

CHAPTER 2: Energy systems part two

STUDENT NOTE

Cardio-respiratory endurance is the component of fitness which is a contributory factor to many sporting situations. As discussed in Chapter 1 from page 17 the major influencing factor of cardio-respiratory performance is the maximum volume of oxygen an individual can consume ($\dot{V}O_{2max}$).

Factors affecting $\dot{V}O_{2max}$ /aerobic power (figure 2.1)

Physiological

The availability of O_2 in the tissue depends upon:

- Whether **haemoglobin** arriving at tissue is fully saturated with O_2 .
- The limitations of the **cardiovascular** and **pulmonary** systems which varies from individual to individual.
- Whether the **myoglobin** in muscle cells is fully saturated with O_2 and sufficient recovery time has elapsed.

Heredity

- Current estimates of the **genetic effect** ascribe about 20-30% role of $\dot{V}O_{2max}$, 50% for maximum heart rate and 70% for physical working capacity.

Exercise testing mode

- Variations in $\dot{V}O_{2max}$ during different test modes reflect the **quantity** of activated muscle mass.
- For example, bench stepping generates $\dot{V}O_{2max}$ scores nearly identical to treadmill values, but higher than an arm-crank test.

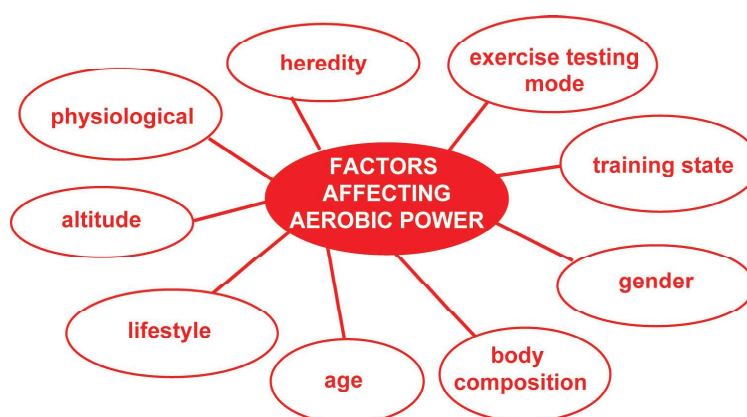
Training state

- $\dot{V}O_{2max}$ must be evaluated relative to a person's training status at the **time of measurement**.
- Following a **period of aerobic training**, such as regular continuous, aerobic interval and fartlek training, aerobic capacity improves between 6% and 20%.
- Larger $\dot{V}O_{2max}$ improvements occur among the most sedentary individuals.

Gender

- $\dot{V}O_{2max}$ expressed in $ml\ kg^{-1}\ min^{-1}$ for women typically average 15% to 30% below values for men.
- Even among **trained endurance athletes**, the disparity ranges between 10% and 20%.
- Apparent gender differences in $\dot{V}O_{2max}$ have been attributed to differences in **body composition** and **blood haemoglobin** concentration.
- Untrained young adult women possess about **26% body fat**, while the corresponding value for men averages around 15%.
- Trained athletes have a lower body fat percentage, yet trained women possess significantly more body fat than their male counterparts.
- Consequently, males generate more total aerobic energy simply because of their **larger muscle mass** and **lower total fat** than females.
- Men have 10% to 14% greater concentration of **haemoglobin** than women.
- This difference in the **blood oxygen carrying capacity** enables men to circulate more oxygen during physical activity and gives them the edge in aerobic capacity.
- Despite these limitations, the aerobic capacity of **physically active women** exceeds that of sedentary men.

figure 2.1 – aerobic power



Body composition

- Differences in body composition explain roughly 70% of the differences in $\dot{V}O_{2\max}$ expressed as $\text{ml kg}^{-1} \text{ min}^{-1}$. This is per kilogramme of body mass, so different sizes of people can be compared.
- Although there are other biological differences between the sexes, research suggests $\dot{V}O_{2\max}$ decreases as body fat percent increases.
- Adjusting the arm-crank $\dot{V}O_{2\max}$ test (figure 2.2) for variations in arm and shoulder size equalises values between men and women, suggesting gender differences in aerobic capacity largely reflect the **size of the active muscle mass**.
- This research implies that **no true gender difference** exist in active muscle mass capacity to generate ATP aerobically.

figure 2.2 – arm crank



Age

- Changes in $\dot{V}O_{2\max}$ relate to **chronological age**.
- After the age of 25, $\dot{V}O_{2\max}$ decreases by 1% per year.
- However, available data indicates that regular physical activity throughout life can offset much of the decline as illustrated in figure 2.3.

