opinion, and hence this is a more subjective form of assessment. Sports that are measured subjectively often attempt to mitigate certain factors in order to create a more objective measure. Gymnastics judges must be experienced, impartial and able to apply the judging criteria. Most athletes and coaches favour the measurement tools that are more objective, as the results have greater reliability.

Validity and reliability of tests

Validity and reliability are two characteristics that establish the credibility of an assessment. If these characteristics are lacking, the results could be inaccurate or misleading.

- The validity of the test is defined by its ability to measure what it intends to. For example, a sit-and-reach test is a valid test of hamstring flexibility. This is proven, as the range of movement required comes through the hamstring muscle and surrounding joints. If the sit-and-reach test were used to measure shoulder flexibility, it would be an invalid test. Validity requires the test and the subject being measured to share a relationship. While a shuttle-run test is a valid measure of cardiorespiratory fitness in a runner, it would be an invalid test of strength. Significant work is often required to establish the validity of a test.

- Reliability is a measure of consistency. Can the test achieve the same result if repeated? For example, if the sit-and-reach test is repeated again and again on the same subject, does that person achieve the same or similar results? There is often a plethora of variables that can potentially influence an assessment or test. In the case of sporting tests, the variables may include weather, opponents, equipment, surface and so on. If the test is to be regarded as reliable, it is important that these variables are controlled. This is why ergometers are often used to test power, speed and oxygen capacity. For example, if a rowing athlete wanted to test their power output, they would be best to use a rowing ergometer. The ergometer would be set up inside, and variables like temperature, wind resistance and water conditions could thus be controlled.

Personal versus prescribed judging criteria

There are two recognised measures for judging: personal or prescribed criteria. A personal criterion is judgement that is based on opinions, feeling and emotions about the performance. Often, coaches may use instinctual understanding and their personal judgement to choose a team. Spectators and fans always use personal criteria to assess the performance of everyone, from their favourite player to the umpire. This is a subjective form of appraisal.

A more complex and objective way to make a judgement is to apply a prescribed criterion. The application of prescribed judging criteria is common in sports like gymnastics and diving. The criterion helps to validate the judge’s opinion and
improves the objectivity. The administrative body that oversees the sport will develop a set of criteria to identify specific elements the performance must include to achieve a certain score.

**Checklist 2.66**

Develop measures to appraise performance. Which appraisal measures were most consistent, and why?

**Figure 2.123** An official stands by to measure the distance of an athlete’s long jump. This is an example of an objective performance measurement.
The living human body is a complex machine, consisting of a number of interdependent body systems (such as the cardiovascular, digestive and muscular systems), carefully organised to produce an amazing holistic system characterised by balance, and the ability to sustain itself and produce vast amounts of mechanical and intelligent output. All of these functions require a constant source of energy or fuel to enable each cellular process.

Three systems are used to resynthesise ATP. The initial system is the phosphocreatine system; the second system is anaerobic glycolysis; the third system is the aerobic energy system. The body’s use of each energy system represents a complex interplay of fuel supplies, as each energy system seamlessly draws energy from all three systems to varying degrees.

Utilising the aerobic energy system, an athlete’s aerobic endurance levels are commonly developed using four traditional methods of training: continuous, fartlek, interval and circuit. Anaerobic training is used by athletes in non-endurance sports, and is effective for developing strength, speed and power. It is also used by body builders to build muscle mass.

The four most commonly used methods of developing joint flexibility are static stretching, ballistic stretching, proprioceptive neuromuscular facilitation and dynamic stretching.

Strength training comprises a variety of resistance exercises and methods that promote muscular contractions to build muscular size, strength and power. Strength training methods include free weights, weight machines, resistance bands and hydraulic machines.

A unique feature of the sporting environment is the high degree of competitiveness and public exposure that exists, which most people do not have to deal with on a day-to-day basis. Highly motivated athletes train more intensely and are more driven to succeed when competing. There are two broad types of motivational factors: positive and negative. There are also two sources of motivation: intrinsic and extrinsic.

Increased anxiety levels can be detrimental to the performance of athletes. Athletes need to learn to handle two categories of anxiety: trait and state anxiety.

All sports require athletes to be in a certain mental state and condition prior to competing. This differs between sports, and athletes also present with individual differences in their mental state during the final moments prior to competing. Research has found that different tasks require different levels of arousal for optimal performance.

Athletes must maintain their concentration and attention on relevant cues, and be able to ignore cues that are largely irrelevant. All sporting scenarios present a unique challenge to the athlete when it comes to maintaining the correct focus.

Being able to control doubt, fear and anxiety while remaining centred and focused can provide the edge required for victory. Both real and fictitious images created in the mind can help athletes to achieve both these goals. Athletes can use their imagination and visual memory to improve performance. Two major types of imagery used are mental rehearsal and visualisation.

Goals are important to help keep athletes accountable to a previously established expectation or standard, and the athlete may have several goals in place at any one time in relation to a range of lifestyle, training and performance factors.

