INQUIRY QUESTION
What legal and illegal substances and methods can be used to enhance the performance of the musculoskeletal system to improve the strength, power and speed of an athlete?
Legal and illegal performance-enhancing substances and methods are used by many athletes to give them an advantage over the competition. As well as providing benefits to the athlete, they may also potentially harm the athlete.

**KEY KNOWLEDGE**
- Actual and perceived benefits and potential harms of legal and illegal substances and methods that enhance performance of the musculoskeletal system, such as training, nutritional supplements, creatine supplementation and hormones (including steroids and growth hormones)
- The ethical and sociocultural considerations of legal and illegal practices associated with enhancing the performance of the musculoskeletal system in sport

**KEY SKILLS**
- Investigate, evaluate and critically analyse a range of performance-enhancing practices from a physiological perspective
- Discuss the ethical considerations and sociocultural influence on the use of legal and illegal practices associated with improving the function of the musculoskeletal system

**CHAPTER PREVIEW**
**KEY CONCEPT** Performance enhancement includes any method, device or substance that has the potential to improve athletic performance. These enhancements can be legal, such as training methods or naturally occurring food sources, or they can be illegal, such as synthetically manufactured hormones.

A number of practices are employed by athletes today to enhance their performance and assist with training and recovery. Performance-enhancing methods and substances are used by many athletes and are thought to improve performance by:

- influencing the physiological capacity of a particular body system (e.g. use of creatine supplementation to increase creatine stores in the muscle for replenishment of ATP)
- removing physiological constraints that impact on performance (e.g. use of diuretics to reduce body weight so the athlete is lighter or makes a weight category)
- increasing the speed of recovery (e.g. use of compression garments to increase blood flow and removal of wastes).

Performance-enhancement techniques can be categorised as mechanical, nutritional, pharmacological, physiological or psychological depending on what the substance or method does and how it interacts with the body to enhance performance. Examples for each of these categories include:

- **Mechanical** — devices including heart rate monitors, weights, sports clothing and footwear, and equipment
- **Nutritional** — food sources including caffeine, creatine and sports drinks
- **Pharmacological** — synthetically produced drugs including anabolic steroids, beta blockers and amphetamines
- **Physiological** — practices and use of naturally occurring products including blood doping, EPO, human growth hormone
- **Psychological** — methods including imagery, meditation, music, relaxation.

![Figure 5.1](image.png)

**FIGURE 5.1** Specially designed clothing can help athletes improve their performance.

**TEST your understanding**

1. Define the term *performance enhancement*.
2. List the five categories of performance-enhancement techniques and include three examples for each category.

**APPLY your understanding**

3. (a) Identify the ways performance-enhancement techniques are thought to improve performance.
   (b) For each way identified in part (a), suggest types of athletes who may use performance-enhancement techniques to gain these improvements.
KEY CONCEPT There are a variety of ways to legally enhance performance. One of the most obvious legal methods is through specific training methods and aids.

As previously discussed, the musculoskeletal system has an important role in body movement, as well as creating energy for movement. Muscles attach to bones to create movement and the reactions that take place with the muscle determine how hard, fast or long we can work. The musculoskeletal system contributes to both aerobic and anaerobic energy production.

A variety of training methods and aids can be used by athletes and coaches to enhance performance of the musculoskeletal system. By determining the relevant fitness components, energy systems and muscles used in each sport, athletes and coaches can decide on the best method to improve an athlete’s performance.

Training methods that can specifically enhance performance of the musculoskeletal system include:

- anaerobic training methods such as resistance training, plyometric training and short, intermediate or high intensity interval training to develop power, strength and speed
- aerobic training methods such as continuous training, fartlek or long-interval training to develop endurance.

Through specific training a number of chronic muscular adaptations occur to enhance an athlete’s performance. These are outlined in table 5.1.

### TABLE 5.1 Chronic muscular adaptations of anaerobic and aerobic training

<table>
<thead>
<tr>
<th>Chronic adaptation</th>
<th>Benefit to performance</th>
<th>Potential harms</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anaerobic training</td>
<td>Increased strength, power and/or speed via: Greater strength and force created by the muscle Greater capacity to produce energy quickly Faster speed of muscle contraction Greater ability to continue to work at higher intensities Increased capacity to tolerate by-products and delay the onset of fatigue</td>
<td>Risk of injury due to: Lack of adequate fitness Incorrect application of training principles Not enough recovery Too heavy resistance Incorrect technique Overtraining</td>
</tr>
<tr>
<td>Increased number and size of myofibrils Increased stores of ATP, CP and glycogen Increased glycolytic capacity Increased speed of contractions Increased tolerance to accumulation of metabolic by-products</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Aerobic training</td>
<td>Increased endurance via: Greater capacity to produce energy due to more sites for aerobic energy production Greater capacity to work for longer due to greater fuel availability Ability to work aerobically at higher intensities for longer Delayed lactate inflection point (LIP) therefore decreased reliance on anaerobic energy systems</td>
<td>Risk of injury due to: Lack of adequate fitness Incorrect application of training principles Not enough recovery Incorrect technique Overtraining</td>
</tr>
<tr>
<td>Increased size and number of mitochondria Increased myoglobin Increased stores of glycogen and triglycerides Increased capacity to oxidise glucose and fats Increase a-VO₂ difference Decreased use of the anaerobic glycolysis system</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Chronic adaptation consists of the long-term responses of body systems, developed over a period of time in response to a training program.
5.2 Legal substances and methods: training methods and mechanical aids

**Figure 5.2** A variety of methods can be used to train the musculoskeletal system, both anaerobic and aerobic training.

**Anaerobic training methods**

**Resistance training**

*Anaerobic training* involves exercising a muscle or group of muscles against a resistance. It is the most common training method used to develop muscular strength, power or endurance.

The main physiological effects of using resistance training to enhance the performance of the musculoskeletal system include:

- Increased muscle size, mass and fuel stores
- Increased bone density and strength.

These changes benefit the performance of the individual as they lead to an increased capacity to produce the greater strength and/or power required to run faster, throw or kick further, or jump higher in their chosen sport.

While resistance training is a very good way to develop the musculoskeletal system, athletes need to consider the potential harms from engaging in this type of training. Harms can include:

- Overtraining — not allowing enough recovery between sessions for the muscles to repair and grow
- Injury — lifting too heavy a weight or using incorrect technique, placing stress on muscles, bones and joints.

As discussed in chapter 3, muscle contractions are classified according to the movement they cause:

- Dynamic (concentric, eccentric, isokinetic, isoinertial) and
- Static (isometric).

Resistance training methods are based on each of these classifications and can involve the use of free weights, machine weights and body weight.

**Figure 5.3** Resistance training methods involve different types of muscle contractions: (a) isoinertial free weight training (b) isometric training.
Mechanical aids to resistance training

In addition to the traditional use of dumbbells, barbells and weighted machines, resistance training can also incorporate a variety of mechanical aids. These aids can include tyres, parachutes, elastic cords and weighted vests. These aids aim to provide added resistance while completing sport-specific movement, such as running, to develop strength and power specific to the muscles used in the activity.

![Figure 5.4](image)

**Figure 5.4** Mechanical aids such as parachutes, tyres and resistance cords can be used to assist resistance training.

Plyometric training

The aim of **plyometric training** is to increase muscular power by first stretching a muscle (eccentric contraction) and then contracting it (concentric contraction) in the shortest time possible.

This training method takes advantage of the stretch-shortening cycle or the stretch reflex. This is where the body attempts to resist the sudden change in muscle length by calling on the stretched muscle to contract, and thus prevent the suddenly stretched muscle from tearing. Essentially, plyometrics trains this reflex to develop a more powerful contraction of the muscle. The benefit of this type of training is it allows the athlete to produce more explosive power when running, jumping, kicking or throwing, depending on the muscles focused on.

Because plyometric exercises can create so much muscular power, potential harms relate to the safety and appropriateness of the exercises being performed and specific guidelines should be followed. These exercises can place considerable stress on the body and joints and are not recommended for individuals with poor fitness levels. Individuals should start with low-impact activities before progressing to those which place greater stress on the body. If not completed correctly and without adequate fitness or recovery, plyometric training has the potential to cause injury through tearing of the muscles.

Examples of plyometric exercises are shown below:

- **Low impact drills**, such as:
  - skipping with and without a rope
  - doing low hops, step and jumps
  - throwing a light (2.5 kg) medicine ball (see figure 5.5a),

- **High impact drills**, such as:
  - bounding with alternate legs
  - clap pushups (see figure 5.5b)
  - jumping on, over and from benches that are 35 cm high
  - throwing a heavy medicine ball (above 4 kg).
Interval training: short, intermediate and high intensity interval training (HIIT)

Interval training involves set periods of work followed by set periods of rest or recovery repeated several times in an exercise session. This type of training allows for repeated high-intensity work periods that improve speed, power, anaerobic capacity and agility. Interval training can be used to develop all three energy systems depending on the manipulation of the work and rest periods and the intensity the repetitions are performed at. The types of interval training specific to the anaerobic enhancement of the musculoskeletal system are outlined in table 5.2.

### TABLE 5.2 Summary of interval training types

<table>
<thead>
<tr>
<th>Interval type</th>
<th>Energy system</th>
<th>Work intensity</th>
<th>Work-to-rest ratio</th>
<th>Suitable sports</th>
</tr>
</thead>
<tbody>
<tr>
<td>Short</td>
<td>ATP-PC</td>
<td>95%+ MHR</td>
<td>1 : 5</td>
<td>100-metre sprints, team sports</td>
</tr>
<tr>
<td>Intermediate</td>
<td>Anaerobic glycolysis</td>
<td>85%+ MHR</td>
<td>1 : 3</td>
<td>200-metre sprint, team sports</td>
</tr>
<tr>
<td>High intensity (HIIT)</td>
<td>Anaerobic and aerobic energy systems</td>
<td>80%+ MHR to maximal</td>
<td>Varied depending on aim of session 2 : 1, 1 : 1</td>
<td>Any</td>
</tr>
</tbody>
</table>

The benefit of short and intermediate interval training for the athlete is through the adaptations that occur at the muscular level allowing them to run faster through improved speed, power and anaerobic capacity. This type of training is useful for team sports where the work-to-rest ratio can resemble that of a game situation, with intense bursts of speed followed by periods of recovery.

The addition of high-intensity interval training (HIIT) into training programs has increased in recent times. HIIT involves repeated bouts of high intensity efforts (90–95%+ HR max) followed by varying periods of complete rest or recovery at a lower intensity (40–50% HR max). HIIT can be adapted from traditional cardio activity to resistance training where the athlete will use explosive effort to move a resistance. These efforts range from 5 seconds to 30 seconds of work, with complete rest recovery in between.
Potential harms of these types of interval training include increased risk of injury due to inadequate fitness levels and incorrect application of training principles, including not allowing enough recovery for the body to adapt between sessions.

