3. Know fatigue and how the body recovers from exercise

3.1 Fatigue

Fatigue involves the exhaustion of muscle from prolonged exertion or over-stimulation. We cannot exercise indefinitely because of neuromuscular fatigue, which occurs as a result of different methods and systems. The symptoms of fatigue include:

- depletion of energy sources, primarily creatine phosphate and glycogen
- increase in lactic acid
- dehydration
- **electrolyte** loss.

Key term

Electrolyte – a substance (usually salts) dissolved in water.

Exercise places demands on the body. Think about the changes that occur when you exercise:

- oxygen levels fall
- carbon dioxide and lactate levels increase
- body temperature increases
- blood glucose and glycogen levels fall
- fluid and electrolytes (salts) are lost as you sweat.

During short-term maximal exercise, insufficient oxygen and/or increased lactate levels can bring about fatigue. Reliance on anaerobic metabolism impairs energy transfer via glycolysis and inhibits the contractile mechanisms of muscle fibres.

Remember

A 2 per cent loss of body weight due to dehydration can lead to a 20 per cent drop in muscle performance.

Depletion of energy sources

The body needs energy to function effectively. When you exercise, your body needs a supply of energy so that heart rate increases, forcing more blood to the skeletal muscles so they can contract more frequently. The energy required comes from the food you eat.

- Carbohydrate (for example, pasta, rice and potatoes) is broken down into glucose in the body.
- Fats (for example, cheese, butter, oils) are broken down into fatty acids in the body.
- Proteins (for example, fish, meat, eggs) are broken down into amino acids that provide energy in extreme circumstances.

The breakdown of all three fuels in the body produces adenosine triphosphate (ATP). All forms of physiology – be it digestion, transmission of nerve impulses or muscular contractions – require energy in the form of ATP. Therefore, if an athlete fails to take in enough carbohydrate, fat or protein, it is likely they will deplete their energy sources quickly when exercise is undertaken.

- **Creatine phosphate** is synthesised in the liver and transported to skeletal muscles for storage. It is used to form ATP from ADP and is particularly important for intense efforts of physical exercise.
- **Muscle and liver glycogen** – a reduction in muscle and liver glycogen and blood glucose during submaximal exercise can occur despite the availability of sufficient oxygen and ATP. Once glycogen stores are depleted, muscles cease contracting – even during steady-state exercise – as the body is unable to use fat as the only fuel source. Marathon runners in particular must be careful not to deplete their glycogen stores early in a race by setting off too fast. To combat this, marathon runners run at a pace that metabolises fats so the rate at which glycogen depletes is lessened.

Effects of waste products

The main waste products of exercise are urea, carbon dioxide, water and lactic acid. Urea and water are filtered through the kidneys and expelled from the body. Carbon dioxide is carried in the blood to the lungs, where it passes into the alveoli and is then expelled from the body.

- **Blood lactate accumulation** – during exercise raised levels of carbon dioxide increase the level of blood acidity. One factor in this increased acidity is lactic acid, which dissociates into lactate and hydrogen ions in blood.

- **Carbon dioxide** – when carried in the blood, carbon dioxide combines with water producing carbonic acid.
- **Increased acidity** – carbonic acid is further broken down into bicarbonate and hydrogen ions. The hydrogen ions contribute to the blood's increased acidity.

Remember

- Muscle lactate is disposed of first by oxidation to pyruvate and then by dissimilation to carbon dioxide and water.
- Some blood lactate is taken in by the liver, which reconstructs it to glycogen.
- Remaining blood lactate diffuses back into the muscle to be oxidised then dismantled.