Recovery is the time required for the repair of damage to the body caused by training or competition, and is crucial to optimal sports performance for many reasons, some of which are physiological and some psychological. Recovery strategies comprise physiological, psychological, neurological and muscle damage strategies: cool-down, hydration, nutrition, long-term recovery, hydrotherapy, massage and foam rollers.

The psychological benefits of sound recovery practices include increased motivation, a sense of well-being and the reduction of training and/or life stress. Examples of psychological recovery
methods include meditation, progressive muscle relaxation, mental imagery and visualisation, breathing exercises, floating for rest and relaxation, and music.

- The cognitive stage is the initial step in learning a new skill. It is essential the athlete gains an understanding of the skill and how it can be applied to their sport. The second stage of skill acquisition is referred to as the associative stage. This stage is characterised by less tuition from the coach and more practice from the athlete. The third and final stage of skill acquisition is the autonomous stage. As the name suggests, the athlete performs the skill automatically at this stage.
- Most skills are classified into one or more of the following categories: open or closed skills; gross motor or fine motor skills; discrete, serial or continuous skills; self-paced or externally paced skills.
- Feedback is a process by which information about a past or present event is provided. The information may come internally or externally, during or after the event, and/or as the result of a game. Feedback is very important as part of the learning process because it is feedback that helps to shape improvement and development.
- Close observation of an athlete who demonstrates not only proficiency but mastery of a skill will highlight key characteristics. The characteristics of a skilled performer include kinaesthetic sense, anticipation, consistency and technique.
- Measuring performance enables the coach and athlete to study and analyse their performance and that of an opponent more closely. Measurement normally involves gathering information and data. There are two styles of measurement: objective and subjective measurement.
- There are two recognised measures for judging: personal criteria or prescribed criteria. A personal criterion is judgement based on opinions, feeling and emotions about the performance. A more complex and objective way to make a judgement is to apply a prescribed criterion.

**Multiple-choice questions**

1. The human body only has enough ATP to survive for how long?
   - A 1 minute
   - B 30 seconds
   - C 10 seconds
   - D 5 seconds

2. Which of the following is NOT one of the three distinct energy pathways or systems that are used to ensure the body is never depleted of its ATP stores?
   - A anaerobic glycolysis
   - B aerobic energy system
   - C phosphocreatine system
   - D adenosine diphosphate

3. Which of the following is NOT a characteristic of the aerobic system?
   - A Lactate is a by-product of energy production.
   - B Carbohydrates and fat are its sources of fuel.
   - C The system can operate for 60 seconds-plus.
   - D Its cause of fatigue is depleted fuel sources.

4. A trained athlete is more likely to have a resting heart rate closer to what?
   - A 70 bpm
   - B 80 bpm
   - C 60 bpm
   - D 50 bpm
Multiple-choice questions (continued)

5 Which of the following is NOT a characteristic of fast-twitch muscle fibres?
   A They are fatigue resistant at submaximal intensities.
   B Shot putters are suited to higher percentages of FT fibres.
   C They are often described as white muscle fibres.
   D ATP is metabolised at a faster rate than ST fibres.

6 High levels of arousal are NOT suited for which of these sports?
   A weightlifting
   B boxing
   C Rugby Union
   D shooting

7 For the athlete, the pre-event meal should NOT be:
   A low in carbohydrates
   B moderate in protein
   C low in fibre
   D low in fats

8 Which of the following is NOT an indicator of over-training and under-recovering?
   A decreased appetite
   B sleep disturbances
   C increased susceptibility to illnesses
   D positive changes in aerobic and anaerobic levels

9 In order to replenish 1 litre of lost fluid, it is necessary to consume at least how many litres of fluid?
   A 2 litres
   B 1 litre
   C 1.5 litres
   D 3 litres

10 Which of the following foods does NOT have a high glycaemic index (GI)?
   A white bread
   B pasta/noodles
   C rockmelon
   D raisins
Exam-style questions

1. Analyse the energy systems used by a triathlete.
2. Identify a team sport and analyse the energy systems used.
3. Which type of training is best suited to marathon running and which training methods would be most appropriate?
4. Which type of training is best suited to weightlifting?
5. How does flexibility training affect performance?
6. Apply the principles of training to aerobic training.
7. Outline physiological adaptations in response to aerobic training.
8. Identify three physiological adaptations due to training, and examine how they would contribute to improved performance.
9. Describe the different types of motivation that can affect performance.
10. Explain the difference between anxiety and arousal in terms of sporting performance.
11. Compare psychological strategies that an archer and a netballer would employ to enhance motivation OR manage anxiety.
12. Compare the dietary requirements of a power athlete and an endurance athlete.
13. Analyse the use of protein as a supplement to improve performance.
14. Analyse the use of creatine as a supplement to improve performance.
15. Describe the range of recovery strategies used by athletes to improve performance.
16. Describe the stages of skill acquisition.
17. Outline the influence of heredity on skill acquisition.
18. Discuss the influence feedback has on the acquisition of skills.
19. Describe the learning environment that would best suit a cognitive learner.
20. Outline the characteristics of a skilled performer.
21. Why may a coach use objective and subjective performance measures to appraise the performance of an athlete?