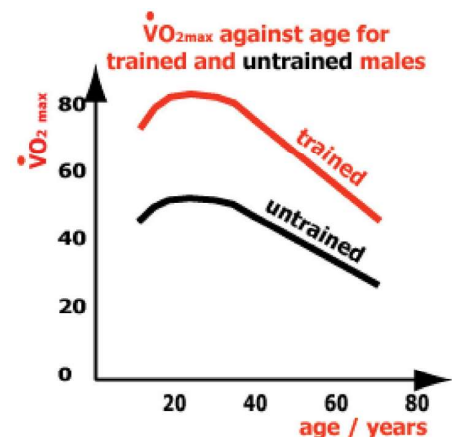
Lifestyle

- A **sedentary** lifestyle, **smoking** and a poor **diet** all reduce $\dot{V}O_{2\max}$ values.

Altitude

- $\dot{V}O_{2\max}$ decreases proportionally to the atmospheric pressure. Refer to page 30 for further details.

figure 2.3 – portable spirometry



Measurement of energy expenditure

Methods for measurement of the various components of daily energy expenditure can be assessed using a variety of techniques. In this section your syllabus identifies four popular techniques namely indirect calorimetry, lactate sampling, $\dot{V}O_{2\max}$ testing and the respiratory exchange ratio (RER).

Indirect calorimetry

STUDENT NOTE

Indirect calorimetry is discussed in relation to the metabolic cart in AS/A1 Revise PE for AQA ISBN 9781901424850, Chapter 15, page 200 onwards.

Indirect calorimetry determines the body's rate of energy expenditure from oxygen consumption or uptake and carbon dioxide production and a measure of substrate utilization as reflected in the Respiratory Quotient (RQ).

There are three common indirect calorimetry procedures that measure oxygen consumption during physical activity:

Portable spirometry

Is discussed in the AS/A1 text, as illustrated in figure 2.4.

figure 2.4 – portable spirometry



Bag technique

Whereby expired air passes into a large Douglas bag for subsequent analysis of O_2 and CO_2 composition.

Computerised laboratory instrumentation

In which a subject's expired air performs metabolic calculations based on electronic signals it receives from the instruments, giving reliable and valid measurements including $\dot{V}O_{2max}$ results.

$\dot{V}O_{2max}$ tests

Tests for $\dot{V}O_{2max}$ rely on activities with sufficient **intensity** and **duration** to activate large muscle groups to properly engage maximum aerobic energy transfer. Considerable research effort has been directed toward the development and standardisation of $\dot{V}O_{2max}$ tests and norms that consider age, gender, state of training, body mass and body composition. Hence, there are many different standardised tests that assess actual and predicted $\dot{V}O_{2max}$.

Within the Sports Science laboratory a **treadmill** protocol is an example of a progressive test of $\dot{V}O_{2max}$ to exhaustion as the treadmill gets **steeper** and moves **faster** with each stage of the test. This indirect calorimetry test lasts between 8 and 10 minutes depending on the fitness of the performer (figure 2.5).

$\dot{V}O_{2max}$ is obtained by measuring exhaled air oxygen consumption using a gas analyser. The $\dot{V}O_{2max}$ criteria, when using direct gas analysis, must show a levelling off or **peaking-over** in oxygen consumption/uptake during increasing exercise intensity as illustrated in figures 2.6.

The region where oxygen consumption fails to increase the expected amount or even decreases slightly with increasing intensity represents the $\dot{V}O_{2max}$.

This type of progressive test to **exhaustion** is not recommended for the untrained individual who may not have the fitness level to cope with a progressive maximal test.

Predicted $\dot{V}O_{2max}$ tests

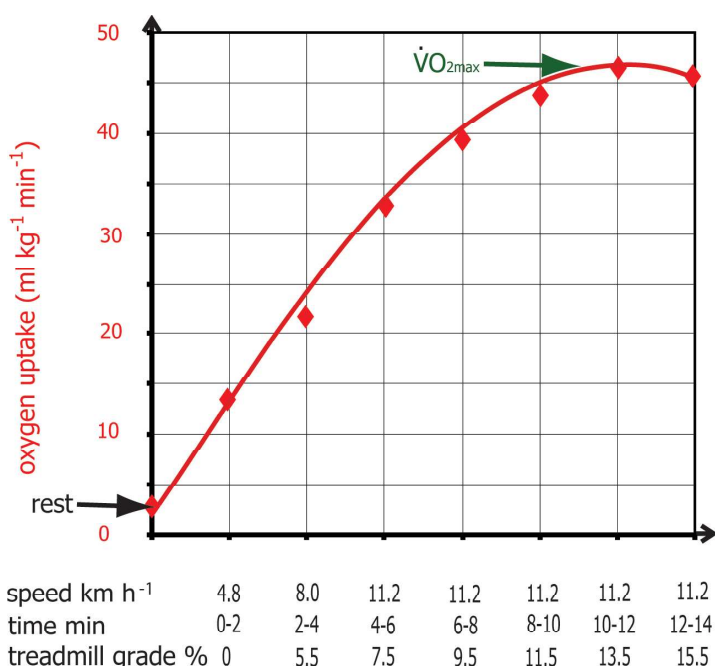
These may require 3-5 minutes of **submaximal** or **maximal** effort and are used as an indicator of aerobic fitness or stamina. Reliable and valid tests include the Physical Work Capacity test (PWCI 70), the Cooper's run/walk test, the Queen's College step test and the Multi-stage shuttle run test.

