CHAPTER 5

Physical fitness, training and movement efficiency

OUTCOMES

On completion of this chapter, you will be able to:

- explain how body structures influence the way the body moves (P7)
- describe the components of physical fitness and explain how they are monitored (P8)
- plan for participation in physical activity to satisfy a range of individual needs (P10)
- assess and monitor physical fitness levels and physical activity patterns. (P11)

OVERVIEW

HEALTH-RELATED COMPONENTS OF PHYSICAL FITNESS

Cardiorespiratory endurance
Muscular strength
Muscular endurance
Flexibility
Body composition

SKILL-RELATED COMPONENTS OF PHYSICAL FITNESS

Power
Speed
Agility
Coordination
Balance
Reaction time

AEROBIC AND ANAEROBIC TRAINING

Aerobic training
FITT principle
Anaerobic training

IMMEDIATE PHYSIOLOGICAL RESPONSES TO TRAINING

Heart rate
Ventilation rate
Stroke volume
Cardiac output
Lactate levels

HEALTH-RELATED COMPONENTS OF PHYSICAL FITNESS

Physical fitness is important in establishing and maintaining total body health. Physical fitness has a number of essential components, all of which contribute to total body fitness. Some fitness components have a direct impact on health. A variation in one or a number of these components can significantly affect our total health and well-being.

Health-related fitness components include:

- cardiorespiratory endurance
- muscular strength
- muscular endurance
- flexibility
- body composition.

Other fitness components relate more specifically to skills required for sports performance. These include:

- power
- speed
- agility
- coordination
- balance
- reaction time.

A brief overview of components of fitness together with tests that can be used to measure these components can be viewed in table 5.1. There is a range of well recognised tests available to measure each of the components. The tests listed below are easy to administer in most school environments and include norms or averages relevant to your age group.

Table 5.1: Components of fitness overview

	Component	Definition	Suitable tests
Health-related components	Cardiorespiratory endurance	The ability of the working muscles to take up and use oxygen	Bicycle ergometry The multistage fitness test
	Muscular strength	The ability to exert force against a resistance	Handgrip dynamometer test
	Muscular endurance	The ability of the muscles to endure physical work for extended periods of time	Sit-up test
	Flexibility	The range of motion about a joint	Sit and reach test
	Body composition	The percentage of fat as opposed to lean body mass in a human being	Body fat measurements using skin fold callipers
Skill-related components	Power	The ability to combine strength and speed in an explosive action	Vertical jump
	Speed	The ability to perform body movements quickly	Sprint test
	Agility	The ability to move the body from one position and direction to another with speed and precision	Agility test
	Coordination	The ability to harmonise the messages from the senses with parts of the body to produce movements that are smooth, skilful and well controlled	The stick flip test

	Component	Definition	Suitable tests
	Balance	The ability to maintain equilibrium while either stationary or moving	Balance board test
	Reaction time	The time taken to respond to a stimulus	The ruler drop test

Hypokinetic disease is a term given to modern lifestyle diseases associated with inactivity.

An improvement in health-related fitness components improves personal health and lifestyle, including lowering the risk of **hypokinetic disease**. Hypokinetic disease includes such conditions as:

- heart disease
- obesity
- high blood pressure
- insomnia
- diabetes
- depression.

Health-related fitness components respond positively to physical exercise. For example, exercise can help us lose weight, improve muscle tone and assist in the prevention of lower back pain. However, exercise should not be considered in isolation. Other factors such as heredity, environment and nutrition, together with lifestyle practices such as drug use and stress management, play an important role in contributing to total body health.

Cardiorespiratory endurance

Cardiorespiratory endurance refers to the ability of the working muscles to take up and use the oxygen that has been breathed in during exercise and transferred to muscle cells.

Cardiorespiratory endurance is by far the most important health-related fitness component. It is commonly referred to as aerobic power. The word aerobic means 'with oxygen', suggesting that this system is powered by oxygen, which is readily available in the cells and breaks down the body's fuels, producing energy.

The importance of cardiorespiratory endurance is evident in endurance events such as cycling, triathlons and marathons. A well-trained cardiorespiratory system ensures:

- the delivery of adequate quantities of blood (high cardiac output)
- a functional ventilation system (respiratory system)
- a good transport system (circulatory system) to ensure efficient and speedy delivery of oxygen and nutrients to the cells.

Figure 5.1: Cardiorespiratory endurance is important in the performance of aerobic activity.

APPLICATION

A laboratory test of cardiorespiratory endurance — bicycle ergometry

Equipment

Bicycle ergometers, stopwatches, Repco calculator, weighing scales, heart rate measuring device (stethoscope/exersentry/pulse rate meter or others)

Procedure

To perform this test, the subject should exercise at a workload (WL) that will raise the heart rate (HR) to a level anywhere between 120 and 170 beats per minute (bpm) where it will 'settle down' (will not fluctuate). This should happen after about two to three minutes of exercise. If the HR fails to make 120 bpm, the WL (resistance or stress applied) must be increased. Similarly, if the HR is above 170 bpm the WL must be decreased.