**Aerobic training methods: benefits and harms**

As identified in table 5.1, aerobic training produces a variety of chronic muscular adaptations to enhance performance. These adaptations allow for greater energy production, especially when working at higher intensities. However, the critical factor in improved performance relates to the efficient delivery of oxygen to the working muscles via the cardiorespiratory system. This aspect will be discussed in depth in chapter 9, ‘Performance enhancement of the cardiorespiratory system’. Training methods most suited to aerobic energy production are briefly outlined in table 5.3.

**TABLE 5.3 Summary of continuous training methods**

<table>
<thead>
<tr>
<th>Training type</th>
<th>Description</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>Continuous</td>
<td>Continuous activity that lasts a minimum of 20 minutes at the required sub-maximal (70–85% HR max) intensity</td>
<td>Runners, swimmers or cyclists exercising continuously for 30 mins at 80% HR max</td>
</tr>
<tr>
<td>Fartlek</td>
<td>Continuous activity that involves surges of higher intensity throughout the session</td>
<td>Changes in intensity can be simply an increase in pace or running up a hill.</td>
</tr>
<tr>
<td>Long interval training</td>
<td>Intervals lasting between 1–6 minutes. Work periods sub-maximal intensity closer to 85% HR max. Rest periods passive or active at lower intensity. Work-to-rest ratio 1 : 1 or below</td>
<td>Middle distance runner — run 4 min 85% HR max, rest 4 min</td>
</tr>
</tbody>
</table>

**Figure 5.6** Continuous training increases the number and size of mitochondria in the muscle to produce energy for aerobic activities.
5.2 Legal substances and methods: training methods and mechanical aids

**TEST your understanding**

1. Describe each of the legal training methods that can be used to enhance musculoskeletal performance.
2. Outline the actual and perceived benefits and potential harms from participating in a resistance training session.
3. Explain how plyometric training makes use of the stretch reflex to increase muscular power.
4. Discuss the ways aerobic training can enhance the performance of the musculoskeletal system.

**APPLY your understanding**

5. Explain why an athlete might use a mechanical aid in addition to normal training. Provide specific examples.
6. **Practical activity: plyometrics session**
   - Participate in the following plyometrics training session. Make sure you have completed a thorough warm-up prior to completing these exercises. For each exercise, perform at a low level with ten repetitions. Recovery of one minute between each exercise.
   - Squat jumps
   - Mountain climbers
   - Alternate leg bounds
   - Power skipping
   - Lateral (side) jumps
   - (a) Discuss the way in which plyometrics can improve the performance of the musculoskeletal system.
   - (b) Outline potential harms of this type of training and link these harms to suggested safety considerations.
   - (c) Design your own plyometrics training session for a sport of your choice. Consider skills required and muscles used when choosing the activities.
**KEY CONCEPT:** Nutritional supplements are commonly used by athletes to enhance performance, however an athlete needs to be aware of the potential doping risks associated with the ingestion of such products.

**Nutritional supplements** have been developed for athletes over the years in an effort to assist the athlete to gain an edge over their competitors. Unfortunately, a number of these supplements have no real scientific credibility and the long-term effects of using them have not yet been fully researched. In addition, any supplement may carry a drug or doping risk. It is the athlete's own responsibility to avoid breaking the anti-doping rules. On the other hand, nutritional supplements can play some part in assisting the athlete to reach their peak performance.

Nutritional supplements can be divided into three broad groups:

1. **Specialised sports foods.** These address an athlete's specific nutritional needs and include sports drinks, sports bars or gels, and liquid-meal supplements. Athletes find that these products can be a useful addition to their specialised nutrition program, in that they are practical and convenient to incorporate into any training regime.

2. **Dietary supplements.** Even through the rigours of regular training and competing, the athlete should not require supplements, provided they have a well-chosen diet that addresses their daily energy intake. Supplements are really only required if a specific nutritional deficiency is identified. For example, calcium and iron supplements are sometimes advised for female endurance athletes.

3. **Performance supplements.** These benefit performance and/or recovery from exercise. Research has found that the benefits claimed by very few so-called nutritional performance supplements are actually supported by scientific evidence and as such these aids should be used with caution. There is some support, in certain circumstances, for the use of caffeine, creatine and bicarbonate being of benefit to the athlete.

The Australian Institute of Sport (AIS) provides information for athletes to inform them of the appropriate use of nutritional supplements. It also educates them in respect to anti-doping regulations as they apply to nutritional supplements.

The AIS uses the ABCD classification system to identify sports supplements and/or ergogenic aids that can be used by athletes, and categorises them according to the amount of scientific evidence available to support their use. Table 5.4 on page 98 gives a summary of these categories or groupings. Currently, only group A supplements have scientific backing and are supported by the AIS for use by its athletes.
### TABLE 5.4 A guide to sports supplement groupings

<table>
<thead>
<tr>
<th>Supplement grouping</th>
<th>Definition of grouping</th>
<th>Subcategory</th>
<th>Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>A</strong></td>
<td><strong>Evidence:</strong> Supported for use in specific situations using evidence-based protocols.</td>
<td>Sports foods</td>
<td>Electrolyte replacement, Liquid meals, Sports bars, Sports confectionary, Sport drinks, Sports gels, Whey protein</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Medical supplements</td>
<td>Calcium, Iron</td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>Performance supplements</strong></td>
<td>Multivitamins/minerals, Probiotics (gut/immune), Vitamin D</td>
</tr>
<tr>
<td><strong>B</strong></td>
<td><strong>Evidence:</strong> Deserving of further research and could be considered for provision to athletes under a research protocol or case-managed monitoring situation.</td>
<td>Food phenolics</td>
<td>Curcumin, Exotic berries (açaí, goji etc.), Quercetin, Tart (Montmorency) cherry</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Other</td>
<td>Antioxidants C and E, Carnitine, Fish oils, Glucosamine, Glutamine, HMB</td>
</tr>
<tr>
<td><strong>C</strong></td>
<td><strong>Evidence:</strong> Have little meaningful proof of beneficial effects. Not provided to athletes within supplement programs.</td>
<td>Category A and B products used outside approved protocols</td>
<td>See lists for category A and B products.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>The rest — if you can’t find an ingredient or product in groups A, B or D, it probably deserves to be here.</td>
<td></td>
</tr>
<tr>
<td><strong>D</strong></td>
<td><strong>Evidence:</strong> Banned or at high risk of contamination with substances that could lead to a positive drug test. Should not be used by athletes.</td>
<td>Stimulants</td>
<td>Ephedrine, Strychnine, Sibutramine, Methyhexanamine (DMAA), Other herbal stimulants</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Prohormones and hormone boosters</td>
<td>DHEA, Androstenedione, 19-norandrosterone/ol, Other prohormones</td>
</tr>
<tr>
<td></td>
<td></td>
<td>GH releasers and peptides</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Other</td>
<td>Glycerol – banned as a plasma expander, Colostrum</td>
</tr>
</tbody>
</table>

**Source:** Adapted from The Australian Institute of Sport.
TEST your understanding

1. Define what constitutes a nutritional supplement.
2. Outline the Australian Institute of Sport (AIS) ABCD classification system and explain why it exists.

APPLY your understanding

3. Nutritional supplements can be divided into three broad groups. List and outline each of the groups, including examples. Suggest athletes or sports that might use these supplements.
4. Choose one of the supplements identified in table 5.4 and use the internet to research:
   - what the supplement is
   - the type of athlete/sport this supplement may be beneficial for
   - the form the supplement comes in
   - how to consume the supplement
   - actual and perceived benefits of consuming the supplement
   - potential harms related to the supplement
   - any other relevant information.
5.4 Specialised sports foods, methods and dietary supplements

**KEY CONCEPT** Specialised sports foods and dietary supplements are useful in providing a practical alternative to food when food cannot be consumed or if a specific nutritional deficiency is identified.

Nutritional supplements play an important role in fuel supply, delaying fatigue and assisting recovery. They can be consumed prior to, during or after a training bout or competition to aid the athlete. Specialised sports foods, methods and supplements that can enhance the performance of the musculoskeletal system are outlined below.

**Carbohydrates**

Carbohydrates are the major fuel required for activities of high intensity as well as sub-maximal, prolonged duration. The body can store only a certain amount in the liver and muscles, therefore it is important for an athlete to make sure they have adequate supplies and continue to consume enough carbohydrates to maintain availability for energy production. The following discusses methods as well as specialised sports food that may be used by athletes to meet the fuel needs and enhance the performance of the musculoskeletal system.

**Application of the glycaemic index**

**Glycaemic index** (GI) is a ranking of carbohydrates on a scale from 0 to 100 according to the extent to which they raise blood-glucose levels after eating. Foods that have a high glycaemic index (70 and above) are those that are rapidly digested and absorbed and result in a rapid increase in blood glucose levels. Foods with a low glycaemic index (55 or less) are slowly digested and absorbed and produce gradual rises in blood glucose and insulin levels (see fig 5.8).

Knowledge of the glycaemic index allows athletes, coaches and sports dietitians to determine what carbohydrate foods to eat and when to eat them. This is particularly important for sub-maximal endurance athletes where glucose is the main fuel for replenishment of ATP.

Low-GI foods are suggested pre-event to maximise stores and provide a sustained release during activity, whereas high GI foods are recommended during activity to replace and top up stores, as well as after activity to replace depleted stores quickly. Manipulated correctly, application of the glycaemic index will benefit the athlete by optimising their carbohydrate availability for energy production and thereby...

---

The **glycaemic index** is a ranking of carbohydrates on a scale from 0 to 100 according to the extent to which they raise blood-glucose levels after eating.

**FIGURE 5.8** Rate of release of glucose for foods with a high and low glycaemic index
optimally enhancing their performance and recovery. It is worth noting that not all athletes respond positively and may experience gastrointestinal upset or bloating in response to the consumption of carbohydrates.

Table 5.5 is a guide to the glycaemic index of many common carbohydrate foods.

