INQUIRY QUESTION
How can an athlete maximise their oxygen-carrying capacity and the efficiency of their cardiorespiratory system to improve their performance in endurance-based events?
There are many legal and illegal substances and methods that can be used to enhance the performance of the cardiorespiratory system. The perceived benefit must be considered against potential harms when deciding on a method to use.

**KEY KNOWLEDGE**
- Actual and perceived benefits and potential harms to the athlete of legal and illegal substances and methods that enhance performance of the cardiorespiratory system, such as altitude training, erythropoietin (EPO), beta blockers and blood doping
- Ethical and sociocultural considerations associated with the use of illegal practices associated with improving the function of the cardiorespiratory system

**KEY SKILLS**
- Critically analyse the physiological effects of legal and illegal strategies that enhance the performance of the cardiorespiratory system on the individual
- Discuss the ethical, social and cultural considerations associated with the use of legal and illegal practices associated with improving the function of the cardiorespiratory system

**CHAPTER PREVIEW**
- **Legal methods and substances**
  - Physiological methods
    - Aerobic training
    - Altitude training
- **Illegal methods and substances**
  - Erythropoietin (EPO)
  - Beta blockers
  - Blood doping
- **Benefits and harms**
  - Ethical and sociocultural influences

**Performance enhancement of the cardiorespiratory system**
**KEY CONCEPT** Legal performance enhancement of the cardiorespiratory system can include the use of aerobic training methods and altitude training to increase the oxygen delivery to working muscles.

As previously discussed, the cardiorespiratory system has an important role in delivering oxygen to muscles to create energy for movement. The respiratory system brings air from the atmosphere into the lungs and transfers oxygen into the blood, while the cardiovascular system transports the oxygen around the body to the working muscles. The cardiorespiratory system primarily contributes to aerobic energy production.

A variety of training methods can be used by athletes and coaches to enhance performance of the cardiorespiratory system. Training methods that can specifically enhance this system include:
- aerobic training methods such as continuous training, fartlek, long-interval or high-intensity interval training to develop endurance
- altitude training to increase the production of red blood cells to allow for greater oxygen-carrying capacity.

Through specific training, a number of chronic cardiovascular and respiratory adaptations occur to enhance an athlete's performance. These are outlined in table 9.1.

<table>
<thead>
<tr>
<th>Chronic adaptation</th>
<th>Benefit to performance</th>
<th>Potential harms</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Cardiovascular:</strong></td>
<td><strong>Increased endurance and VO₂ max via:</strong></td>
<td>Risk of injury due to:</td>
</tr>
<tr>
<td>Increased left ventricle size and volume</td>
<td>Increased blood flow and delivery of oxygen to working muscles</td>
<td>Lack of adequate fitness</td>
</tr>
<tr>
<td>Increased stroke volume</td>
<td>Increased oxygen-carrying capacity and waste removal</td>
<td>Incorrect application of training principles</td>
</tr>
<tr>
<td>Decreased heart rate at rest and submaximal workloads</td>
<td>Increased diffusion from bloodstream into muscle resulting in greater uptake of oxygen by muscle to produce energy</td>
<td>Not enough recovery</td>
</tr>
<tr>
<td>Increased cardiac output during maximal exercise</td>
<td></td>
<td>Incorrect technique</td>
</tr>
<tr>
<td>Increased arterio-venous difference (a-V̄O₂ diff)</td>
<td></td>
<td>Overtraining</td>
</tr>
<tr>
<td>Increased blood and plasma volume</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Increased red blood cell and haemoglobin levels</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

| **Respiratory:** | Increased oxygen available for diffusion | |
| Increased pulmonary diffusion | Increased diffusion from alveoli into bloodstream | |
| Increased lung ventilation during maximal exercise | | |
| Increased maximum oxygen uptake (VO₂ max) | | |
Aerobic training methods

Aerobic training methods can include continuous, fartlek and long-interval training. Each of these methods aims to improve the delivery of oxygen to working muscles as well as increase oxygen consumption ($\text{VO}_2\text{ max}$) for energy production. The performance benefits of a more efficient cardiorespiratory system mean that during aerobic activity, athletes will not have to work as hard at the same intensity or they will be able to work at a higher intensity for longer while still using the aerobic system and therefore delaying fatigue. An athlete can reach steady state faster, accumulate lactate more slowly and recover more quickly.