For example, the **Queen's College Step test** is a **submaximal** predicted $\dot{V}O_{2max}$ test that requires the subject to step up and down on a 41.3 cm step bench at a rate of 22 steps per minute for females and at 24 steps per minute for male using a four-step cadence, 'up-up-down-down' for 3 minutes. The subject stops immediately on completion of the test, and the heart beats are counted for 15 seconds from 5-20 seconds of recovery. This heart rate reading is multiplied by 4 to give the beats per minute (bpm) value, which is then converted by referring to a percentile ranking table for a predicted $\dot{V}O_{2max}$ value.

figure 2.5 – a gas analyser worn during a lab test



figure 2.6 – results from treadmill test



Predicted $\dot{V}O_{2\max}$ tests

For example, the **NCF multi-stage shuttle run test** (the bleep test, figure 2.7) is a **maximal** 20m shuttle run test whereby the subject runs progressively quicker shuttle runs to a point when he or she can no longer keep up with the set pace. Each level in the progression is numbered and the level reached by the subject is correlated to the standard $\dot{V}O_{2\max}$ results table. Unlike the step test described on page 28, this test requires the subject to be highly motivated to push him or herself to a maximal limit of aerobic endurance.

Lactate sampling

A **lactate sampler** is a small hand-held device (figure 2.8) that can be taken into the training environment, with which top athletes take pin prick blood samples and test for lactate concentration (immediate read-out from the device). This enables them to work out the maximum possible exercise intensity within which they must work to avoid **Onset of Blood Lactate Accumulation (OBLA)**.

One of the **advantages** of lactate testing is that it may be more sensitive to changes in **fitness** than a $\dot{V}O_{2\max}$ test. An athlete may have a stable $\dot{V}O_{2\max}$ through a hard training period, yet the fitness of that athlete may be increased significantly, and this change in fitness is usually reflected in the lactate response to exercise rather than the $\dot{V}O_{2\max}$ measurement.

Lactate sampling can be taken at fixed times during an interval training session, such as a set time at the completion of each repetition of 6x300m paced sprints. The readings measure lactate threshold and OBLA which occurs at around 4 mmols of lactic acid.

Lactate sampling can be used as accurate and objective **guide** to recovery between repetitions. Readings from lactate sampling can be used by the coach to determine **training intensity**. Different athletes will produce higher or lower amounts of lactate, depending upon factors, such as muscle fibre composition. The athlete should be treated as an **individual**, and so a lactate profile for that athlete should be recorded and the training programme evolved from such an individual profile.

Respiratory exchange ratio (RER)

RER is an indicator which is a way of estimating which fuel type (CHO, fat or protein) is being used within a given activity. It can be estimated by measuring oxygen taken in and carbon dioxide expired during the activity, using a portable or laboratory based gas analyser. Estimation of RER for a person can also tell you whether or not the sportsperson is operating anaerobically (without sufficient oxygen for aerobic effort) or not.

Energy released by a given volume of oxygen

- This energy depends on whether the fuel is carbohydrate, fat or protein.
- Different amounts of energy are released by combination with oxygen because of the different chemical formulae of CHO, fat or protein.
- Complete combination with oxygen will produce CO_2 and water.
- The amount of O_2 needed to completely oxidise a molecule of CHO, fat or protein is proportional to the amount of carbon in the fuel.

figure 2.7 – results from shuttle run test

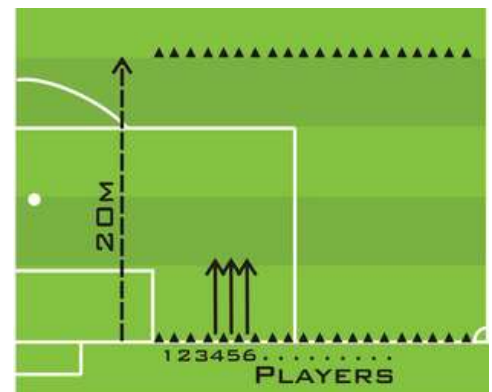


figure 2.8 – lactate sampler



RER

RER is the ratio:
$$\frac{\text{volume of CO}_2 \text{ produced}}{\text{volume of O}_2 \text{ consumed}}$$

For glucose: $6\text{O}_2 + \text{C}_6\text{H}_{12}\text{O}_6 \rightarrow 6\text{CO}_2 + 6\text{H}_2\text{O} + \text{energy to resynthesise 36ATP}$