**TABLE 5.5** Average glycaemic index of some common carbohydrate-rich foods

<table>
<thead>
<tr>
<th>Food</th>
<th>Glycaemic index (glucose = 100)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>High glycaemic index</strong></td>
<td></td>
</tr>
<tr>
<td>Rice crackers</td>
<td>87</td>
</tr>
<tr>
<td>Cornflakes</td>
<td>81</td>
</tr>
<tr>
<td>Porridge, instant oats</td>
<td>79</td>
</tr>
<tr>
<td>Potato, boiled</td>
<td>78</td>
</tr>
<tr>
<td>Watermelon</td>
<td>76</td>
</tr>
<tr>
<td>White bread</td>
<td>75</td>
</tr>
<tr>
<td>White rice, boiled</td>
<td>73</td>
</tr>
<tr>
<td><strong>Moderate glycaemic index</strong></td>
<td></td>
</tr>
<tr>
<td>Popcorn</td>
<td>65</td>
</tr>
<tr>
<td>Sweet potato, boiled</td>
<td>63</td>
</tr>
<tr>
<td>Honey</td>
<td>61</td>
</tr>
<tr>
<td>Soft drink</td>
<td>59</td>
</tr>
<tr>
<td>Pineapple</td>
<td>59</td>
</tr>
<tr>
<td>Muesli</td>
<td>57</td>
</tr>
<tr>
<td>Porridge, rolled oats</td>
<td>55</td>
</tr>
<tr>
<td><strong>Low glycaemic index</strong></td>
<td></td>
</tr>
<tr>
<td>Sweetcorn</td>
<td>52</td>
</tr>
<tr>
<td>Pasta, white</td>
<td>49</td>
</tr>
<tr>
<td>Orange</td>
<td>43</td>
</tr>
<tr>
<td>Chocolate</td>
<td>40</td>
</tr>
<tr>
<td>Milk, full fat</td>
<td>39</td>
</tr>
<tr>
<td>Apple</td>
<td>36</td>
</tr>
<tr>
<td>Lentils</td>
<td>32</td>
</tr>
</tbody>
</table>


**Carbohydrate loading**

Carbohydrate loading is a method typically used by endurance athletes competing in events lasting longer than 90 minutes (marathons, triathlons, cross-country skiing) to maximise carbohydrate (glycogen) stores in the muscle and liver. Additional carbohydrates are consumed prior to the event to increase stores by 50–100 per cent above normal resting levels.

Consumption of 7–12 grams of carbohydrate per kilogram of body mass, along with tapering for 36–72 hours prior to the event, is the most successful strategy for increasing the muscle glycogen stores in endurance athletes. During the event, athletes are also recommended to consume small amounts of carbohydrates (30–60 g per hour) to delay the depletion of stores.

The benefit to the athlete from carbohydrate loading is that they are able to exercise at optimal pace for longer, due to increased availability of glycogen stores. However, this strategy does not work for all athletes and potential harms include bloating, weight gain and gastrointestinal discomfort. A sample carbohydrate loading suitable for a 70 kg athlete is outlined in table 5.6 on page 102.
TABLE 5.6 Sample carbohydrate loading meal plan

<table>
<thead>
<tr>
<th>Time</th>
<th>Meal Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Breakfast</td>
<td>3 cups of low-fibre breakfast cereal with 1½ cups of reduced fat milk</td>
</tr>
<tr>
<td></td>
<td>1 medium banana</td>
</tr>
<tr>
<td></td>
<td>250 mL orange juice</td>
</tr>
<tr>
<td>Snack</td>
<td>toasted muffin with honey</td>
</tr>
<tr>
<td></td>
<td>500 mL sports drink</td>
</tr>
<tr>
<td>Lunch</td>
<td>2 sandwiches (4 slices of bread) with filling as desired</td>
</tr>
<tr>
<td></td>
<td>200 g tub of low-fat fruit yoghurt</td>
</tr>
<tr>
<td></td>
<td>375 mL can of soft drink</td>
</tr>
<tr>
<td>Snack</td>
<td>banana smoothie made with low-fat milk, banana and honey cereal bar</td>
</tr>
<tr>
<td>Dinner</td>
<td>1 cup of pasta sauce with 2 cups of cooked pasta</td>
</tr>
<tr>
<td></td>
<td>3 slices of garlic bread</td>
</tr>
<tr>
<td></td>
<td>2 glasses of cordial</td>
</tr>
<tr>
<td>Late snack</td>
<td>toasted muffin and jam</td>
</tr>
<tr>
<td></td>
<td>500 mL sports drink</td>
</tr>
</tbody>
</table>

This sample plan provides approximately 14 800 kJ, 630 g carbohydrate, 125 g protein and 60 g fat.

Source: Written by the AIS Department of Sports Nutrition, last updated June 2009. © Australian Sports Commission

Sports gels

Sports gels are a compact, solid source of carbohydrate designed to provide a large boost of fuel in one serving. They are easily consumed and digested quickly, allowing a more concentrated intake of carbohydrate (60–70 per cent), which is beneficial both during and after activity to replenish depleted stores in the muscle. Sports gels can vary in flavour, consistency, type and amount of carbohydrates in the gel. Other ingredients such as electrolytes and caffeine may also be present in the sports gel. Due to their highly concentrated form, sports gels should be consumed with water or similar fluids to reduce the risk of gastrointestinal upset. Athletes are advised to experiment with gels during training sessions to assess tolerance prior to competition.

Sports bars

Like sports gels, sports bars provide a compact and practical source of carbohydrates to boost fuel levels pre-, during and post-activity and replenish fuel stores at the muscle site. As well as containing a high concentration of carbohydrates, sports bars often contain protein and micronutrients. They are similar to muesli or cereal bars, having a chewy consistency and can be coated with chocolate or include nuts and grains. A concern with sports bars is overuse and the replacement of nutritious whole food with the convenience of a bar. Again, athletes are advised to experiment with bars during training sessions to assess tolerance prior to competition.

Liquid-meal supplements

Liquid-meal supplements are supplements typically containing a carbohydrate-rich, protein-moderate, low-fat powder (or liquid) that can be mixed with water or milk. They often include additional sources of vitamins, minerals and essential amino acids. Liquid meal supplements can be purchased as ready-to-drink or in powder mix. They can vary in flavour, fat and fibre content and in the amount of protein, carbohydrates, vitamins and minerals present.

This compact form of energy is especially useful for athletes who are aiming to increase lean body mass, coping with demanding training programs or undergoing growth spurts. Liquid meal supplements are also useful as a post-exercise recovery
snack to replace fuel and promote repair of muscle cells. A concern with liquid meal supplements is overuse and the replacement of nutritious whole food with the convenience of a drink, as well as overconsumption of kilojoules and unwanted weight gain.

**Hydration**

Adequate hydration is very important for an athlete to maintain and even enhance their performance. Depending on the type of fluid an athlete consumes, they have the potential to rehydrate as well as refuel. Hydration can assist the musculoskeletal system to function at optimal levels and reduce the potential for fatigue via dehydration and depletion of energy stores. Dehydration, via the loss of water and electrolytes, interferes with the ability of the muscles to contract, thus decreasing performance. Depletion of energy stores, specifically glycogen, limits the capacity of the muscles to produce energy for contraction and the intensity at which the athlete can perform will decrease.

**Sports drinks**

Sports drinks (carbohydrate–electrolyte drinks) provide both fluid and carbohydrate to allow an athlete to rehydrate and refuel at the same time. These drinks are ideal to consume before, during or after training and competition, and help delay the fatigue that can be caused by dehydration and depletion of energy stores.

Sports drinks typically containing 6–8 per cent carbohydrate and 10–25 mmol/L electrolyte (sodium and potassium) rapidly deliver both fluids and fuels when consumed. The taste of sports drinks encourages athletes to increase fluid intake. Electrolyte replacement, particularly sodium, helps to maintain the athlete’s desire to drink, and can help to reduce further fluid loss through urination.

Concerns with the use of sports drinks relate to overconsumption and the additional carbohydrates impacting on energy balance and displacement of other nutrients. Sports drinks can also cause gastrointestinal discomfort for some athletes and they can contribute to dental erosion, therefore minimal contact time with teeth is recommended.

There are different types of sports drinks to meet the different needs of athletes. These are outlined below.

**TABLE 5.7 Types of sports drinks**

<table>
<thead>
<tr>
<th>Type</th>
<th>Content</th>
<th>Absorption rate</th>
<th>Example</th>
<th>Suitable for</th>
</tr>
</thead>
<tbody>
<tr>
<td>Isotonic</td>
<td>6–8 per cent CHO, 10–25 mmol/L electrolytes</td>
<td>Rapid</td>
<td>Gatorade, Powerade</td>
<td>Widely used by most athletes</td>
</tr>
<tr>
<td>Hypotonic</td>
<td>Low level CHO (&lt;4 per cent), 1–25 mmol/L electrolytes</td>
<td>Rapid</td>
<td>Water, Mizone</td>
<td>Athletes that require fluid replenishment without CHO, e.g. jockeys (weight restriction sports)</td>
</tr>
<tr>
<td>Hypertonic</td>
<td>High level of CHO (&gt;8 per cent)</td>
<td>Slow</td>
<td>PowerBar, Isomax, High5 Energy Source, Fruit juice, Soft drink</td>
<td>Prolonged endurance Ultra distance events Note: need to be consumed with water or isotonic drink for hydration</td>
</tr>
</tbody>
</table>
### TABLE 5.8 Specialised sports foods

<table>
<thead>
<tr>
<th>Nutritional supplement</th>
<th>Form</th>
<th>Composition</th>
<th>Perceived benefit</th>
<th>Potential harm or disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sports gels</td>
<td>Gel 30–40 g sachets or tubes</td>
<td>60–70 per cent CHO</td>
<td>High concentration of CHO to top up/refuel stores for energy production</td>
<td>Expensive \n Concentrated CHO can cause gastrointestinal upset</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Reduce/delay the effects of fatigue due to fuel depletion</td>
<td></td>
</tr>
<tr>
<td>Sports bars</td>
<td>Bar 50–60 g</td>
<td>40–50 g CHO 5–10 g protein</td>
<td>High concentration of CHO to top up/refuel stores for energy production</td>
<td>As per sports gels \n Overconsumption can impact on energy balance</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Reduce/delay the effects of fatigue due to fuel depletion</td>
<td></td>
</tr>
<tr>
<td>Liquid meal supplements</td>
<td>Powder (mix with water or milk) Liquid</td>
<td>1–1.5 kcal/mL 15–20 per cent protein 50–70 per cent CHO Vitamins/minerals: can supply 50–100 per cent of RDI</td>
<td>Post exercise recovery snack to replenish fuel and promote repair of muscle cells</td>
<td>Overconsumption can impact on energy balance \n Unwanted weight gain \n May displace other whole foods</td>
</tr>
<tr>
<td>Sports drinks</td>
<td>Powder</td>
<td>Isotonic: 6–8 per cent CHO 10–25 mmol/L sodium</td>
<td>Rehydration Replenishment of fuel (glucose) stores</td>
<td>Overconsumption can impact on energy balance \n Gastrointestinal upset \n Dental erosion</td>
</tr>
</tbody>
</table>

### Vitamin and mineral supplements

**Vitamins**, which assist chemical reactions in the body (and thus help to release energy from food), and **minerals**, which are important in muscle contraction, nerve transmission, fluid balance and enzyme activity, are a very important part of an athlete’s diet.