As with all training, there are potential harms associated with aerobic training. The athlete needs to develop a solid base relative to their level of fitness before working at higher intensities or increasing training distances. Overtraining or incorrect application of training principles, such as inadequate recovery between sessions, can increase the risk of injury.

Continuous training

Continuous training involves continuous activity that lasts a minimum of twenty minutes at the required submaximal (70–85 per cent max HR) intensity. It leads to an improvement in aerobic power and hence the delivery of oxygen to working muscles. Commonly used by runners, swimmers and cyclists, as well as in team sports as a pre-season training method to establish a sound aerobic base. An example of a continuous training session is a 30-minute cycle working at 80 per cent of HR max.

Fartlek training

Fartlek training is a variation of continuous training that involves changes of intensity throughout the session. Continuous submaximal efforts interspersed with high-intensity efforts allow the athlete to work both the aerobic and anaerobic energy systems, simulating the interplay that may be required in many individual and team sports. This benefits the athlete through improvements in anaerobic capacity and speed, as well as aerobic power and endurance. Examples of changes in intensity can be simply an increase in pace or running up a hill to increase the contribution of the anaerobic glycolysis energy system.
9.1 Legal substances and methods: training methods and mechanical aids

**Interval training**

**Long-interval training** involves set periods of work followed by set periods of rest or recovery, repeated several times in an exercise session. Unlike the shorter distance interval training methods, long-interval training involves working at a submaximal intensity for longer distances with a work-to-rest ratio of 1:1. It is important to note that the athlete can work at a higher intensity, closer to 85 per cent HR max, due to the longer rest period, generally involving an active recovery at a lower submaximal intensity. A sample long-interval session for a middle-distance runner might be completing three sets of running for four minutes at 85 per cent + HR max followed by rest recovery for four minutes.

**High-intensity interval training (HIIT)** involves repeated bouts of high intensity efforts (90–95+ per cent HR max) followed by varying periods of recovery at a lower intensity (40–50 per cent HR max). These efforts can be manipulated to suit endurance athletes, with work periods ranging from 30 seconds to eight minutes. Overall sessions can last from 20 to 60 minutes. The benefit of including HIIT as part of a training program is that similar cardiovascular adaptations to participating in continuous training can be achieved, but in a shorter time frame with fewer sessions.

Athletes may include HIIT as part of their training but due to the demanding nature of working at very high intensities, adequate recovery must be factored in. It is suggested that two to three sessions per week is sufficient to achieve the necessary cardiorespiratory adaptions to increase VO₂ max.

**FIGURE 9.2** Changing intensity by running up a hill is a way to work the anaerobic energy system during fartlek training

**Mechanical aids to aerobic training**

Athletes can use a variety of movement- and intensity-tracking devices to assist traditional aerobic training methods and enhance the performance of the cardiorespiratory system. Devices include heart-rate monitors, GPS/activity trackers and cycling power metres.
These devices can provide instantaneous feedback, allowing the athlete to monitor and track the work being completed and ensure they are meeting proposed training aims. In particular, when athletes monitor the intensity at which they are working, they can establish if they are training in the correct aerobic training zone to gain maximal benefit from their training sessions.

**Altitude training**

Altitude training is a legal training method that involves training at levels greater than 1500 metres above sea level to induce physiological changes that enhance the oxygen-carrying capacity of the blood. The physiological adaptations that occur at altitude are thought to benefit performance at sea level. While this method is practised by a variety of athletes, research into the benefits for athletes performing at sea level is inconclusive.

As there is a lower level of oxygen present in the air at altitude, the body must adapt (acclimatise) to this reduced oxygen level. Physiological changes that occur with acclimatisation include:

- increase in the number of capillaries
- increase in the production of the naturally occurring hormone **erythropoietin** (EPO)
- increase in the production of red blood cells (RBC)
- increase in buffering capacity (especially waste removal)
- changes in the microscopic structure and function of muscles, including an increase in the number of mitochondria, the amount of myoglobin and the activity of oxidative enzymes.

These changes contribute to improvements in the oxygen-carrying capacity of the blood, increasing the delivery to and use of oxygen by the muscles. This benefits the performance of the athlete via improved maximal oxygen uptake (VO2 max), thus enhancing their endurance capacity.