Therefore for **glucose:**
$$\text{RER} = \frac{6\text{CO}_2}{6\text{O}_2} = 1.00$$

For fat: $23\text{O}_2 + \text{C}_{16}\text{H}_{32}\text{O}_2 \rightarrow 16\text{CO}_2 + 16\text{H}_2\text{O} + \text{energy to resynthesise 129ATP}$

Therefore for **fat:**
$$\text{RER} = \frac{16\text{CO}_2}{23\text{O}_2} = 0.70$$

For protein: $\text{C}_{72}\text{H}_{112}\text{N}_2\text{O}_{22}\text{S} + 77\text{O}_2 \rightarrow 63\text{CO}_2 + 38\text{H}_2\text{O} + \text{SO}_3 + 9\text{CO}(\text{NH}_2)_2$ (for example)

Therefore for protein:
$$\text{RER} = \frac{63\text{CO}_2}{77\text{O}_2} = 0.82$$

Protein is rarely used as an energy source except in extreme conditions.

Measuring RER

RER is estimated for a sportsperson by measuring CO_2 output and O_2 input while exercising either on a treadmill or a cycle ergometer, or while out running with a portable spirometer device (figure 2.9). During this process, the sportsperson breathes in and out of a tube connected to a gas analyser.

A value of RER near 1.0 means that the sportsperson is deriving most of his or her energy from CHO aerobically.

A value of RER over 1.0 means that less O_2 is being used than is required to produce the CO_2 from aerobic respiration which means that anaerobic respiration and lactate production are occurring.

So measurement of RER can tell a sportsperson whether he or she is reaching his or her aerobic limit or not, and whether the training intensity is too high for aerobic work.

The average value for RER for a mixed diet and for mild aerobic exercise is 0.82, showing a mixed uptake of carbohydrate and fats.

figure 2.9 – measuring RER while in action



Impact of specialised training methods on energy systems

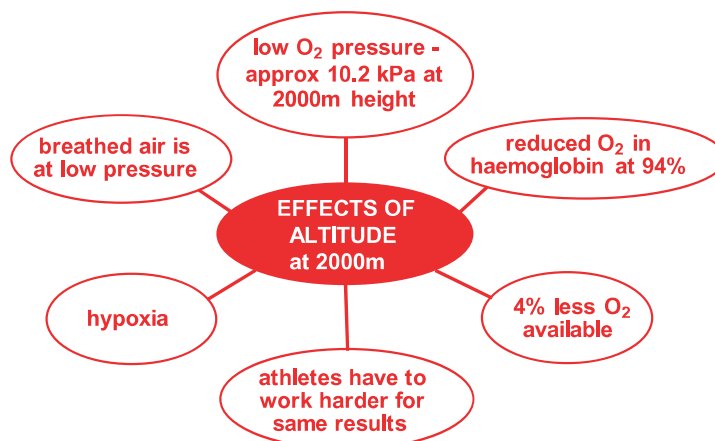
Altitude training

Partial pressure (p) is defined as 'the pressure a gas exerts within a mixture of gases',

At sea level, the **partial pressure** of oxygen is 160 mm/Hg, which is 21% of the total atmospheric pressure of 760 mm/Hg. As the atmospheric pressure decreases with an increase in altitude, the partial pressure of oxygen will also decrease, even though it will still remain 21% of the total air mass.

The effects of altitude on body systems are summarised in figure 2.10.

figure 2.10 – effects of altitude



Altitude training

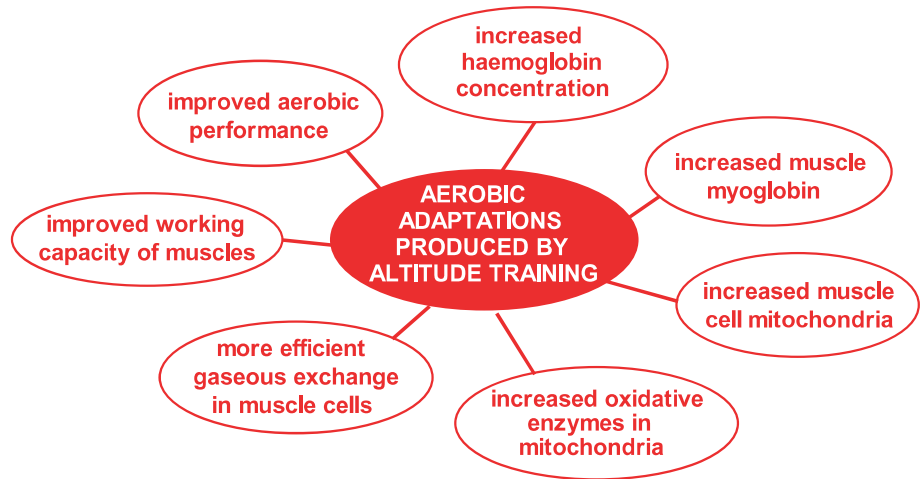
Athletes who travel to altitude for training purposes are at risk of suffering the detrimental effects of altitude. In addition to altitude illness (hypoxia), weight loss, immune suppression and sleep disturbance may serve to limit athletic performance.

