4. Know how the body adapts to long-term exercise

There are differences between responses to exercise and how the body adapts to exercise. The immediate changes to the energy and neuromuscular systems during exercise are called responses. How the body adapts are permanent changes that take place as a result of long-term exercise. If you exercise regularly, your body adapts and you get fit. This means you are able to cope with exercise that previously you might have found difficult. Consequently, the human body is able to adapt and respond to exercise, allowing you to cope with your chosen sport.

4.1 Long-term exercise

A long-term exercise programme is one in which you exercise to a structured plan over a period of time. Examples might include an eight-week programme of four 30-minute sessions per week or a six-week resistance programme. Responses to long-term exercise include changes to the heart, lungs and muscles, although the extent of the changes depends on the type and intensity of exercise undertaken.

4.2 Cardiovascular adaptations

Cardiac hypertrophy

An increase in heart size indicates the adjustment of a healthy heart to exercise training. Regular aerobic exercise (for example, four 30-minute jogging sessions per week for eight weeks) stimulates the increase in both the thickness of the muscle fibres and the number of contractile elements contained in the fibres.

Increase in stroke volume

Over time, aerobic training increases the size of the heart. This is due to an increase in the muscle mass of the heart chambers, especially the walls of the left ventricle. This increase in size increases ventricular contraction and the athlete's stroke volume.

Increase in cardiac output

An increase in stroke volume allows a greater cardiac output, so trained athletes are able to pump a greater volume of blood to the working muscles and organs.

Decrease in resting heart rate

As a result of increased stroke volume and cardiac hypertrophy, the athlete's resting heart rate decreases. When the heart can pump more blood per beat, it does not have to beat as often when the body is at rest. This is why getting fitter causes a decrease in resting pulse rate. Some of the world's top athletes have a resting pulse rate between 30 and 40 beats per minute.

Blood volume

Blood volume increases because of capillarisation during long-term exercise. Consequently, there is more space for blood to circulate which, in turn, allows for a greater supply of oxygen to skeletal muscles. In trained males, blood volume equates to approximately 75 ml per kg of bodyweight, and in females it is approximately 60 ml per kg of bodyweight.

Capillarisation

Long-term exercise can lead to the development of a capillary network to a part of the body. Aerobic training improves the capillarisation of cardiac and skeletal muscle by increasing the number of capillaries and the capillary density (the number of capillaries in a given area of muscle tissue).

4.3 Respiratory adaptations

Increase in minute ventilation

Minute ventilation depends on breathing rate and tidal volume. During exercise, adults can generally achieve 100 litres per minute or approximately 15 times the resting value. In trained athletes minute ventilation can increase by 50 per cent to 150 litres per minute.

Efficiency of respiratory muscles

An increase in strength allows the external intercostal muscles greater contraction, while the internal intercostal muscles relax during inspiration, forcing more air into the lungs. Likewise, during expiration the greater degree of contraction of the internal intercostals and relaxation of the external intercostals allows the athlete to breathe out a greater volume of air.

Increase in resting lung volumes

An increased surface area of the alveoli allows more deoxygenated blood access to the site of gaseous exchange. The carbon dioxide is offloaded and a greater amount of oxygen is diffused into the blood for its journey back to the heart. This increased ability of the blood to take on more oxygen due to the increased surface area of alveoli aids trained athletes tremendously.

Increase in oxygen diffusion rate

An increase in diffusion rates in tissues favours oxygen movement from the capillaries to the tissues, and carbon dioxide from the cells to the blood. Long-term exercise causes these rates to increase, allowing both oxygen and carbon dioxide to diffuse more rapidly.

4.4 Neuromuscular adaptations

Hypertrophy

Long-term exercise improves muscle tone and stamina. Training with a greater resistance brings about an increase in muscle size, a process known as hypertrophy. Muscular hypertrophy increases the cross-sectional size of existing muscle tissue due to the increase in the number of myofibrils and connective tissue (tendons and ligaments), which then become more pliable.

Increase in tendon strength

As the skeletal muscles of a trained athlete become larger, stronger or more efficient, the connective tendons have to adapt to meet these increased demands. Without such adaptations, serious injury may follow if the increased forces of contraction developed by the muscle cannot cause the lever or bone to move properly.

Increased myoglobin stores

With training, muscles increase their ability to store glycogen and myoglobin.

Increased numbers of mitochondria

With training, muscles increase their oxidative capacity. This is achieved by an increase in the number of mitochondria in the muscle cells, an increased supply of ATP and an increase in the quantity of the enzymes involved in respiration.

Increased storage of glycogen and triglycerides

With training (especially steady-state exercise), muscles increase the ability to use triglycerides as an energy store.