A variety of techniques have been developed for training at altitude, however the ‘Live high – train low’ technique is the most common and involves the athlete living in a low-oxygen environment and training in a normal oxygen environment. This allows the body to acclimatise to low levels of oxygen by living at altitude, while not compromising training intensity. The recommended minimum time spent living at altitude is at least three weeks for more than 12 hours per day to gain benefits.

Training can occur at actual altitude (greater than 1500 metres elevation) or, in more recent times, in altitude or hypoxic chambers which can be rooms, houses or tents. These are specifically designed spaces that simulate altitude. Athletes can train or sleep in these artificially induced low-oxygen environments. As training at altitude
9.1 Legal substances and methods: training methods and mechanical aids

is often costly and inconvenient, organisations such as the Australian Institute of Sport (AIS) and many Australian Rules Football (AFL) clubs have their own simulated altitude rooms in their training facilities.

These rooms are designed for a number of athletes and can be used for:
- preparation for competition at high altitude
- maintaining the benefits of altitude training camps
- using the ‘live high – train low’ training technique (athletes can sleep at simulated altitude).

While altitude training has many actual and perceived benefits, there are also potential harms from altitude exposure that an athlete must take into consideration.
- The increase in red blood cells increases blood viscosity; that is, it makes blood thicker, reducing the speed of flow and making it harder to pump blood around the body, ultimately decreasing the delivery of oxygen to muscles.
- At very high altitudes (greater than 5000 m elevation) weight loss occurs, the immune system can weaken and due to the lower level of oxygen, the body cannot exercise as intensely as at sea level.
- Due to the reduced amount of oxygen, athletes find it difficult to maintain their intensity of training and their aerobic fitness may decrease.
- There is a risk of developing altitude sickness.

**FIGURE 9.4** Athletes train at altitude or in altitude rooms in an attempt to increase the oxygen-carrying capacity of their blood.

---

**TEST your understanding**

1. Outline the legal training methods that can be used to enhance cardiorespiratory performance.
2. Define the term ‘altitude training’.
3. Explain the perceived benefits and potential harms of altitude training for an athlete.

**APPLY your understanding**

4. Discuss why an athlete may use a mechanical aid in addition to normal training. Provide specific examples.
5. Discuss the physiological benefits an athlete can gain from participating in a continuous training program.
6. **Practical activity: participate in a fartlek training session**
   Participate in the following fartlek training session, based on the Gerschler Fartlek method.
   - Five minute warm-up
   - Repeat three times: Stride hard for 30 seconds, jog 90 seconds. Repeat with 15-second decreases in recovery jog, e.g. 30–90, 30–75, 30–60, 30–45, 30–30 and 30–15.
   - Five minute cool-down
      (a) Outline the physiological benefits of participating in a fartlek training program.
      (b) Explain how fartlek training differs from continuous and long-interval training.
      (c) Identify sports that would be suited to fartlek training. Choose one and design a fartlek training session specific to the requirements of that sport.
Illegal substances and methods that enhance performance of the cardiorespiratory system

KEY CONCEPT Illegal substances and methods that enhance the cardiorespiratory system can appeal to endurance athletes due to their ability to improve the delivery of oxygen to working muscles.

As outlined in chapter 5, performance-enhancing drugs are currently banned or considered illegal in most sports. Illegal substances and methods that athletes may use to enhance the cardiorespiratory system are quite different to those used to enhance the musculoskeletal system. The focus of these methods primarily revolves around the enhanced delivery of oxygen to the working muscles, improving and/or altering the function of the cardiorespiratory system.

Substances and methods that increase the amount of red blood cells in the body, such as erythropoietin (EPO) and blood doping, are prohibited at all times under the WADA code. The use of substances to manipulate the functioning of the cardiorespiratory system, such as beta blockers, are prohibited in certain sports where they offer a competitive advantage.

Famous doping cases involving these types of substances and methods have been linked to endurance sports, such as the now infamous case of Lance Armstrong who was stripped of seven Tour de France titles due to doping violations, or those sports requiring accuracy and precision, such as pistol shooting where North Korean athlete Kim Jong-Su returned a positive test to beta blockers at the 2008 Beijing Olympics and was stripped of both a silver and bronze medal.

For most illegal practices, there are safer legal alternatives that can produce exactly the same results but are neither banned nor illegal. For example, the illegal drug erythropoietin (EPO) can create an increase in red blood cell levels; however, the same effect can be obtained legally by living and training at altitude, or by spending time (usually while asleep) inside an altitude chamber or tent, as discussed earlier in this chapter.