Eating a balanced diet ensures an adequate vitamin and mineral intake; however, supplementation may be required to prevent or treat a dietary deficiency in some athletes. This may be caused from dieting, not consuming a certain food or food groups, or recovering from injury or illness. If there is no deficiency, use of supplements has been shown to have no effect on performance enhancement and excess consumption tends to be excreted by the body. Supplementation can take the form of a multivitamin/mineral that contains a variety of vitamins and minerals, for example Centrum, or a single-nutrient supplement such as calcium or iron.

**Calcium** is a mineral found mainly in the hard part of bones and is essential for healthy bones. It is also important for muscle contraction, nerve transmission, enzyme activity and blood clotting. **Calcium** is important for muscle contraction, nerve transmission, enzyme activity and blood clotting. It is also an essential component of bones and teeth. Calcium requirements increase during childhood, adolescence, pregnancy and breastfeeding.
Inadequate calcium intake may lead to low bone-mineral density and the risk of stress fractures. Calcium is important for athletes and those at risk include athletes with an insufficient intake of dairy in their diet, those with a poor calcium balance due to malabsorption from the small bowel, and females with impaired menstrual function. Supplementation is recommended for athletes who may require more or who are at risk of not consuming enough calcium in their diet and is only recommended under medical supervision.

**TEST your understanding**

1. Outline how carbohydrate-based sports food can assist the performance of the musculoskeletal system.
2. Discuss how knowledge of the glycaemic index of foods can help an athlete optimise his or her performance.
3. Identify which specialised sports foods are suitable for post-exercise snacks. Link each to a specific sport and explain why.
4. Discuss whether or not it is necessary for an athlete to consume supplements. Provide specific examples.
5. Outline the differences between the three types of sports drinks.

**APPLY your understanding**

6. Compare and contrast sports gels, sports bars and liquid meal supplements.
7. Discuss the importance of hydration for an athlete and why an athlete would consume a sports drink in preference to water.

**Learning activity: sports supplements**

Visit a supermarket or health food shop. Look at the range of liquid-meal supplements, sports bars and sports gels and make a list of the available supplements. Choose a product from each of these categories (liquid-meal supplements, sports bars and sports gels) and answer the following questions.

(a) What are the main ingredients and nutrients (in contents per 100 grams)?
(b) What are the claimed benefits?
(c) What is the most appropriate time to consume the supplement?
(d) What is the recommended intake during exercise and how does this compare with the product content?
Protein supplements

Protein is a popular nutritional supplement used by many athletes, due to its function in the growth and repair of muscle tissue and cells. Protein can be found naturally in foods such as red meat, poultry, nuts, eggs and legumes as well as a formulated supplement in the form of a drink, bar or powder.

**Protein supplements** can assist performance of the musculoskeletal system through increased muscle protein synthesis and therefore an increased muscle cross-sectional area. This increase leads to a greater storage of fuels and a greater ability to produce strength and power. Training intensity and frequency can increase due to the increased repair of the muscle cells.

Timing of protein consumption is important and the most benefit is gained by consuming protein immediately after exercise. At this time, muscle uptake and retention of amino acids is enhanced and appears to continue to be enhanced for up to 24 hours.

Endurance athletes in heavy training, athletes wanting to gain muscle mass and strength athletes in initial stages of training have all been shown to have higher need for protein than other athletes, however this intake can be achieved through manipulation of diets.

Protein powders

The most common forms of supplementation are protein powders made into shakes and protein bars. The amount of protein is generally higher than can be achieved in consuming foods containing protein. They are classified according to the amount of protein and other nutrients they contain.

Whey protein is the most common supplement form as it is rapidly digested and rich in branched chain amino acids. It comes in three forms:

- Whey protein isolate: highest amount of protein with all lactose and fat removed
- Whey protein concentrate: high amount of protein with small amounts of lactose and fat present
- Whey protein hydrolysate: a combination of the above forms.

It is interesting to note that current nutritional guidelines do not foresee the need for protein supplements for athletes, and research suggests that supplements offer no advantage over consuming protein-rich foods as part of a balanced diet. Protein consumption well above recommended intakes (>2 grams per kilogram BM) does not stimulate further muscle building or recovery and is not recommended by sports dietitians. In fact, extra consumption may displace other important nutrients from the diet. Some health risks might also be associated with excessive protein intake because of the extra demand placed on the kidneys to excrete any unused amino acids. Furthermore, excessive protein intake can compromise bone density and may also lead to weight gain if food choices are also high in fat.

However, athletes may require a supplement when consumption of food is difficult post-exercise and products such as liquid meal supplements offer convenience and a practical solution to consuming adequate protein.
Caffeine supplementation

Caffeine was removed from the World Anti-Doping Agency (WADA) prohibited list on 1 January 2004. Since then, caffeine has been used by some athletes to enhance their performance. In terms of the effects of caffeine on the body, it has previously been believed that caffeine:
- mobilises fat from adipose tissue and muscle cells, resulting in glycogen sparing in endurance athletes
- alters the nervous system, creating a change in perception of effort and fatigue
- stimulates both the release and the action of adrenaline
- causes a diuretic effect, leading to dehydration.

Recent research now brings into question the ability of caffeine to enable glycogen sparing, as well as its diuretic effect on the athlete. There is, however, sound evidence that caffeine can enhance endurance and performance of:
- short-duration, high-intensity events of 1–5 minutes
- prolonged high-intensity events of 20–60 minutes
- endurance events of a minimum of 90 minutes
- prolonged intermittent, high-intensity team or racquet sports.

Any performance enhancement effect on strength, power or brief sprint activities is unclear. The reason for the enhancement is still unclear but seems to be linked to a decreased perception of effort and fatigue in the athlete.

How much caffeine?

Caffeine doses of 1–3 milligrams per kilogram BM or 70–200 milligrams have proven to be beneficial in prolonged exercise lasting longer than 60 minutes. Caffeine can be consumed prior to or throughout the exercise. Furthermore, studies show that ingestion of more than 3 milligrams per kilogram BM of caffeine does not further increase performance, but may increase the risk of side-effects, including increased heart rate, impairment of technique and over-arousal. Athletes need to be conscious of the fact that there is great individual variability in the response to caffeine intake.

The AIS no longer provides caffeine to athletes for performance enhancement; however, it does educate about the use and potential benefits of low doses of caffeine as well as the risk of side-effects.

TABLE 5.9 Typical content of caffeine in selected food and drink

<table>
<thead>
<tr>
<th>Food or drink</th>
<th>Serve</th>
<th>Caffeine content (mg)</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>Tea</td>
<td>250 mL cup</td>
<td>27 (9–51)*</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>Coca Cola</td>
<td>375 mL can</td>
<td>49</td>
</tr>
<tr>
<td>Red Bull energy drink</td>
<td>250 mL can</td>
<td>80</td>
</tr>
<tr>
<td>V energy drink</td>
<td>250 mL can</td>
<td>50</td>
</tr>
<tr>
<td>Mother energy drink</td>
<td>500 mL can</td>
<td>160</td>
</tr>
<tr>
<td>PowerBar caffeinated sports gel</td>
<td>40 g sachet</td>
<td>50</td>
</tr>
<tr>
<td>No-Doz</td>
<td>1 tablet — Australia</td>
<td>100</td>
</tr>
<tr>
<td></td>
<td>1 tablet — USA</td>
<td>200</td>
</tr>
</tbody>
</table>

*The caffeine content of tea and coffee varies widely, depending on the brand, the way that the individual makes their cup of tea or coffee, and the size of their mug or cup.
Caffeine: a legal performance-enhancing drug

BY KATE SCHLAG

If you were to rifle through almost any of my teammate’s bags — or even mine, for that matter — there’s a good chance you’d find performance-enhancing drugs. I promise we’re not cheating, though: every other team uses (and, often, relies on) the same drug — caffeine.

Believe it or not, there’s little scientific question that caffeine is an effective performance-enhancing drug. The first study to investigate the relationship between caffeine and exercise performance, published in 1978, reported that caffeine reduced cyclists’ rating of perceived exertion by increasing fat oxidation; theoretically, those fatty acids were mobilised to be used by muscles early on, sparing glycogen for later use when your muscles are really exhausted.

Since then, several other theories have been proposed to explain caffeine’s ergogenic capacity: caffeine stimulates the central nervous system, thereby enhancing mental alertness and reaction times (key in a sport that relies on mental acuity to make both offensive and defensive plays). It also increases calcium release and inhibits calcium re-uptake, two actions that play a role in muscle contraction. These effects result in increased muscle contraction force, allowing you to play longer and harder.

Initially, these studies focused on high amounts of caffeine (10–13 mg/kg body weight — for a 77 kg man, that’s about 5–8 cups of coffee) in endurance events, but more recent studies have focused on low to moderate doses (≤3 mg/kg body weight, or 1–2 cups of coffee for a 77 kg man) in sustained high-intensity sports (like swimming and rowing) and stop-and-go sports. Researchers confirm that these lower doses can and do enhance performance. Here’s what else you should know about caffeine and athletic performance.

All caffeine isn’t created equal

There are over 60 sources of naturally occurring caffeine in nature, from coffee and cocoa beans to tea leaves and kola nuts. Because these plants and the foods and drinks they’re turned into contain many other micronutrients, antioxidants and compounds in addition to caffeine, their effects on the body can vary widely. Tea, for example, contains higher amounts of theobromine and theophylline, which also stimulate the central nervous system. But it also contains L-theanine, an amino acid that increases the generation of alpha waves, which are associated with a more relaxed — but still alert — state of consciousness. The added sugar in a can of Coke — about 10 teaspoons — leads to a huge sugar spike immediately but often leaves you feeling even more lethargic (and in need of another caffeine boost) hours later.

The takeaway: If you’re used to caffeinating with one type of caffeine before games and suddenly switch to another, be aware that it might not affect you in the same way. As with other tenets of sports nutrition, experiment with different forms of caffeine during practices and workouts and find out which type works best for you.

More isn’t necessarily better

If two cups of caffeine can improve your performance, what can four cups do? It might make you incrementally faster, but it’s likely that it will also make you jittery, shaky and anxious, which might not translate into success on the ultimate field. Too much caffeine might also hinder your decision making: one study found that while 200 mg of caffeine improved the accuracy and speed of problem solving, doubling the dose to 400 mg impaired problem-solving abilities. After 600 mg of caffeine, cognitive performance is said to decline rapidly. Experts seem to agree that the optimal range for exercise performance is 3–6 mg per kg of body weight. For that 170-lb man, that’s between 1.5 and 3 cups of coffee.

It’s also important to note that habitual coffee or tea drinkers can build a tolerance to caffeine, which means that if you regularly consume caffeine throughout the day, you may not feel the effects of one dose of caffeine on game day. If you’re a regular consumer, try cutting out caffeine three or four days before a tournament and then reintroducing it Saturday morning.

The takeaway: The difference between ‘alert and focused’ and ‘jittery and anxious’ might be small; again, find your optimal range during practices and workouts. If you’re really looking to improve performance from caffeine, you may want to consider saving it for when you really need it — which means decreasing your weekly caffeine intake.