Sea level residents who train at altitude are found to adapt by producing more haemoglobin at a rate of 1% and 2% per week.

This is done by increased manufacture of red blood cells (**erythropoietin - EPO**) production and an associated reduction in plasma volume, a slower long-term adaptation to living at altitude.

The effect of these two factors is to increase haemoglobin concentration in the blood flowing to active tissue, and hence an increase in the oxygen-carrying capacity of the blood.

Aerobic physiological adaptations produced by altitude training, are summarised in figure 2.11.



- High altitude training is regarded as an integral component of modern athletic preparation, especially for a range of endurance sports such as middle/long distance running and triathlon.
- Most elite athletes have a minimum of 2 training blocks or visits per year, one long training block of between 4-6 weeks during the preparation training phase, and then a shorter block of between 2-3 weeks just prior to a major competition. During a second visit the body adapts more quickly.
- Some elite athletes spend several weeks training at altitude. For example, Sir Mo Farah spends up to three months at a time training at altitude in Kenya's Rift Valley (1830 metres) and in Ethiopia (1,000 metres) preparing for key sea level events such as the London Marathon figure 2.12.
- **Short-term symptoms** to altitude exposure include headaches and dizziness and increased breathing and heart rates. The key is to adjust gradually (**acclimatise**) to higher altitude.
- During the first week of altitude training an elite athlete would normally work at between 60-70% of sea level intensity thus avoiding very hard lactate sessions.
- During the second week, the training would increase to full intensity (within days 10-14) and continue until returning to sea level. This would include 'tapering' or reducing the workload during the final couple of days just prior to a major competition. Paula Radcliffe chose to compete 2 days after returning to sea level.
- The process of altitude training will stimulate production of more **haemoglobin** and bigger increases in **myoglobin**, **mitochondria** and **oxidative enzymes** than at sea level in the way outlined above and in figure 2.11.
- Hence on return to sea level the sportsperson would have **increased $\dot{V}O_{2\max}$** and tissue cell respiration, leading to enhanced aerobic performance.
- The optimum time to compete is within 2 to 14 days of return to sea-level. After this, the adaptations gradually return to sea-level norms over a period of weeks, depending on the time spent at altitude and the individual's basic physiological state.

figure 2.12 – Sir Mo Farah



Altitude training and the energy systems

As explained on page 31, altitude training, for sea level endurance athletes, stresses the aerobic energy system, however, the physiological aerobic adaptations are temporary.

While **endurance performance** generally **declines at altitude** in running events longer than 400 metres, explosive **anaerobic events** such as sprinting, jumping and throwing, **benefit** from the rarefied air as exemplified by the world records achieved in the Mexico Olympic Games in 1968. Note that all track events in excess of 400 metres were won by African athletes who lived at altitude.

High Intensity Interval Training (HIIT)

This is a type of interval training that involves repeated bouts of **high intensity training** followed by a varied **recovery time**. **Duration** of work periods may range from 5 seconds to 8 minutes long and are performed at an **intensity** of between **80% to 95% of HR_{max}**.

Repetitions and **sets** are created depending on the intensity and duration of the exercise period.

Recovery periods are performed at an intensity of between **40% to 50% of HR_{max}**. Exercise continues with alternating work and a **1:1 rest relief ratio**.

HIIT benefits both aerobic and anaerobic fitness, blood pressure, cholesterol profiles and body fat whilst increasing muscle mass. The completion of Physical Activity Readiness Questionnaire (**PAR-Q**) is a sensible first step for participants who are planning to increase their levels of physical activity.

HIIT workouts can be created for every exercise preference which could take as little as 10 minutes for the novice performer. For example, following a warm-up, 30 seconds brisk walk, 30 seconds sprint x 10 repetitions, followed by a cool down. The specific sprint part of the session is anaerobic stressing both **ATP-PC** and **anaerobic glycolytic** energy systems. During the recovery the **aerobic** energy system is stressed.

A more general session (figure 2.13) could involve one minute activity bouts at about 90% of HR_{max}, followed by one minute of easy recovery with 10 total intervals and recovery, for a total workout time lasting 20 minutes. Note that in this type of session the exercise has alternating **work and recovery at a 1:1 rest relief ratio**.

An increase in skeletal muscle buffering capacity may be one mechanism responsible for an improvement in HIIT training.

HIIT has demonstrated that **improved insulin action** stimulates glycogen synthesis, thereby improving glycaemic control (the maintenance of glucose levels) in healthy middle aged individuals at risk of developing type 2 diabetes.