**Erythropoietin (EPO)**

EPO is a naturally occurring hormone, secreted by the kidneys. This hormone stimulates the production of red blood cells. Athletes may use a synthetic version of EPO in order to gain an advantage over others, particularly in endurance-based sports.
As the role of EPO is to stimulate an increase in red blood cell production (RBC), there is more haemoglobin available for oxygen to attach to and be delivered to working muscles. This increase results in better oxygen transportation and a higher rate of aerobic energy production. The performance benefit of EPO use is greater aerobic endurance and VO₂ max, as athletes can produce more energy aerobically at a higher level before relying on the anaerobic energy systems.

As the use of EPO increases the amount of red blood cells beyond normal level, this poses risks to the health of the athlete. Potential harms include increased viscosity (thickening) of the blood, blood clots, increased risk of heart attack and stroke, and dehydration. Synthetic EPO is administered by a series of injections over a period of time so there is also the risk of infection and blood-borne disease if not administered correctly.

Legal alternatives to the use of EPO in order to increase the amount of red blood cells and their oxygen-carrying capacity include training methods such as aerobic or altitude training.

Blood doping

Blood doping involves the process of infusing extra human blood (red blood cells) into the body prior to performance. It can be an athlete’s own blood or that of someone else of same blood type. If using their own blood, the athlete will remove some blood, then concentrate, freeze and store the blood to be reinfused at a later date. In the meantime, the body replaces removed red blood cells with new red blood cells. WADA prohibits this method at all times.

As with EPO, the increased amount of red blood cells leads to improved oxygen delivery to the muscles via the increased amount of haemoglobin in the blood. This has the potential to increase endurance via enhancement of the VO₂ max and aerobic capacity of the athlete.

Potential harms associated with blood doping are similar to those of EPO including increased viscosity (thickening) of the blood, blood clots, increased risk of heart attack and stroke, and dehydration. In addition to these, there is the associated risk with blood transfusions such as infectious diseases or the blood being toxic due to incorrect storage.

Legal alternatives that produce the same effect as blood doping, albeit not as fast, include aerobic and/or altitude training.
**Beta blockers**

Beta blockers are medical drugs that block adrenalin hormones from binding to receptors on nerves, thus reducing the effect these hormones have on the heart and blood vessels. Legally they are prescribed for people who have medical conditions such as high blood pressure, angina and cardiac arrhythmias.

Illegally they are used by athletes to control and reduce blood pressure, slow the heart rate and reduce body tremor. They can also reduce pre-competition tension by relaxing the body. Sports that benefit from beta blockers are those requiring precision, accuracy and a steady hand. WADA prohibits the use of beta blockers during competition in the following sports: archery, billiards, darts, golf, shooting, some skiing and snowboarding events, and some underwater sports. The use of beta blockers is also prohibited out of competition in archery and shooting.

Potential harms of using beta blockers include hypotension (low blood pressure), decreased heart rate, hypoglycaemia, cardiac failure, tiredness and decreased capacity in endurance sports.

A legal alternative to the use of beta blockers to manipulate the functioning of the cardiorespiratory system is the use of psychological methods such as breathing techniques and mental rehearsal to reduce arousal and aid concentration and relaxation.

---

**TABLE 9.2** Illegal methods used to enhance the performance of the cardiorespiratory system

<table>
<thead>
<tr>
<th>WADA classification</th>
<th>Examples</th>
<th>Performance benefits</th>
<th>Potential harm (side-effects)</th>
<th>Legal alternative</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>S2: Peptide hormones</strong></td>
<td>Erythropoietin (EPO)</td>
<td><strong>Increased endurance and VO₂ max via:</strong> increased red blood cell production, and thus oxygen-carrying capacity to working muscles</td>
<td>Increased viscosity (thickening) of blood, Blood clots, Increased risk of stroke and heart attack, Dehydration, Cardiac failure</td>
<td>Aerobic training methods, Altitude training</td>
</tr>
<tr>
<td><strong>M1: Manipulation of blood and blood components</strong></td>
<td>Blood doping</td>
<td><strong>Increased endurance and VO₂ max via:</strong> increased red blood cell mass, thus improved oxygen delivery to muscles</td>
<td>Increased viscosity (thickening) of blood, Blood clots, Increased risk of stroke and heart attack, Dehydration, Cardiac failure</td>
<td>Aerobic training methods, Altitude training</td>
</tr>
</tbody>
</table>