It doesn’t affect everyone the same way

Some people can drink coffee all day without feeling any negative side-effects; others have to take their last sip of a caffeinated beverage before 3 pm or they risk staying up all night. In general, women metabolise caffeine twice as fast as men, as do smokers compared to non-smokers (a faster caffeine metabolism means that you’ll process caffeine faster, abating its effects more quickly).
Genetics play a pretty big role as well: an enzyme called CYP1A2 is responsible for metabolising caffeine, and multiple studies have shown a high inter-individual variation in its expression. Your nervous system could also account for some variation, as caffeine's effects partly depend on the percentage of receptors that bind to caffeine.

Caffeine can cross the blood-brain barrier as soon as 15 minutes following ingestion, increasing alertness and wakefulness almost immediately (in fact, just smelling roasted beans or the aroma of a steaming pot can increase brain activity). Peak caffeine levels usually occur around 45–60 minutes, when lipid oxidation is also increased. From there, you — an average, non-smoking adult — will probably feel the effects for another three to four hours, although this can be highly variable as well.

The takeaway: By now, you should know whether you’re more sensitive or more tolerant to caffeine. If you don’t, look to your parents, as caffeine sensitivity is hereditary. Aim to get your caffeine 45–60 minutes before the first pull, although you can play around with this timeline at practice.

Some side-effects might hinder performance
While caffeine improves the immediate physical aspects of performance, it may have longer-term impacts that, ultimately, could lead to a net decrease in performance. The consumption of caffeine might interfere with sleep duration and quality, which has further implications when you consider that many important tournaments last three, or even four, days. Ingesting caffeine before a night game might improve performance, but it also might hinder your sleep, making you more tired and groggy for your morning game. In addition, no studies have looked at how taking caffeine multiple times a day affects performance — for example, once before quarters, semis and finals. If you’re sensitive to the effects of caffeine, this begs the question: should you ingest caffeine before each and every game, or save the jolt for, hopefully, your appearance in finals?

With respect to other potential side-effects, some studies have shown that caffeine intake may affect hydration status and carbohydrate metabolism. However, these studies have found either inconsistent or statistically insignificant results on performance.


Creatine
A naturally occurring compound found in skeletal muscle, creatine is created through daily intake of foods such as fish, poultry and red meat. It is also manufactured in the kidneys through the intake of some amino acids. Creatine monohydrate is the commonly supplemented form of creatine.

The use of creatine phosphate in the regeneration of adenosine triphosphate (ATP) for short-duration, high-intensity exercise is well known. Initial research cited a 25 per cent increase in stored creatine when taking a creatine supplement in comparison to not taking a supplement. However, subsequent research findings have varied considerably. What is agreed on is that creatine supplementation will enhance performance involving repeated sprints or bouts of high-intensity, short-duration activity separated by short recovery intervals of less than 1 minute. It is also recommended for developed, elite athletes who use resistance training to increase lean body mass, or for team athletes who participate in intermittent sports such as netball, football or racquet sports.

There are two recognised creatine supplementation regimens used by the AIS:
1. Rapid loading protocol — 20 grams daily (4 x 5-gram doses) for a total of five days. This protocol is linked to weight gain, usually in the form of fluid retention.
2. Slow loading protocol — smaller doses (3 grams) ingested each day.

To enhance creatine uptake, it is suggested that creatine also be taken with a large amount of carbohydrates (50–100 grams). Once loaded, a maintenance dose of 3 grams daily is recommended. Extended loading protocols are not required.

Creatine is a naturally occurring compound found in skeletal muscles that assists in the regeneration of ATP in the muscle cells.
Although no recognised findings have been reported on the possible side-effects of long-term use of creatine, there are anecdotal reports of weight gain due to fluid retention, cramps and harmful effects on the liver and kidney when creatine has been consumed in excess of recommended doses. If protocols such as those presented on page 109 are followed, creatine has not been seen to cause these side-effects in healthy people.

**Bicarbonate**

Bicarbonate increases the body's ability to dispose of excess hydrogen ions that are produced during anaerobic glycolysis. Hydrogen ions are thought to have a significant fatiguing effect on the body when working anaerobically. Bicarbonate loading acts as a buffer within the muscle, reducing the fatiguing effect of hydrogen on the functioning of the muscle. It is relevant to high-intensity events lasting between 1 and 7 minutes.

Bicarbonate can be consumed as a capsule or effervescent powder. The AIS recommends the following two protocols for ingestion of bicarbonate:

1. **Acute bicarbonate loading** — 300 milligrams per kilogram BM dose ingested 1–2 hours prior to the session.
2. **Chronic bicarbonate loading** — 500 milligrams per kilogram BM dose ingested per day over five days and split into four doses over the day.

Studies have shown that acute bicarbonate loading has a moderate effect in enhancing the performance of anaerobic exercise or events, and chronic bicarbonate loading can increase buffering capacity, with effects lasting for at least 24 hours following the last dose. It should be noted that very few studies have been completed in a sports setting.

At this point, the only side-effects noted have been reports of gastrointestinal distress. It is recommended that athletes do not combine this supplement with other nutritional supplements such as caffeine and creatine.

<table>
<thead>
<tr>
<th>Performance supplement</th>
<th>Performance benefits</th>
<th>Potential harms</th>
</tr>
</thead>
<tbody>
<tr>
<td>Protein</td>
<td>Used for muscle growth and repair</td>
<td>May displace other foods</td>
</tr>
<tr>
<td></td>
<td>Increases muscle cross-sectional area — increase power and strength</td>
<td>Expensive</td>
</tr>
<tr>
<td></td>
<td>Increases PC storage</td>
<td>Extra consumption may displace other important nutrients from the diet</td>
</tr>
<tr>
<td></td>
<td>Allows increased training intensity and frequency</td>
<td>Health risks associated with excessive protein intake because of the extra demand placed on the kidneys to excrete any unused amino acids</td>
</tr>
<tr>
<td></td>
<td>Promotes glycogen resynthesis for increased fuel availability</td>
<td>Can compromise bone density</td>
</tr>
</tbody>
</table>

Caffeine

Change in perception of effort and fatigue

Stimulates release and action of adrenalin

Overuse can lead to dependence

Excessive consumption can lead to:

- Increased heart rate
- Impairment of technique
- Overarousal
- Anxiety
- Insomnia
<table>
<thead>
<tr>
<th>Performance supplement</th>
<th>Performance benefits</th>
<th>Potential harms</th>
</tr>
</thead>
<tbody>
<tr>
<td>Creatine</td>
<td>Increased stores of creatine in muscle allows for: Increase in force and power produced in muscle contractions Train harder at higher intensities Delays CP depletion and fatigue Decreases reliance on anaerobic glycolysis, reduce lactate accumulation delaying fatigue</td>
<td>Weight gain due to fluid retention Possible side-effects: gastrointestinal upset, muscle cramps Excessive use may cause liver and kidney damage</td>
</tr>
<tr>
<td>Bicarbonate</td>
<td>Buffers hydrogen out of muscle at a faster rate allowing for more to be produced Delays fatigue</td>
<td>Gastrointestinal upset</td>
</tr>
</tbody>
</table>

**TEST your understanding**

1. Outline why nutritional ergogenic aids should be used with caution.
2. Define protein supplementation. Is it recommended for athletes?
3. Study table 5.9. Identify examples of caffeine products that you would consume in a normal day. Calculate your caffeine intake.
4. Define the term creatine. List food sources containing creatine.

**APPLY your understanding**

5. For each of the following sports, choose one nutritional ergogenic aid and outline how it may be beneficial for that sport.
   (a) 100-metre runner
   (b) 400-metre runner
   (c) team sportsperson (60–90 minutes duration)
   (d) ultra-distance athlete.

6. **Learning activity: caffeine and sports performance**

   Read the article ‘Caffeine: a legal performance enhancing drug’ on pages 108–9 and summarise the key elements of the article by answering the following questions.
   (a) How is caffeine thought to enhance performance?
   (b) For each of the benefits of caffeine listed in the article, suggest types of athletes for whom the benefit would be particularly relevant.
   (c) Identify reasons why athletes might choose not to use caffeine prior to an event.
5.6 Illegal substances and methods that enhance performance of the musculoskeletal system

**KEY CONCEPT** Illegal performance-enhancing substances and methods have been employed by coaches and athletes in order for the athlete to gain an advantage over their competitors. While they might bring about improved performance, the health and associated risks of doping to the athlete need to be taken into consideration prior to use.

Taking or using (illegal) performance-enhancing substances or methods is commonly referred to as ‘doping’. This issue has been, is and will continue to be the most dominant moral and ethical controversy in sport.

Recent high-profile cases, including the alleged drug use of the Essendon Football Club (Australian Football League) and the Cronulla Sharks (National Rugby League) in Australia, as well as the international scandals involving Lance Armstrong (cycling) and American sprinters Tyson Gay and Justin Gatlin (athletics), have all tainted sport and cast doubt over the legitimacy of individual and team performances.

Indeed, the International Olympic Committee (IOC) has singled out doping as the greatest challenge to the integrity and future of world sport.

The World Anti-Doping Agency (WADA) was established in 1999 in response to the concerns of the IOC. WADA is an independent agency that is composed of and funded by governments and sporting movements of the world. The mission of WADA is to ‘promote, coordinate and monitor the fight against doping in sport in all its forms’.

The introduction of anti-doping codes in sport has been an integral part of the fight to eradicate the use of drugs and other illegal performance-enhancing methods in sport. These practices are prohibited because they:

- artificially enhance the performance of an athlete
- are potentially harmful to the health of an athlete
- are contrary to the spirit of sport.

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**Doping** is the use by, or distribution to, an athlete of certain substances or methods that could have the effect of artificially improving the athlete’s physical and/or mental condition and enhancing their performance.

**Anti-doping codes** are codes established to eradicate the use of drugs and other illegal performance-enhancing methods in sport.

---

**FIGURE 5.13** (a) American sprinter Tyson Gay has been recently involved in a drug scandal. (b) Concerns were raised about Essendon’s supplements program in season 2012, which subsequently led to a full investigation into illegal use of drugs at the club.

**Performance-enhancing substances and methods**

Performance-enhancing substances and methods have been employed by athletes and coaches for a variety of reasons:

- to increase strength and muscle mass (anabolic agents, steroids)
- to counteract undesirable side-effects (hormones, anti-oestrogenic substances)
- to mask the presence of banned substances (diuretics)
- to increase alertness and/or aggressiveness (caffeine, amphetamines)
to enhance oxygen transfer (blood doping)
- to alter samples provided for testing (urine substitution)
- to speed up the rehydration process (intravenous infusions)
- to reduce pain (narcotics).