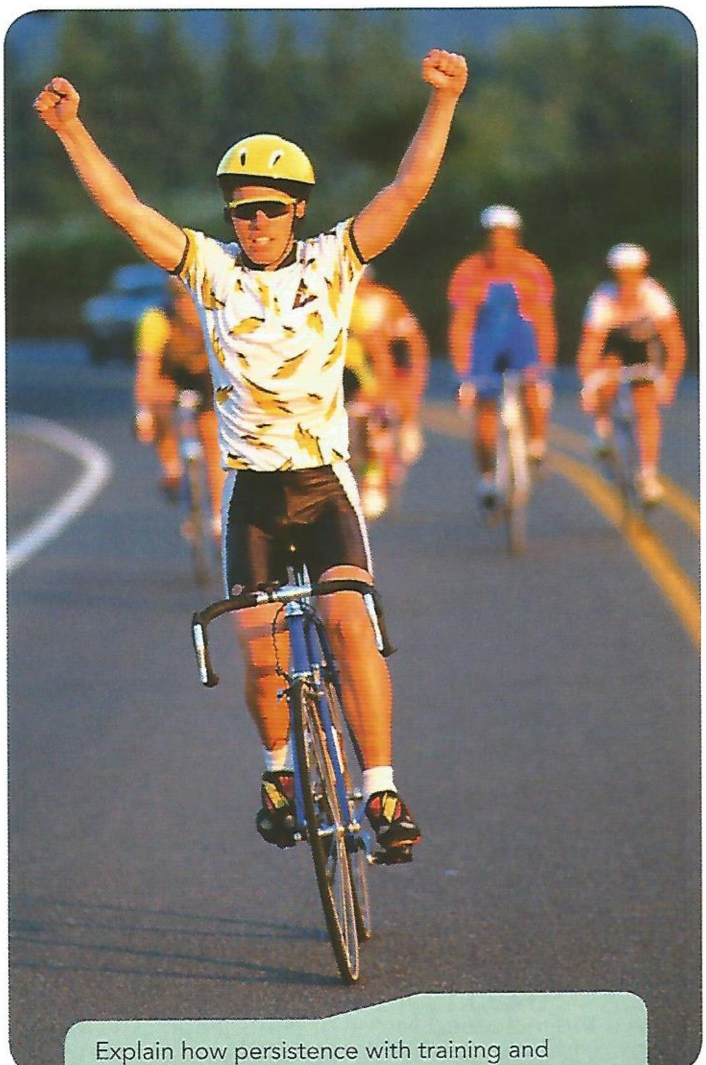
Neural pathways

Neural structures and pathways show changes as a result of long-term exercise training. These changes include **cellular adaptations**, modifications of **neurotransmitters**, alterations in reflex, and chemical and biochemical responses. For example, sprint training actually produces relatively small metabolic changes but has substantial effects on performance.

Key terms

Cellular adaptations – changes within the cell structure (for example, an increase in mitochondrial size).

Neurotransmitters – chemicals used to carry signals or information between neurons and cells.



Explain how persistence with training and an understanding of the responses and adaptations to training can be a winning combination.

4.5 Energy system adaptations

Increased anaerobic and aerobic enzymes

Long-term exercise brings about a number of cellular changes that enhance the ability of muscle tissue to generate ATP. Cellular adaptation such as the increase in size of mitochondria is usually accompanied by an increase in the level of aerobic system enzymes. A combination of these changes probably accounts for why an athlete can sustain prolonged periods of aerobic exercise as a result of longer-term training. The anaerobic system also undergoes a number of changes, including the increase in enzymes (especially in fast-twitch muscles) that control the anaerobic phase of glucose breakdown.

Increased use of fats as an energy source

The use of fats as an energy source occurs during low-intensity exercise. Fat combustion powers almost all exercise at approximately 25 per cent of aerobic power. Carbohydrate and fat contribute in equal measures during moderate exercise. Fat oxidation increases if exercise extends to over an hour as glycogen levels deplete. Beyond an hour of an exercise session, fats can account for approximately 75 per cent of the total energy required. Therefore, when considering the effects of long-term exercise, it is clear that trained athletes have far greater opportunity to burn fat as fuel than non-trained adults.

Higher tolerance of lactic acid

If your lactate threshold is reached at low-exercise intensity, your aerobic energy system in your muscles is not working well. As you get fitter, you begin to use oxygen to break down lactate to carbon dioxide and water, preventing lactate from pouring into the blood. If your lactate threshold is low, it is due to one or more of the following:

- not getting enough oxygen inside your muscle cells
- insufficient mitochondria in your muscle cells
- muscles, heart and other tissues are inefficient at extracting lactate from the blood.

A long-term adaptation to exercise is to saturate the muscles in lactic acid, which educates your body to deal with it more effectively. The accumulation of lactate in working skeletal muscles is associated with fatigue after 50–60 seconds of maximal effort. Therefore, training continuously at about 85–90 per cent of your maximum heart rate for 20–25 minutes improves the body's tolerance to lactic acid.

4.6 Skeletal adaptations

Increased calcium stores

Long-term exercise slows the rate of skeletal ageing. Athletes who maintain active lifestyles have greater bone mass compared with those who participate in less exercise. Exercise of moderate intensity provides a safe and potent stimulus to maintain and increase bone mass. Weight-bearing exercises such as running or walking are particularly beneficial, but this is also dependent on adequate calcium supply.

Remember

Strength training can have a positive effect on osteoporosis (brittle bone disease).

Increased tendon strength

Tendons attach muscles to bones or to muscles, whereas ligaments attach bone to bone and are usually found at joints. Both are able to withstand tensile stress when forces are applied. However, both types have poor blood supplies (vascularised). Both tissues are constructed of closely-packed bundles of collagen fibres. Crowded among the collagen fibres are rows of **fibroblasts**. The main function of the fibroblasts is to maintain the structural integrity by secreting compounds to help manufacture replacement fibres.

Key term

Fibroblast – connective tissue cell that makes and secretes collagen proteins.

Increased stretch of ligaments

An athlete requires stronger tendons and more pliable ligaments to handle heavy weights or an increased running distance. If an athlete lifts progressively heavier weights as part of a strength-training exercise programme, the athlete's muscles will gain strength. To accommodate this increase, tendons increase their load-bearing capacity relative to the increased strength of the muscle, while the ligaments need to adapt their pliability. This adaptation occurs when fibroblast secretions increase the production of collagen fibres relative to the training undertaken. Without this relationship, injury is likely to occur.

Take it further

On retirement?

Consider what happens to an athlete when he or she retires from competition: what do you think happens to the adaptations their body has developed over years of training?