(continued)
Illegal substances and methods that enhance performance of the cardiorespiratory system

**Table 9.2 (continued)**

<table>
<thead>
<tr>
<th>WADA classification</th>
<th>Examples</th>
<th>Performance benefits</th>
<th>Potential harm (side-effects)</th>
<th>Legal alternative</th>
</tr>
</thead>
<tbody>
<tr>
<td>P2: Beta blockers</td>
<td>Lopressor Propranolol</td>
<td>Accuracy and a steady hand via reduced heart rate, tension, body tremors. Helps stop the hands from shaking</td>
<td>Lowered blood pressure Decreased heart rate Tiredness Decreased capacity in endurance sports Cardiac failure</td>
<td>Psychological methods (breathing, mental rehearsal) to reduce arousal, aid concentration and relaxation</td>
</tr>
</tbody>
</table>

**Test your understanding**

1. Outline the performance benefits of illegal substances and methods that can be used to enhance the cardiorespiratory system.
2. Explain the term ‘enhancement of oxygen transfer’.
3. Suggest legal methods that can be used to enhance the performance of the cardiorespiratory system.

**Apply your understanding**

4. Discuss the similarities and differences in potential benefits and harms of EPO use and blood doping for an athlete.
5. Using examples of illegal substances that can enhance the performance of the cardiorespiratory system, explain why some drugs are banned all the time but others are only prohibited in certain sports.
6. **Practical activity**
   - Participate in an activity that requires accuracy and precision such as archery, darts or golf putting.
   - Prior to completing the actual skill (e.g. shooting at the archery target) each student should complete the following scenarios:
     (i) Sitting down quietly for one minute visualising the task you are about to complete.
     (ii) High intensity exercise, such as sprinting, for one minute prior to completing the task.
   - Take your heart rate immediately before executing your shot. Record your heart rate.
   - Perform the skill.
   - Record your result.
   (a) Discuss your heart rate in relation to the results you achieved.
   (b) Identify one legal and one illegal substance or method that an athlete might use to assist their performance in the activity you participated in.
   (c) Outline the benefits and harms an athlete needs to be aware of if using the substance or method identified in part (b).
In chapter 5 we explored the ethical concerns and sociocultural influences regarding the use and misuse of performance-enhancing substances and methods relevant to the musculoskeletal system. Our focus now changes to consider the impact of these on the functioning of the cardiorespiratory system.

As outlined in this chapter, there are a number of legal and illegal substances and methods available to improve the functioning of the cardiorespiratory system. All focus on increasing endurance by improving the delivery of oxygen to working muscles. This allows an athlete to not have to work as hard at the same intensity or to allow them to work at a higher intensity for longer, while still using the aerobic system and therefore delaying fatigue.

**Ethical considerations of the use of performance-enhancing practices**

The zero tolerance approach to the use of illegal substances and methods, and the opposing argument of allowing the use of performance-enhancing substances are similarly applied to the substances and methods that can be used by endurance-based athletes to gain that winning edge over their fellow competitors.

Illegal substances and methods such as the use of EPO and blood doping are banned at all times not only because they have the capacity to enhance the performance of the athlete but also because of the significant health risks they pose to athletes. The harms from engaging in these illegal practices, such as increased viscosity (thickening) of the blood and the formation of blood clots leading to an increased risk of heart attack and stroke and possible death, do not seem to be a deterrent to some athletes and the chance of winning overrides the fear of these potential outcomes.

A number of endurance athletes in the sports of road cycling, cross-country skiing, triathlon, and 20-km and 50-km race walking have been implicated in the use of banned substances such as EPO to improve the functioning of the cardiorespiratory system. The consequence of use has been titles being rescinded, medals stripped and bans served, some lifetime, from their chosen disciplines.
The assumption of widespread use of EPO in these events has led to the suggestion to allow all athletes to use this substance at a medically safe, determined level to create a level playing field and reduce the risk of misuse and possible future deaths. Ethicist Julian Savulescu contends that ‘we should allow doping within safe, measurable physiological parameters. For example, if an athlete’s haematocrit is under say 50 per cent, we should not worry about whether she reached that level by altitude training, hypoxic tent use, genetic good luck, or EPO. We should focus resources on drugs which are unreasonably risky for athletes, or which are against the spirit of the individual sport (by which I mean they substantially remove the human component of a given sport). The doping we allow should be supervised by a medical professional, within prescribed safe ranges, and tested by independent accredited and monitored laboratories.’