Performance-enhancing drugs are currently banned or considered illegal in most sports. Furthermore, some performance-enhancing practices currently used in sport produce exactly the same results, but are neither banned nor illegal. For example, the illegal drug anabolic steroid increases lean muscle mass, thus enhancing the strength and power an athlete can generate. However, the same effect can be obtained legally by participating in a resistance training program, as discussed earlier in this chapter.

WADA produces a list of prohibited substances and methods annually. Many drugs are prohibited at all times, whereas others are prohibited only in competition. Some substances are banned only in certain sports. Athletes caught using these drugs have been stripped of their medals and records and banned from their sports, sometimes for years and, on occasions, for life.

The performance-enhancing drugs and methods most relevant to the development of the musculoskeletal system include those based on naturally occurring hormones in the human body, specifically anabolic steroids, and growth hormones and related substances. These substances are prohibited at all times.

**Anabolic steroids**

**Steroids** are synthetically produced drugs that mimic the effect of the hormone testosterone. Testosterone has both an anabolic effect and an androgenic effect on the human body. The anabolic effect promotes bone density, muscle growth and rapid recovery from injury, while the androgenic effect relates to the development and maintenance of male secondary sexual characteristics, such as growth of the male reproductive system and development of muscle mass, a deeper voice and facial hair.

Athletes may use steroids for their anabolic effects; that is, the building of bone and muscle to increase the amount of strength and power they can produce. With greater strength and power, athletes are able to produce more force to run quicker,
Illegal substances and methods that enhance performance of the musculoskeletal system

• The human body in motion

to jump higher and throw further. The other reason for athletes using steroids is an increased rate of recovery which allows an athlete to train more often and for longer periods of time. The use of anabolic steroids allows an athlete to increase muscle growth and strength quicker than through legal methods such as resistance training.

Potential harms related to the use of steroids can be different for males and females, due to the increased level of testosterone in the body. Males are at risk of possible infertility, increased libido, testicular atrophy, baldness and development of breast tissue. Females are at risk of menstrual problems, increased body and facial hair, an enlarged clitoris and deepening of the voice. Both genders are at equal risk of tendon injury, fluid retention, liver damage, tremors, mood swings and depression, hypertension, acne (face and back) and cancer.

A legal alternative to steroids to promote muscle growth is resistance, plyometric and short interval training and the use of protein supplementation to assist the growth and repair of muscle.

Human growth hormone

Human growth hormone (hGH) is a peptide hormone that is naturally produced by the pituitary gland. This hormone determines the height, bone and muscle growth of an individual.

Synthetic growth hormone may be taken by athletes in the belief that it will increase muscle strength, and hence athletic performance, through its capacity to build muscle. However, research indicates that the effects of hGH are inconclusive at best and any performance benefits to the athlete are most likely through taking a combination of steroids and hGH. Other growth factors such as Hexarelin, stimulate the release of growth hormone and have been linked to quicker recovery and healing times from injury. Similar to steroids, use of human growth hormone and related factors allows an athlete to increase muscle growth and strength quicker than through legal methods such as resistance training.

Potential harms of human growth hormone use include fluid retention, acromegaly, thickened skin, hypertension, hairiness, cardiac disease, osteoarthritis, and joint and bone pain.

Like steroids, a legal alternative to using human growth hormone to promote muscle growth and strength development is resistance, plyometric and short interval training, as well as the use of protein supplementation to assist the growth and repair of the muscles being exercised.
### Table 5.11: Illegal methods used to enhance the performance of the musculoskeletal system

<table>
<thead>
<tr>
<th>WADA classification</th>
<th>Examples</th>
<th>Performance benefits</th>
<th>Potential harms (side-effects)</th>
<th>Legal alternative</th>
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</thead>
<tbody>
<tr>
<td>S1 Anabolic agents</td>
<td>Anabolic steroids</td>
<td>Increased lean muscle mass and strength</td>
<td>In males: Possible infertility</td>
<td>Resistance training</td>
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<td></td>
<td>Nandrolone</td>
<td>Reduced fatigue</td>
<td>Increased libido</td>
<td>Plyometric training</td>
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<td>Stanozolol</td>
<td>Increased rate of recovery</td>
<td>Testicular atrophy</td>
<td>Short interval training</td>
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<td>Tetrahydrogestrinone (THG)</td>
<td>Increased aggression</td>
<td>Baldness</td>
<td>Protein supplementation</td>
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<td></td>
<td></td>
<td></td>
<td>Development of breast tissue</td>
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<td>In females: Menstrual problems</td>
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<td></td>
<td>Increased body and facial hair</td>
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<td>Enlarged clitoris</td>
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<td>Deepening of the voice</td>
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<td>Both: Tendon injury</td>
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<td></td>
<td>Fluid retention</td>
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<td></td>
<td>Liver damage</td>
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<td>Tremors</td>
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<td>Mood swings and depression</td>
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<td>Hypertension</td>
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<td>Cardiac disease</td>
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<td>Fluid retention</td>
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<td>Osteoarthritis</td>
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<td>Joint and bone pains</td>
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<tr>
<td>S2 Growth factors</td>
<td>Growth hormone releasing hormone (GHRH)</td>
<td>Enhanced muscle and bone development</td>
<td>Acromegaly</td>
<td>Resistance training</td>
</tr>
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<td></td>
<td>Insulin-like growth factor-1 (IGF-1)</td>
<td>Increased muscle size and strength</td>
<td>Thickened skin</td>
<td>Plyometric training</td>
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<td></td>
<td>Hexarelin</td>
<td>Reduced recovery time</td>
<td>Hypertension</td>
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<td>Joint and bone pains</td>
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</table>

**TEST your understanding**

1. Define the term *doping*.
2. List some of the reasons why some athletes may use performance-enhancing drugs in sport.
3. What is WADA? Explain its role in anti-doping initiatives.

**APPLY your understanding**

4. Explain the difference between a performance-enhancing substance and a performance-enhancing method.
5. Discuss why some drugs are banned all the time but others are prohibited only in certain sports.
6. Outline how hormone-based drugs such as steroids and human growth hormone can physiologically enhance the performance of athletes.
The use of performance-enhancing substances and methods in sport, whether they are legal or illegal, remains a hotly debated topic within sport, media and society. Performance-enhancing practices have the potential for both positive and negative outcomes, providing physiological benefits as well as potential harms to the athlete.

The big question facing many athletes is whether or not to use performance-enhancing substances and methods and, if they choose to do so, which ones will be of most benefit to the athlete. As outlined in this chapter, there are a number of legal and illegal substances and methods available to improve the functioning of the musculoskeletal system. In addition to these, the area of performance enhancement is constantly developing. New products designed to assist athletes to develop their strength and power, enhance their energy stores and improve their recovery times in order to train at higher intensities more frequently are entering the market all the time.

Ethical considerations regarding the use of performance-enhancing practices

The debate surrounding the use of both legal and illegal performance-enhancing substances and methods is not as definitive as ‘is it right or wrong to use them’.

Illegal performance enhancement incites many different opinions regarding whether or not a substance should be classified as illegal. The IOC and many professional and amateur sporting organisations subscribe to the WADA Anti-Doping Code classification, which states that if a substance has the capacity to artificially enhance the performance of the athlete, place the health of the athlete at risk or is contrary to the spirit of sport, it should be banned. Supporters of the code consider the use of any illegal substance or method is wrong and amounts to cheating as it provides an unfair advantage of one athlete over another. Athletes who have been implicated in the use of banned substances, such as anabolic steroids, to improve the functioning of the musculoskeletal system, have had their medals stripped and served bans from their chosen sport. Examples include the three track and field athletes, Ben Johnson, Marion Jones and Justin Gatlin.

There is also a school of thought that argues in favour of the use of some current illegal substances and methods. They argue that performance enhancers are so prevalent in sport that the right and only realistic option is to allow athletes to use what they want as long as they do it safely. Suggestions of scientifically backed, medically supervised doping programs are common. Such suggestions argue that administration of the naturally occurring substances within the body, such as testosterone, within safe limits should be allowed to enhance the performance of an athlete.
While most of the debate centres around the use of illegal substances and methods, there are also ethical considerations regarding the use of legal substances and methods. Because a substance is legal, is it right to use it? Should all legal substances be available to or given to all athletes? This is particularly pertinent for junior athletes in relation to nutritional supplements such as creatine, caffeine and protein powders. These substances have credible evidence for improving the functioning of the musculoskeletal system in well-trained, developed bodies but the safety of supplement use in juniors with developing bodies is unknown due to lack of studies in this demographic.

The Australian Institute of Sport (AIS) does not recommend the use of nutritional supplements such as creatine and protein powders, instead they encourage a well-planned, balanced and varied diet, along with training practices such as resistance training, to meet muscle growth and repair demands. Consumption of liquid meal replacements and food sources such as yoghurt with high protein content are recommended for the developing athlete, rather than synthetically produced supplements.

Another consideration for legal performance enhancement relates to access to these substances and methods, and the concept of a fair and level playing field. Some athletes and teams have access to specialised support staff (medical professionals, nutritionists, physiologists) and an array of training equipment and expertise to focus their training on improvements in strength, power and speed. Many others do not. Financial support also plays a large role in the ability of an individual or team to achieve success. It has been widely documented that in 2012, the success of the UK team at the London Olympics was attributed to an increased amount of funding dedicated to its Olympic team to help them perform well on home soil. Does this gap in levels of professional support and funding mean there is a fair and level playing field for all athletes?
Case study: Where does an athlete draw the line in terms of using performance-enhancing substances?

Associate Professor Craig Fry and Australian athlete Kimberley Crow put their cases forward for the use of legal and illegal performance-enhancing substances in sport.

Bring truth into play by saying yes to drugs in sport

BY CRAIG FRY

Bans on performance enhancers don’t make elite competition fairer.

THE 2012 Tour de France starts this weekend under yet another drugs cloud. The US Anti-Doping Agency’s recent announcement of “doping” charges against Lance Armstrong and others is no small matter.

If the case is proven, it will nullify Armstrong’s record seven Tour de France wins between 1999 and 2005, and reverberate much more widely through international cycling. This being an Olympic year, it amplifies the relevance of this case for world sport generally.

It is a good time to reflect on our current thinking about performance enhancement in sport.

Most people are against performance enhancing drugs in elite sport based on the fairness and equity ideal of a level playing field, and a belief that ‘doping’ is unnatural and poses a health risk.

But what is the truth of performance enhancement in elite competition? Let’s take the level playing field idea first.

These days, elite-level sportspersons have an increasing array of performance-enhancing options and technologies available — from lighter, smoother, stronger and more aerodynamic competition clothing and equipment to scientifically advanced skills and fitness training regimes. The list goes on.

Access to these resources is far from equal. Major equity gaps exist across and within countries as a function of national wealth, development and politics. Gaps also exist between certain sports due to differences in marketability and public profile, and related funding.