HIIT and energy systems

The HIIT training method stresses all three energy systems when the high intensity part of the session utilises the both ATP-PC and anaerobic glycolytic energy systems for explosive energy and the aerobic energy system is fully utilised during the recovery part of the session.

figure 2.13 – TRX HIIT training



Plyometric training

A type of power training **involving eccentric-to-concentric actions at 100% effort** designed to improve elastic strength and power.

Plyometric leg training occurs when, on landing, the muscle performs an eccentric contraction (lengthens under tension) performed quickly so that the loaded agonist muscle stretches slightly prior to concentric action. This stimulates adaptation within the neuromuscular system as muscle spindles cause a **stretch reflex** to produce a more powerful concentric muscle contraction. The throwing and catching of medicine balls is a way of developing elastic shoulder strength.

In figure 2.14, two athletes are throwing a medicine ball back and forth. The catch phase of this movement is eccentric for the trunk musculature and the shoulders, with the throw movement being concentric in the same muscle groups.

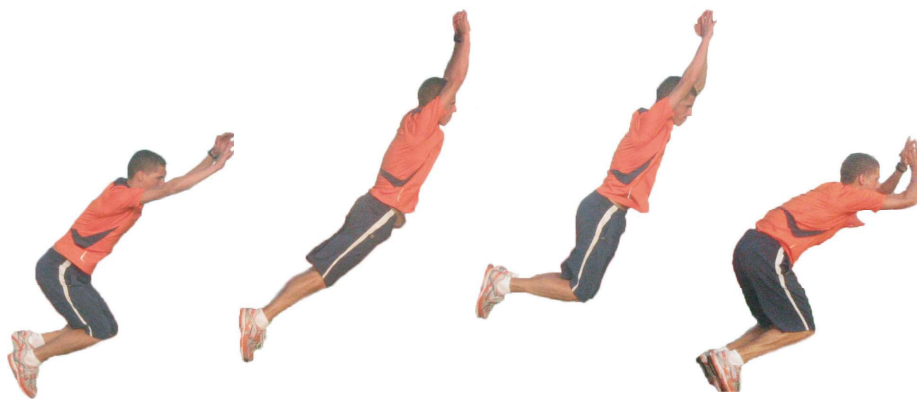
Normally this exercise is done too slowly to activate the stretch reflex, but a rapid rebound movement could have the desired effect.

figure 2.14 – catch and throw as eccentric then concentric exercise – similar to plyometrics



In figure 2.15, the athlete is performing two-footed jumping (bunny jumps), which would have to be performed quickly to activate the stretch reflex in time with the concentric phase of the jump.

figure 2.15 – bounding and jumping can be plyometric



Further examples of plyometric training sessions:

- Depth jumping from a box and rebounding quickly from impact point.
- Two foot bounds over a flight of hurdles.
- 3-5 sets of 3-10 repetitions with medium recovery of 1-3 minutes.

Plyometric training and the energy systems

Plyometric drills predominantly stress **anaerobic** energy systems namely the ATP-PC system and the anaerobic glycolytic system (lactic acid system).

The **ATP-PC system** depends on energy stores that already exist in skeletal muscle tissue.

Plyometric drills, such as repeated depth jumping of a series of boxes lasting 4 to 8 seconds, deplete this energy source very quickly.

The **lactic acid threshold** is reached when the muscles' energy stores have exhausted the ATP-PC stores.

Plyometric training and the energy systems

After this **threshold** point, energy is supplied predominantly by the **anaerobic glycolytic system**, for example, multiple bounding drills that take between 10-20 seconds duration to complete.

A short recovery period or rest relief should be allotted between high quality plyometric drills.

Speed agility and quickness training (SAQ)

Speed represents the maximum velocity an athlete can achieve and maintain.

Agility is the ability to change direction quickly without losing speed or balance.

Quickness involves rapid and energetic movements.

SAQ combines speed, agility and quickness over **short distances** using a variety of drills and agility as the main motor fitness component, with emphasis on **precision** and **speed of foot placement**. The drills vary from using equipment such as foot ladders (placed on the floor), low hurdles and cones in a variety of foot placement patterns, forcing rapid changes of direction that can replicate specific movement patterns required by the athlete in his or her specific sport.

Examples of SAQ training drills

Example 1: low hurdle agility drill

Ten low hurdles are set out in a set spaced formation. The athlete moves over the hurdles as fast as possible (figure 2.16). This drill is intended to replicate specific movement patterns needed in games such as soccer and rugby.

Example 2: foot ladder agility drills

Foot ladder agility drills are an excellent way to improve foot speed, agility, coordination and overall quickness. In figure 2.17, the athlete is sprinting between each rung of the ladder.