Legal methods available to improve the functioning of the cardiorespiratory system spark debate regarding access and equity, and whether or not there is in fact a ‘fair and level playing field’ for all athletes to begin with. The practice of altitude training and use of altitude chambers involves significant cost to attend training camps or use facilities to gain the benefits of training at high altitude. Athletes from less privileged backgrounds or those who don’t have the financial support of clubs or sporting organisations may not have the resources to partake in this type of training. When a legal method is not accessible to all athletes, it brings into question the ideal of a fair and level playing field.

**Sociocultural influences on the use of performance-enhancing practices**

While improved sporting performance is one of the most commonly cited motivators for an athlete using a performance-enhancing substance or method, there are a number of influences that sway the decision of an athlete to take additional steps to enhance their performance. As previously mentioned in this text, sociocultural influences are numerous and can have a varied impact on an individual. They include:

- income
- education
- influence of self, family, peers
- influence of coaches and sporting organisations
Cultural norms in the society or the particular sporting culture

The ‘culture of cycling’ is a term often used to describe the long history of performance enhancement use and misuse in this sport. The alleged use of amphetamines during the 1960s followed by the use of blood doping and EPO from the late 1980s until now has constantly dogged the sport. As Chris Froome discovered during his success in the 2015 Tour de France, in which he was accused by the media of taking illegal substances, the level of trust in cyclists to be competing without some form of illegal enhancement has diminished and they are constantly questioned about the authenticity of their success.

This public doubt has arisen because of a number of doping scandals. The highest profile was the scandal surrounding Lance Armstrong and his subsequent admissions to a variety of doping offences during his time as a professional cyclist. The fallout of this investigation involved a number of cyclists admitting to using performance-enhancing substances, particularly EPO. The pressure of team expectations and the knowledge and/or belief that others were using illegal substances have often been cited as major influences on their decisions. In a tough, demanding and often gruelling event such as the Tour de France, it is conceivable that athletes would agree to almost anything to give them a competitive advantage and a chance to wear the yellow jersey.
National and political ideology

Sport is important to the culture and identity of many countries around the globe. The medal tally at Olympic Games and success in World Championships allow a country to prove its sporting prowess on the global stage. For this reason, many governments and their national sporting organisations contribute to the pressure placed on athletes to perform at their best and possibly use performance-enhancing substances to uphold the reputation of the country.

At the end of 2015, the Russian athletics team made headlines around the world. Medals won by Russian athletes at the 2012 London Olympics and the methods by which they were able to achieve their successes were questioned. A number of endurance athletes, particularly those competing in the 20-km and 50-km walk races, had returned abnormal samples with elevated haemoglobin values, suggesting the use of EPO or blood doping prior to the Olympics, but were still allowed to compete. A WADA investigation into both the Russian Athletics Federation and the IAAF has suggested a culture of ‘state-sanctioned doping’ where athletes were administered with banned substances and authorities overlooked the problem. Life bans have been announced for individual athletes and the Russian Athletics Federation has been warned that they will be unable to compete in the 2016 Rio Olympics unless they review their operations and adhere to the WADA anti-doping code, especially rigorous testing of athletes for use of illegal performance-enhancing substances.

With such pressure as this, it raises the question: Did these athletes have an opportunity to not use illegal performance-enhancing substances or was it an expectation that as part of the team and when representing your country you would do whatever it took to be successful?

**FIGURE 9.11** Russian race walk athletes implicated in the ‘state-sanctioned doping’.

---

**TEST your understanding**

1. The ‘culture of a sport’ is often cited as a reason for accepting or dismissing the behaviours that may occur within a sport. Discuss the sociocultural influences that may be present within the ‘culture of a sport’ to influence an athlete to use performance-enhancing substances and methods.

2. Explain the phrase ‘state-sanctioned doping’. Discuss how this may influence an athlete in relation to performance enhancement.