The genetic lottery of sporting ability is hardly fairer either. The people who compete for Olympic medals, world championships and Tour de France jerseys are the genetic exceptions, not the rule.

We might all agree in principle that striving for greater equity in sporting competition is important. But belief in that ideal doesn’t commit us to judging all examples of advantage or disadvantage as unfair or morally wrong. Like it or not, in sport there is difference and this is determined by more than natural abilities alone.

What about the argument that performance-enhancing drugs are problematic because they are unnatural, dangerous and risky?

In elite sport, no one gets to be the fastest, strongest or most skilled through natural hard work alone. In addition to the performance technologies already highlighted above, a cornucopia of nutritional, medicinal and other aids for energy, recovery, pain and stress relief, and emotional and mental health is now available to athletes.

Use of these consumable performance enhancers is widespread in the highest levels of all sports, with government-funded scientific programs and large teams of health and other professionals devoted to maximising outcomes.

Why make a distinction between these accepted examples and performance enhancement through use of corticosteroids, testosterone, erythropoietin, clenbuterol and the like?

Many say such substances and other doping practices should be restricted because of risks to athlete health. There are indeed risks with the use of these banned substances. But safe forms of most of these are in use in other areas of life. And legally obtained drugs and medicines have risks and side effects too if used inappropriately.

For many people, the fact that certain practices are defined as illegal or prohibited in the sporting context is reason enough to accept them as such. Regulations that aim to govern sporting conduct are necessary at all levels, but we should acknowledge there is no divine or universal truth to the rules of sporting competition. These are subjectively defined, and history confirms that these change over time as knowledge and attitudes evolve and societal expectations shift.

We may like to believe that our modern sporting rules and laws uphold the ideals of equity and natural risk-free achievement in elite sport. Yet current practices suggest that the true spirit of elite sporting competition is more consistent with the Athenian ideal of superhuman effort at any cost.

The truth is ‘health risk’ occupies a central place in sporting competition. We applaud our sporting heroes when they take risks and triumph through injury. Putting your body on the line, pushing physical limits, and courageous play are as much a part of the allure of elite sporting competition as any interest in fairness and upholding the rules.

There will always be athletes at the highest levels willing to use banned drugs and other substances. The allure of fame, money, power and position for the successful will see to that.

The inconvenient truth is that the current drugs and substances prohibited from elite sporting competition are not uniquely dangerous or risky, or inherently harmful. Nor are they the only or biggest sources of risk.

We have the knowledge to use such things safely in sport if we so choose. Instead, our approach encourages clandestine doping.

As we have seen with drugs and other substances regarded as dangerous, prohibition policies serve to create illicit markets of hidden, uninformed and unregulated consumption. The evidence confirms such conditions exacerbate a range of health and other harms to both individual and community.

The level playing field and natural, risk-free achievement in elite sport are also mental myths. Using these ideals to argue against performance-enhancing drugs in sport makes little sense, and does not reflect the truth of elite sporting competition as it occurs today.

An alternative would be an open and regulated approach to performance-enhancing drugs in elite sport. This would be consistent with the range of other enhancement technologies and resources used now. It would also better enable us to prevent and or minimise the health risks to those athletes already using prohibited substances secretly.

Associate Professor Craig Fry is a principal fellow at the Centre for Health & Society and Centre for Applied Philosophy and Public Ethics, Melbourne University. He specialises in drugs in society, health ethics and policy.

Source: The Age, 29 June 2012.
Allow drugs in sport? I nearly choked on my (low-fat) Weeties

BY KIMBERLEY CROW

I can remember the moment when I choked. I was happily reading *The Age* online from the Australian Institute of Sport’s training base in Northern Italy. I was shovelling down a pre-training bowl of muesli (natural) with milk (low-fat) when Craig Fry’s opinion piece ‘Bring truth into play by saying yes to drugs in sport’ (29/6) sent my throat into oesophageal reflux.

Fry’s contention was that “the level playing field and natural, risk-free achievement in elite sport are sentimental myths” and that, therefore, it is anomalous to ban performance-enhancing drugs.

A highly scientific vox-pop of the breakfast table uncovered a startling result. Of those surveyed (three), 100 per cent would not participate in sport if performance-enhancing drugs were required to become successful. We are not lab-rats, nor are we the pin-cushions of sports doctors. We are living, breathing, thinking, aspiring human beings.

What Fry fails to tackle is why people pursue elite sport in the first place.

From the outside looking in, I can understand why it appears that elite sport is about winning, fame and self-aggrandisement. That we do this for the Weeties boxes.

We don’t. Motivations will differ markedly from person to person, but speaking for myself, I aspire to Olympic gold because I see it as an opportunity to test my limits, to challenge myself to be better, to grow as a person.

For me, the most important asset I will take with me to the start line of the Olympics is willpower. It is willpower strengthened over years of refining technical skills under duress, of pushing my body to work harder when all it wants to do is stop, that will enable me to be the best I can be at the Olympics.

While it is easy to look at elite sportspeople and see genetic freak-ism, the truth is far removed. I was genetically blessed with long limbs and an above-average aerobic capacity. I was also genetically slammed with below-average strength and my fair share of dodgy bones. Like every rower, it was hard work, persistence and an unrelenting desire to get better that enabled me to improve.

With a few small exceptions in niche events — such as 100-metre sprinting, which requires a God-given gamut of fast-twitch fibres — the common thread among elite athletes is exceptional dedication, not exceptional genes.

An Olympics where willpower is displaced, and the competition becomes about who has taken the most or the best drugs, is an Olympics I never want to be a part of.

Elite sport would move from a test of personal strength, courage and commitment, to a giant game of chicken, where the winner is the one prepared to risk their health the most in order to win.

One need only look to the tragic deaths of riders before cycling got serious about stamping out doping, or the ruined lives from East Germany’s doping regime, to see that the health ramifications far outweigh any theoretical imperfections cited by Fry in the ‘level playing field’ concept.

Certainly, some performance-enhancing substances and methods used to gain an ‘edge’, such as using ice baths for recovery, training at altitude or using biomechanical expertise, may be unfairly accessible to some but not all athletes.

But a line delineating the acceptable and unacceptable must be drawn somewhere.

The speed limit in school zones is set at 40 km/h, not because 39 is definitively ‘safe’ and 41 definitively ‘unsafe’, but because it is the most appropriate limit to balance the competing considerations of safety and the ability of cars to get from place to place in reasonable time.

The line between which drugs are permitted in sport and which are not is premised on a similar balancing act. Drugs that are clearly performance-enhancing and risky to athletes, such as steroids, are banned. Drugs that are used every day for common ailments and pose little risk to athletes’ long-term health, such as paracetamol, are not.

There will always be grey areas. Should intravenous drips to administer permitted substances be allowed? Should caffeine, a performance-enhancing stimulant, yet one common in society, be banned?

These issues are constantly monitored by our anti-doping agencies, and change over time to reflect where best the line should be drawn.

Yet the presence of grey areas is no reason for failing to draw a line at all.

Beyond the consequences for elite athletes themselves, the trickle-down ramifications for grassroots sport is deeply concerning.

Nor should anyone assume that the fight against doping is failing. The artillery of detection mechanisms is greater than ever. We have to record our whereabouts for every single day of the year. We can be tested anywhere, any time.

We can be required to provide blood, urine or both. Our samples can be stored for up to eight years, and can be retested when tests for new drugs become available. Our blood samples can be compared against each other over the duration of our careers (the ‘blood passport’) and be monitored for changes concerning.

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Doping detection mechanisms and the ‘level playing field’ may be imperfect, but elite athletes should not have to play Russian roulette with their health in order to win.

Kimberley Crow is a member of the Australian rowing team.

Sociocultural influences on the use of performance-enhancing practices

All athletes strive to achieve their best but the pressure placed on athletes to succeed may greatly influence the decisions they make about the most effective way to achieve the goals they have set for themselves. While many would say it is the responsibility of the individual athlete to know what they are using — whether the substance is legal or illegal or if it has any side-effects — it is not always clear cut. Athletes are individuals but are also part of a wider support group which has the capacity to influence their behaviour and the choices they make, especially in relation to their performance. A variety of sociocultural reasons may influence an athlete to use performance-enhancing substances and methods to gain an edge over their fellow competitors.

Sociocultural influences come from the power structures and relationships within society and the culture that creates shared ways of thinking and doing things. In sport, these sociocultural influences include:

- income
- education
- influence of self, family, peers
- influence of coaches and sporting organisations
- cultural norms in the society or the particular sporting culture
- national and political ideology.

These may all have an impact on whether athletes choose to use legal or illegal performance-enhancing substances. Some examples are highlighted below.

**Income**: The financial and material rewards of success can be a major influence on athletes. The need to earn an income to support training and travel, and the celebrity status that may come with product endorsements or sponsorship can influence choices made. The fame and prestige associated with being the ‘fastest person in the world’ are often cited as the reason why athletes, in particular sprinters, have been linked with illegal substance use. The opportunity to move out of poverty may also be a strong influence for an athlete. In many of the African nations, where being an elite athlete provides you with an avenue to change the course of your life, there is incentive to use a performance-enhancing substance to win races, get noticed by talent scouts and make national teams.

**Influence of self, family, peers**: Pressure can be derived from the expectations of family members, or of the individual themselves, to win and be successful. Individual pressure is often derived from the want to improve performance, receive the accolades that go with winning and be a sporting hero. Peers can also be a significant source of pressure, whether that be through encouragement to use, or from the belief that other athletes around them are using substances to enhance their performance. Youth are often faced with pressure from their peers to take legal substances such as creatine or protein powders to increase muscle bulk, strength and power. This extends to recreational and amateur sportspersons, as well as those hoping to make it professional in their sports. The risk with this revolves around level of education and understanding of the benefits and harms of using these substances, as the advice is often not from an informed individual.

**Influence of coaches and sporting organisations**: The Essendon football club supplements saga has highlighted the strong influence a coach, their support personnel and the sporting organisation can have on an athlete. In 2016, 34 players...
received WADA bans for alleged use of the performance-enhancing substance thymosin beta 4, a banned peptide that can enhance healing via production of new cells. The introduction of this drug, along with other supplements in 2012, was part of a program to assist the football club to gain an edge over fellow teams and bring them closer to a premiership. The players were told by the club that the supplements were legal and there was no risk of infringing the WADA anti-doping code. The blind faith and possibly misplaced trust of the players highlights the pressure that an athlete can face, especially in a team sport, to win at all costs.

TEST your understanding
1 Outline some of the specific pressures that athletes face, which may influence the use of performance-enhancing substances or methods.