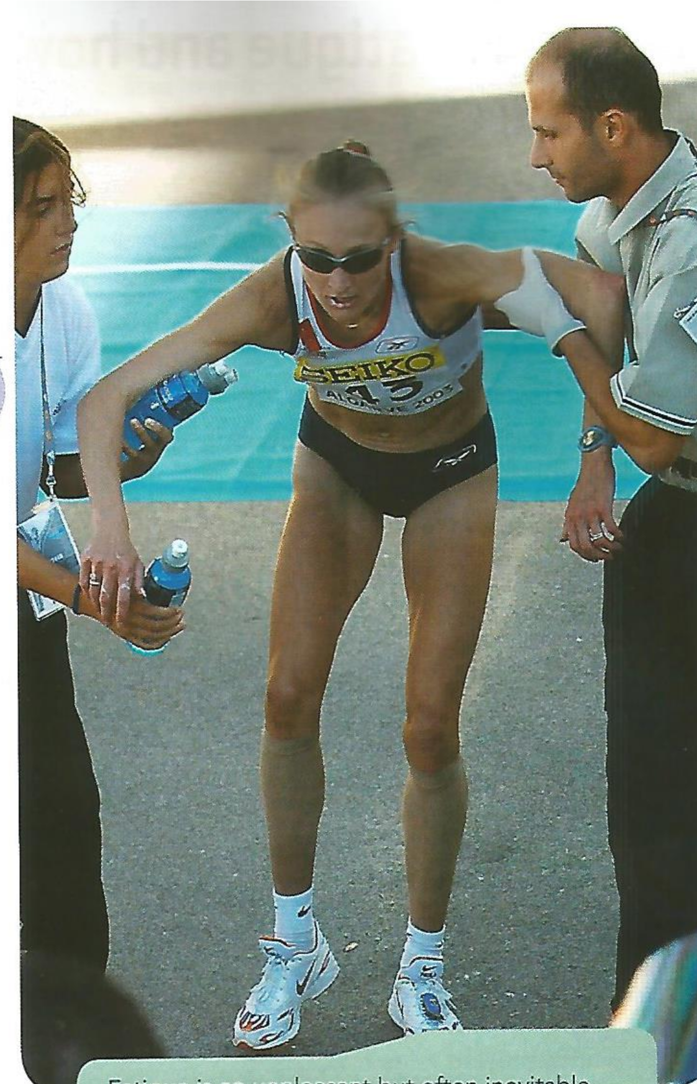
Neuromuscular fatigue

Depletion of acetylcholine – acetylcholine is a neurotransmitter released to stimulate skeletal muscles and the parasympathetic nervous system. Its effect is short-lived because it is destroyed by acetylcholinesterase – an enzyme released into the sarcolemma of muscle fibres to prevent continued muscle contraction in the absence of additional nervous stimulation.

Reduced calcium-ion release – as part of the sliding filament theory, calcium ions are known to be released allowing actin and myosin to couple and form actomyosin. If the store of calcium ions is reduced, the ability of the actin and myosin to couple is compromised, thus preventing continued muscle contraction.

Activity: Importance of calcium

Explain why the mineral calcium is important in the prevention of fatigue.



Fatigue is an unpleasant but often inevitable result of elite competition. Why do you think it is vital sport scientists understand the impact and consequences of fatigue and recovery?

3.2 Recovery

Four processes have to be satisfied before the exhausted muscle can perform to its optimum level. These are:

- restoration of muscle phosphagen stores
- removal of lactic acid
- replenishment of myoglobin stores with oxygen
- replacement of glycogen.

Excess post-exercise oxygen consumption (EPOC)

The need for additional oxygen to replace ATP and remove lactic acid is known as oxygen debt or excess post-exercise oxygen consumption (EPOC). The two major components of EPOC are:

- fast components (alactacid oxygen debt) – the amount of oxygen required to synthesise and restore muscle phosphagen stores (ATP and creatine phosphate)
- slow components (lactacid oxygen debt) – the amount of oxygen required to remove lactic acid from muscle cells and blood.

Bodily processes do not immediately return to normal after exercise. After light exercise such as golf or walking, recovery takes place quickly and often without realisation. With more intense steady-state exercise, however, it takes time for the body to return to normal.

Fast components

The restoration of muscle phosphagen stores – alactacid oxygen debt (without lactic acid) represents the oxygen used to synthesise and restore muscle phosphagen stores (ATP and creatine phosphate) that have been almost completely exhausted during high-intensity exercise. During the first three minutes of recovery, EPOC restores almost 99 per cent of ATP and creatine phosphate used during exercise (see Table 2.2).

Recovery time (seconds)	Muscle phosphagen restored (%)
10	10
30	50
60	75
90	87
120	93
150	97
180	99
210	101
240	102

Table 2.2: Restoration of muscle phosphagen.

The removal of lactic acid – lactic acid is catabolized and removed resulting in the feeling of pain or burning sensation in the muscles.

Slow components

The slow component of EPOC concerns the removal of lactic acid from the muscles and the blood. This can take several hours, depending on the intensity of the activity and whether the athlete was active or passive during the recovery phase. Around half of lactic acid is removed after 15 minutes, and most is removed after an hour. Once exercise is over, the liver synthesises lactic acid into glycogen while the remainder of the body can remove small amounts of lactic acid through respiration, perspiration and excretion.

- **Replenishment of myoglobin stores** – myoglobin is an oxygen-storage protein found in muscle. Like haemoglobin, it combines with oxygen while the supply is plentiful, and stores it until the demand for oxygen increases. During exercise, the oxygen from myoglobin is quickly used up and after exercise additional oxygen is required to pay back any oxygen that has been borrowed from myoglobin stores.
- **Replacement of glycogen** – the replenishment of muscle and liver glycogen stores depends on the type of exercise. Short-distance, high-intensity exercise may take two or three hours, whereas long endurance activities such as a marathon may take several days. Replenishment of glycogen is most rapid during the first few hours after training. Complete restoration of glycogen stores is accelerated with a high carbohydrate diet.

Take it further

Speeding up the recovery process

In groups, research the commercially available products designed to help athletes recover after exercise. What do these products contain that helps athletes with the recovery process? Discuss your answers.