In figure 2.18, the athlete is taking alternating single step in, single step out into and out of the ladder. There are many possible foot combinations for ladder agility drills.

figure 2.16 – low hurdle agility drill



figure 2.17 – footladder agility drill

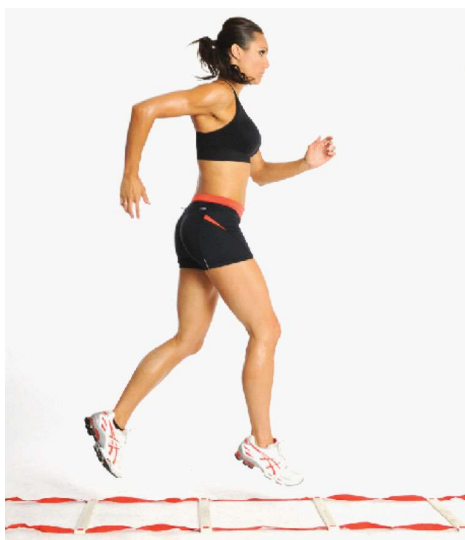
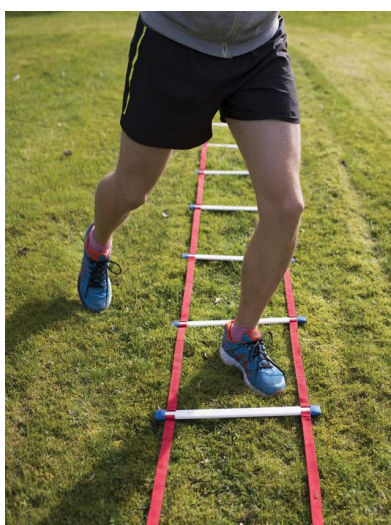


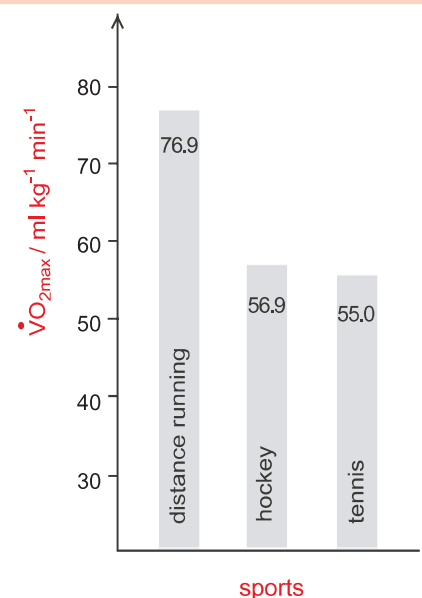
figure 2.18 – footladder agility drill



Practice questions

- 1) Which one of the following is defined as the greatest amount of oxygen the body can take in and utilise during exercise?
 - a. $\dot{V}O_{2\cdot}$
 - b. cardiovascular endurance.
 - c. $\dot{V}O_{2max}$
 - d. $ppO_{2\cdot}$
- 2) The respiratory exchange ratio is a measurement of:
 - a. lactic acid accumulation.
 - b. lack of oxygen (hypoxia).
 - c. the ratio between the amount of hydrogen produced in metabolism and oxygen used.
 - d. the ratio between the amount of carbon dioxide produced in metabolism and oxygen used.
- 3) Which one of the following is not an aerobic adaptive response to altitude training?
 - a. improved working capacity of muscles.
 - b. increased muscle myoglobin.
 - c. increased utilisation of fast twitch motor units.
 - d. increased haemoglobin concentration.
- 4) Which one of the following best describes the plyometric training method?
 - a. involves mainly stretching.
 - b. involves continuous running.
 - c. involves interval training.
 - d. involves mainly bounding/hopping.
- 5) Which one of the following is not a maximal predicted $\dot{V}O_{2max}$ test?
 - a. Multi-stage shuttle run test.
 - b. 1-mile jog test
 - c. Cooper's run/walk test
 - d. 1.5 mile run test
- 6) a) Define the term $\dot{V}O_{2max}$ and describe two main factors which limit $\dot{V}O_{2max}$. 3 marks
 b) Describe a field test used to estimate a person's $\dot{V}O_{2max}$. 3 marks
- 7) a) Figure 2.19 shows variation in $\dot{V}O_{2max}$ between three different sports. Suggest reasons for variations in $\dot{V}O_{2max}$ between these three sports. 3 marks
 b) Explain the potential physiological advantages for endurance athletes having a high $\dot{V}O_{2max}$. 2 marks
- 8) Discuss the factors that affect maximal oxygen consumption ($\dot{V}O_{2max}$) and the accuracy of $\dot{V}O_{2max}$ prediction from submaximal exercise heart rate. 15 marks