APPLY your understanding
2 Case study: Read the articles written by Craig Fry and Kimberley Crow and answer the following questions.
(a) Craig Fry questions whether or not sport really is a ‘level playing field’. Outline his concerns.
(b) What motivations did Kimberley Crow suggest as the reasons people pursue elite sport?
(c) Fry and Crow both mention ‘grey areas’ of performance enhancement. List some of these.
(d) Who do you agree with? Write a brief paragraph comparing the two articles and provide a personal summation of whether you think there is a place for all forms of performance enhancement in sport.

FIGURE 5.20 James Hird, former coach of Essendon football club, who received a 12-month suspension for his role in the illegal drug use by players under his leadership.
Investigate, evaluate and critically analyse a range of performance-enhancing practices from a physiological perspective.
Discuss the ethical considerations and sociocultural influence on the use of legal and illegal practices associated with improving the function of the musculoskeletal system.

STRATEGIES TO DECODE THE QUESTION
- Identify the action word:
  a. Name — identify or state
  b. Provide — give or state
  c. Outline — general description but not in detail
- Key terminology:
  - Physiological benefit — changes that occur within the body to enhance the performance of the musculoskeletal system
  - Side-effects — harm or risk associated with the use of the substance or method
  - Key concept/s:
    - Illegal substance or method
    - Legal substance or method
  - Performance enhancement — improves the functioning of the musculoskeletal system
- Marking scheme:
  a. 2 marks
  b. 2 marks
  Always check marking scheme for depth of response required, linking to key information highlighted in the question.

EXAMPLE OF PRACTICE QUESTION
(adapted from ACHPER Trial Exam 2014, question 1)
Australian athlete, Sally Pearson, is the current Olympic champion in the women’s 100 m hurdle event. In winning this event in the 2012 London Olympics, her time was 12.35 seconds. As an elite athlete, Sally has been drug tested numerous times in her career.

a. **Name one** illegal ergogenic aid that an athlete may use in order to enhance performance in the 100 m hurdles and provide **one legal alternative** that could be used to give similar performance improvement. **2 marks**

b. **Outline one** perceived physiological benefit and one harmful side-effect (other than heart attack or death) of the illegal ergogenic aid given in part a. **2 marks**

Sample response:
**Illegal ergogenic aid** — one of anabolic steroids or growth hormone

**Physiological benefit**
- Anabolic steroid — can include increased muscle bulk, increased aggression, faster recovery rates after training
- Human growth hormone — can include enhanced muscle/bone development, anti-inflammatory effects

**Potential side effect**
- Anabolic steroid — can include cancer, hypertension, fluid retention, acne, testicular atrophy, breast atrophy, anger issues
- Human growth hormone — can include fluid retention, cancer, infertility, hypertension

HOW THE MARKS ARE AWARDED
a. 1 mark — naming an illegal ergogenic aid relevant to improving performance to compete in the 100 m hurdles
b. 1 mark — naming a legal ergogenic aid relevant to improving performance to compete in the 100 m hurdles

PRACTICE THE KEY SKILLS
1. Choose either caffeine, creatine or bicarbonate. Outline perceived benefits and possible harms for an athlete who might consume these supplements.
2. Identify one legal and one illegal method that athletes might use to build muscle strength and power. Discuss performance benefits and potential harms of these methods.
3. Discuss some of the specific pressures athletes experience that may influence them to use performance-enhancing drugs and/or methods to improve the musculoskeletal system.

KEY SKILLS EXAM PRACTICE
(ACHPER Trial Exam 2008, question 9)
Creatine supplementation is a dietary enhancement practice thought to enhance performance.

a. Outline the major perceived benefit to performance from the use of creatine supplementation. **2 marks**
b. What type of athletes would most benefit from the use of creatine supplementation? **1 mark**
c. Outline one other possible effect that creatine supplementation may have on an athlete. **2 marks**
CHAPTER REVIEW

CHAPTER SUMMARY

Performance enhancement

- Performance enhancement includes any methods, devices or substances that have the potential to improve athletic performance. They can be legal or illegal and are categorised as mechanical, nutritional, pharmacological, physiological or psychological aids to enhance performance.
- Performance-enhancing substances and methods improve performance by influencing the physiological capacity of a particular body system, removing physiological constraints that impact on performance or increasing the speed of recovery.

Legal substances and methods

- Legal substances and methods to enhance performance of the musculoskeletal system include training methods such as resistance training, plyometric training, and short and intermediate interval training.
- Training methods and mechanical devices can improve an athlete’s performance by increasing the strength, power and speed generated by the muscles to run faster, jump higher and throw further.
- Nutritional supplements can also benefit the athlete. There are myriads of nutritional supplements on the market, although many of them have no scientific backing to support their performance-enhancement claims. While specialised sports foods or drinks are very popular and can be a useful addition to a specialised program, nutritional performance supplements should be used with caution. Only a few so-called nutritional performance supplements actually offer benefits supported by scientific evidence.
- The AIS provides an information program for its athletes, which categorises sports supplements and/or ergogenic aids. Currently, only those supplements found in group A have scientific backing and are supported by the AIS for use by its athletes. Examples of these supplements include sports drinks, electrolyte replacement supplements, sports bars or gels, liquid-meal supplements, orally ingested vitamin or mineral supplements, protein supplements, caffeine, creatine and bicarbonate.

Illegal substances and methods

- Doping is the use of certain substances or methods that could artificially improve an athlete’s physical and/or mental condition, thus enhancing their performance. Performance-enhancing drugs are currently banned or considered illegal in most sports.
- Performance-enhancing drugs may be taken by athletes to increase their strength and muscle mass, counteract undesirable side-effects, mask the presence of other banned substances, increase alertness or aggressiveness, or reduce pain.
- The World Anti-Doping Authority (WADA) produces a list of banned substances and methods annually that athletes and sporting organisations must abide by. Drugs can be prohibited at all times, only in competition or only in certain sports depending on their classification and effects on the body.
- Performance-enhancing drugs most relevant to the development of the musculoskeletal system include those based on naturally occurring hormones in the human body, including anabolic steroids and growth hormones and related substances.
- There are a variety of reasons why athletes take drugs. These can include dissatisfaction with performance and progress; belief that others are using drugs; being easily influenced by others; lack of knowledge about side-effects; culture of the sport; pressure to win from coach, parents, public, media; and financial reward.

MULTIPLE CHOICE QUESTIONS

1. The most relevant anaerobic training methods to enhance performance of the musculoskeletal system are
   (A) resistance training, fartlek training, flexibility training.
   (B) plyometric training, continuous training, circuit training.
   (C) resistance training, plyometric training, short-interval training.
   (D) plyometric training, flexibility training, long-interval training.

2. Plyometrics aims to increase muscular power by which of the following methods of contraction?
   (A) A rapid isokinetic contraction followed by a rapid concentric contraction
   (B) A rapid eccentric contraction followed by a rapid concentric contraction
   (C) A rapid concentric contraction followed by a rapid eccentric contraction
   (D) Holding an isometric contraction
3 Which of the following is not a legal supplement that can be used by an athlete to enhance performance?
   (A) Creatine
   (B) Protein
   (C) Caffeine
   (D) Steroids

4 Sports gels are commonly used by athletes to increase fuel supply of which nutrient?
   (A) Protein
   (B) Carbohydrates
   (C) Fats
   (D) Vitamins and minerals

5 Sports drinks can limit the fatigue of an athlete during an event, as they can
   (A) hydrate an athlete.
   (B) hydrate and refuel an athlete.
   (C) refuel an athlete.
   (D) stop hunger.

6 Caffeine is commonly used by athletes to enhance their performance as it is thought to
   (A) decrease perception of fatigue and effort.
   (B) decrease glycogen-sparing capacity.
   (C) increase heart rate.
   (D) increase fuel stores.

7 Illegal performance-enhancing drugs most relevant to the musculoskeletal system include
   (A) steroids and stimulants.
   (B) steroids and blood doping.
   (C) steroids and growth hormone.
   (D) steroids and beta blockers.

8 WADA have prohibited the use of a number of substances and methods by athletes, as they have the potential to
   (A) artificially enhance the performance of an athlete.
   (B) be potentially harmful to the health of an athlete.
   (C) be contrary to the spirit of sport.
   (D) All of the above.

9 Power athletes may use human growth hormone (hGH) in an attempt to increase their muscle bulk. A potential harm of taking this drug could be
   (A) increased blood viscosity.
   (B) Hypertension.
   (C) decreased libido.
   (D) Increased heart rate.

10 A legal alternative to using steroids that could induce the same physiological changes to enhance performance would be
   (A) creatine supplementation.
   (B) human growth hormone injections.
   (C) resistance training.
   (D) continuous training.

**EXAM QUESTIONS**

**Question 1**

(ACHPER Trial Exam 2013, question 12)

In January 2013 Lance Armstrong, winner of seven Tour De France titles, admitted that he had used numerous performance-enhancing drugs and/or practices to help him secure these wins.

List one perceived benefit and one side-effect that Armstrong would have experienced by consuming the substance anabolic steroid.

Benefit:

Side-effect:
Question 2  (ACPER Trial Exam 2015, question 10)
Michael Clarke is an Australian cricketer who hit a score of 128 off 163 balls in two days of play during a five-day test match against India. In the same summer season Peter Handscomb hit a score of 103 off 64 balls in a Twenty20 game that was completed in three hours.

a. Michael Clarke was advised to consume caffeine during the five-day test match.
   Evaluate the perceived benefits of caffeine supplementation as a nutritional strategy for Michael Clarke during a five-day test match.  
   4 marks

b. List and explain one hydration technique, other than drinking water, that Michael Clarke could utilise during a five-day test match to enhance performance.  
   2 marks

Question 3  (ACPER Trial Exam 2011, question 6)
Samuel Wanjiru of Kenya won the Olympic Marathon in Beijing 2008 in an Olympic record time of 2 hours, 6 minutes and 32 seconds. The event was held in hot and humid conditions. In preparation for the event Samuel regularly trained over 160 kilometres per week.

a. Elite endurance athletes like Samuel Wanjiru will carbohydrate (CHO) load before their event. Outline the dietary and training strategies that should be used in conjunction with CHO loading.  
   2 marks

b. i. Other than the associated benefits of increasing muscle and liver glycogen stores, describe one advantage of CHO loading and how it assists performance.  
   3 marks

   ii. Outline two disadvantages that may be associated with CHO loading.  
   2 marks

Question 4  (ACPER Trial Exam 2012, question 12)
Protein is a vital component in an athlete’s diet.

a. Name two foods that are a high source of protein.  
   2 marks

b. Outline two roles that protein plays in exercise recovery.  
   2 marks

Question 5  (ACPER Trial Exam 2008, question 19)
During 2005, the media ran a number of stories relating to the use of caffeine supplements as a performance-enhancing practice for elite athletes.

a. Outline two supposed performance benefits associated with the use of caffeine.  
   2 marks

b. Outline two potential side-effects associated with the use of caffeine as a performance-enhancing substance.  
   2 marks