**APPLY your understanding**

3. Using the Swans’ altitude room weblink in your eBookPLUS, read the article and answer the following questions.
   (a) Outline the advantage to an athlete or team of having unlimited access to an altitude room, as does the Sydney Swans football team.
   (b) Access and equity are cited as factors that may have an impact on a level playing field for all athletes. Discuss this in relation to the use of legal performance-enhancing methods such as altitude training.

4. **Class debate: Should all performance enhancement practice be legal?**
   Ethicist Julian Savulescu contends that “we should allow doping within safe, measurable physiological parameters”. Conduct a class debate arguing whether or not some illegal performance-enhancement substances and methods should be legal.
KEY SKILLS
- Critically analyse the physiological effects of legal and illegal strategies that enhance the performance of the cardiorespiratory system on the individual.
- Discuss the ethical, social and cultural considerations associated with the use of legal and illegal practices associated with improving the function of the cardiorespiratory system.

UNDERSTANDING THE KEY SKILLS
To address these key skills, it is important to remember the following:
- Understand the potential benefits and perceived harms of a range of legal and illegal strategies that can be used by an athlete to enhance the functioning of the cardiorespiratory system.
- Physiological refers to changes that occur within the body, specifically to the cardiovascular or respiratory system.
- Performance enhancement relates to improvements in the functioning of the cardiorespiratory system.
- Provide a clear link between the cardiorespiratory physiological adaptation and how it can enhance performance.
- There are a range of ethical and sociocultural influences on an athlete when making the choice to use or not use performance-enhancing substances and methods.

PRACTICE QUESTION (adapted from ACHPER 2013 Trial Exam, Unit 3 and 4, 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. Armstrong also admitted to ‘blood doping’ and using erythropoietin (EPO). Both blood doping and the use of EPO are believed to enhance an athlete’s VO₂ maximum.

Critically evaluate how these different methods lead to improvement in an athlete’s VO₂ maximum.

Sample response
EPO is a hormone produced naturally in the kidneys. Artificial EPO stimulates the production of red blood cells and thus enhances the oxygen-carrying capacity of the athlete, enabling an improved VO₂ maximum.

Blood doping, however, requires blood transfusion where an athlete’s own blood, or that of another person, is transfused into the athlete.

The extra red blood cells are infused into the athlete’s body, increasing the red blood cells and therefore the VO₂ maximum of the athlete.

PRACTICE THE KEY SKILLS
1. Identify legal and illegal methods that athletes might use to enhance oxygen transfer. Discuss performance benefits and potential harms of these methods.
2. Describe the changes that occur in the body when undertaking altitude training and why they might improve performance.
3. Discuss some of the specific pressures athletes experience that may influence them to use performance-enhancing drugs and/or methods to improve the cardiorespiratory system.

KEY SKILLS EXAM PRACTICE
Question 1 (ACHPER Trial Exam 2011, question 1)
Australian athlete Sarah Jamison won a silver medal for the 1500 metre running event at the 2006 Commonwealth Games in a time of 4:06:64. The ability of the body to transport oxygen to the working muscles is important during this event.

a. i. Name the structure responsible for transporting oxygen in the blood.

1 mark

ii. Describe one legal and one illegal method an athlete may use to increase the amount of the structure named.

2 marks

iii. Other than cardiac problems or death, outline one physiological side effect of using this illegal method.

1 mark

HOW THE MARKS ARE AWARDED
- 1 mark — describing EPO and the physiological change caused though using EPO.
- 1 mark — linking the physiological change to improved VO₂ maximum.
- 1 mark — describing blood doping and the physiological change caused though using blood doping.
- 1 mark — linking the physiological change to improved VO₂ maximum.
CHAPTER REVIEW

CHAPTER SUMMARY

Legal substances and methods

- Training methods to enhance the functioning of the cardiorespiratory system include aerobic training methods such as continuous training, fartlek training, long-interval and high-intensity interval training, as well as altitude training.
- Altitude training is a legal training method that induces physiological changes to enhance the oxygen-carrying capacity of the blood, thus increasing the delivery of oxygen to the muscles. This training can occur at actual altitude (greater than 1500 metres above sea-level) or in specifically designed chambers or rooms that simulate altitude.
- Performance benefits of a more efficient cardiorespiratory system are that during aerobic activity, athletes will not have to work as hard at the same intensity or they will be able to work at a higher intensity for longer while still using the aerobic system and therefore delaying fatigue.