figure 2.19 – $\dot{V}O_{2max}$ for different sports

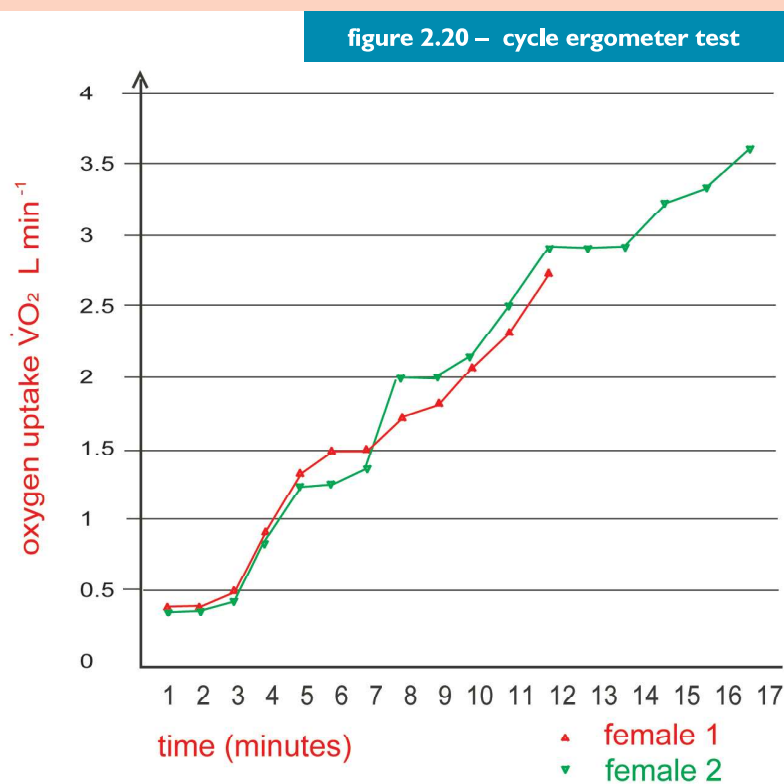


Practice questions

- 9) Two female athletes, one trained runner and the other untrained runner, performed a $\text{VO}_{2\text{max}}$ test on a cycle ergometer. The results of the test are shown in the graph, figure 2.20.

	female 1	female 2
body mass	75 kg	65 kg
height	174 cm	176 cm

- Use the information in the graph and table to determine if the values given are absolute or relative measures. Explain which measure (absolute or relative) is more useful when comparing the oxygen uptake for the two runners. 3 marks
- Using the data in figure 2.20, explain which female is the trained runner. 2 marks
- Identify one chronic adaptation to the cardiovascular system and explain how it has resulted in the trained runner achieving a greater result. 2 marks



- For female 2, explain what occurs physiologically between 12 and 14 minutes, and then what happens between 14 and 15 minutes. 4 marks
- The cycle ergometer test is not specific to running. Name a recognised field test that could be used to determine a runner's $\text{VO}_{2\text{max}}$. 1 mark

- 10) Volleyball is a team sport and a match generally takes between 30 and 60 minutes. Players are involved in high intensity, short duration play, such as serving, passing, spiking and blocking. The game is explosive in nature with rest periods between points.

- Using the information provided, describe the interplay of the three energy systems in a volleyball match. 6 marks
- Plyometric training can improve muscular power and is a suitable training method for volleyball players. Outline two principles needed to create a plyometric training session supporting your answer with a practical example. 3 marks
- Why does muscle soreness (DOMS) often occur following a plyometric training session and how could muscle soreness be reduced? 4 marks

Practice questions

- 11) Many elite swimmers use blood lactate sampling during training as a means of establishing their training load.
- What do you understand by the term lactate threshold? 2 marks
 - How is lactate threshold related to $\dot{V}O_{2max}$? 2 marks
 - How might knowledge of blood lactate levels taken during a swimming session assist both coach and elite swimmer? 2 marks
- 12) a) Show how the data in the following equation can be used to calculate the respiratory exchange ratio (RER) and identify which fuel food is being used. Show your workings. $6O_2 + C_6H_{12}O_6 \rightarrow 6CO_2 + 6H_2O + \text{energy}$. 3 marks
- b) How can this information be of value to an elite sports performer? 2 marks
- 13) Altitude training is used by some marathon runners as part of their physiological preparation for sea level racing. Discuss whether altitude training is always beneficial to marathon runners. 8 marks
- 14) a) Describe the conditions at altitude that could limit performance. 3 marks
- b) An elite group of endurance athletes spend three weeks training at 2000 metres. What major physiological responses and adaptations would they expect during this period of acclimatisation? 8 marks
- 15) Elite athletes must develop and maintain extremely high levels of fitness to maximise their chances of winning, and may use the results from lactate sampling and the respiratory exchange ratio (RER) to ensure that their training is effective. Explain the terms lactate sampling and respiratory exchange ratio and how elite athletes benefit from these two measurements of energy expenditure. 4 marks
- 16) Discuss the impact of specialist training methods on energy systems. 15 marks

Answers link: http://www.jroscoe.co.uk/downloads/a2_revise_pe_aqa/AQAA2_ch2_answers.pdf