Illegal substances and methods

- Illegal methods that can be used by athletes to enhance performance include EPO, blood doping and beta blockers.
- EPO and blood doping increase the red blood cell count, therefore creating more sites to carry oxygen, resulting in better oxygen transportation and a higher rate of aerobic energy production.
- Beta blockers may be used illegally by athletes in precision sports such as archery and shooting to increase their accuracy and steadiness, and reduce body tremor and pre-competition anxiety.

Ethical and sociocultural influences

- There are a variety of influences on athletes to use performance-enhancing substances. These can include sociocultural reasons such as income, education, influence of self, family and peers, the influence of coaches and sporting organisations, cultural norms in society or the particular sporting culture, and national and political ideology.

MULTIPLE CHOICE QUESTIONS

1. Training methods to best enhance the performance of the cardiorespiratory system include
   (A) continuous training, resistance training, flexibility training.
   (B) continuous training, speed training, fartlek training.
   (C) continuous training, fartlek training, plyometrics.
   (D) continuous training, fartlek training, long-interval training.

2. Altitude training causes which of the following physiological adaptations to occur in the body?
   (A) Increased muscle mass
   (B) Increased blood plasma, red blood cells and white blood cells
   (C) Increased production of erythropoietin (EPO) and increased red blood cells
   (D) Decreased heart rate

3. Activity trackers are aids that can be used to assist training of the cardiorespiratory system. The most relevant information to address training goals of this system would be
   (A) movement patterns and intensity of effort.
   (B) movement patterns and amount of sleep.
   (C) calories burned.
   (D) power output.

4. Aerobic training is likely to result in which of the following chronic adaptations to improve performance of the cardiorespiratory system?
   (A) Increased left ventricle size, increased fast-twitch fibres, increased haemoglobin levels
   (B) Increased pulmonary diffusion, decreased heart rate during submaximal loads, increased stroke volume
   (C) Increased muscle mass, increased stroke volume, increased red blood cells
   (D) Increased haemoglobin, decreased maximal oxygen uptake, increased left ventricle size
5 A continuous training method that includes changes of intensity to work both the aerobic and anaerobic energy systems is called
(A) aerobic training.
(B) long-interval training.
(C) fartlek training.
(D) flexibility training.

6 In recent years some endurance athletes have been found guilty of using the illegal drug erythropoietin (EPO) to gain an edge over their competitors. A potential harm of using this drug is
(A) low blood pressure.
(B) increased risk of blood clots.
(C) male infertility.
(D) decreased muscle mass.

7 Beta blockers have been used in sports that require precision and accuracy such as archery, shooting and golf. They are banned by WADA as they have the potential to
(A) reduce body tremors.
(B) reduce perception of effort and fatigue.
(C) increase focus and attention.
(D) increase heart rate.

8 A legal alternative to blood doping is
(A) using a heart-rate monitor.
(B) psychological training.
(C) altitude training.
(D) consuming high amounts of iron in your diet.

9 A perceived benefit and potential harm of blood doping is
(A) increased maximal oxygen uptake and decreased heart rate.
(B) increased haemoglobin levels and decreased tremor.
(C) increased endurance and increased infertility.
(D) increased amount of red blood cells and increased risk of stroke.

10 Illegal methods used to enhance the transfer of oxygen include
(A) EPO and beta blockers.
(B) EPO and blood doping.
(C) EPO and altitude training.
(D) blood doping and beta blockers.

**EXAM QUESTIONS**

**Question 1** *(ACHPER Trial Exam 2015, question 11)*

Biological Passports have been introduced by the World Anti-Doping Authority (WADA) in order to monitor physiological parameters of athletes to determine whether athletes are adhering to the WADA Code. In 2015, five Russian female race walkers, including three Olympic champions and one World Champion, were banned by the Russian Anti-Doping Agency for irregularities in their Biological Passports. The irregularities were deemed to indicate the use of performance-enhancing drugs.

a. With reference to the WADA code, explain why these athletes received sanctions by the Russian equivalent to the Australian Sports Anti-Doping Authority (ASADA).  

b. Elite female race walking is a 20 km endurance event averaging 90 minutes duration. One of the parameters monitored in a Biological Passport is an athlete’s haematocrit which indicates the concentrations of red blood cells in their blood.

Provide one legal and one illegal strategy that may result in an athlete’s haematocrit increasing.

*2 marks*