Adjustments to WL can be made any time, but a period of established HR to a specific WL must follow for about three to four minutes. HR must level out between 120–170 bpm, otherwise the test will be invalid. This is because researchers have established linear values between HR and WL within these ranges. Outside these ranges, the values are inaccurate.

1. Form groups of three. The first person is the subject, the second person checks HR, the third person records HR and WL. The subject should not have exercised strenuously for two hours prior to the test.
2. Weigh the subject and record their weight.
3. Adjust saddle height of the bike if necessary. The knee should be almost fully extended when the pedal is at the bottom of its circle.
4. Attach the HR measuring device. Be sure contact is firm. The HR may well be higher than anticipated due to anxiety. If taking it manually be sure that you can feel the pulse.
5. The suggested workload is 600 kp.m for boys and 450 kp.m for girls. Begin pedalling and start the stopwatch. HR and WL must be recorded every minute, using table 5.2.

Table 5.2: Record of aerobic power using bicycle ergometer

Test characteristics	Minute	Workload (kp.m)	Heart rate (bpm)
HR 116–128	1		
	2		
Adjust WL if necessary	3		
	4		
HR settling down	5		
	6		
HR settled	7		
	8		
Recovery	9		
	10		

6. After one minute, HR should be between 116–128 bpm. After three minutes, HR must start to settle down to between 120–170 bpm. If the value is much lower than 120 bpm and settling down, increase the workload. If much higher than 170 bpm, the workload must be decreased.
7. Continue the test for seven minutes, recording HR and WL every minute. Continue for an extra minute or two if HR fails to 'settle down'; that is, be within a couple of beats of the previous reading.

8. To obtain a final result, average the sixth and seventh minute HR and note the WL.
9. To assess aerobic capacity, using the Repco calculator, line up age with body weight, then HR and WL and read aerobic power in mL/kg/min. Alternatively, use the **Astrand cycle test** weblink in your eBookPLUS and use the online calculator under the 'Assessment' heading to establish your maximal aerobic power (VO_2 max).
10. Use the **VO_2** max weblink in your eBookPLUS to establish your rating by examining the normative data for VO_2 max in 2005.

INQUIRY

My cardiorespiratory fitness level using bicycle ergometry

1. What is oxygen uptake?
2. What is meant by a test of maximal aerobic power?
3. What is a submaximal test?
4. Why do we test fitness levels using submaximal tests?
5. What are the possible disadvantages of using bicycle ergometry?
6. Copy and complete the graph (figure 5.2) for yourself as a subject by plotting your heart rate for each minute of exercise. Indicate where your heart rate levelled out.

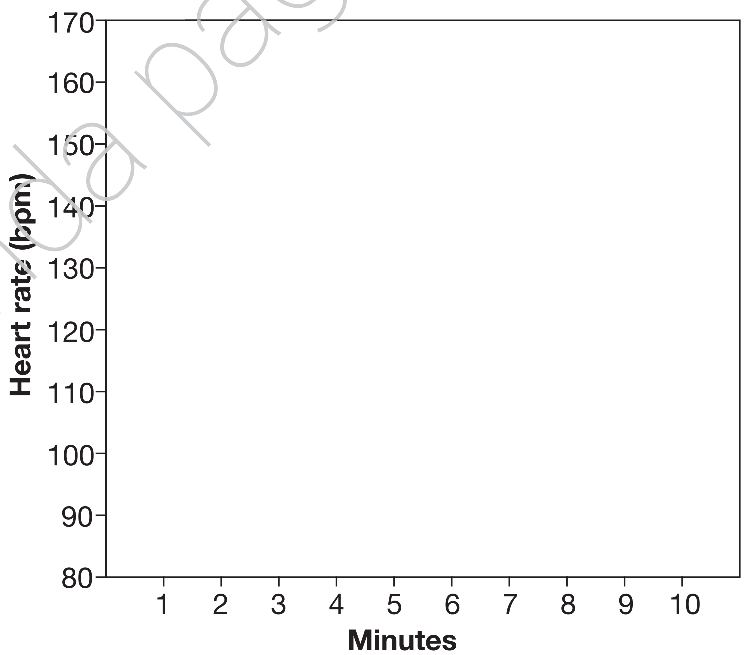

Figure 5.2: Graph of heart rate

7. What was your rating?
8. Were you satisfied with this rating? Why or why not?
9. Design a simple fitness program aimed at improving your aerobic power.

Editor Note: 3 Line short

APPLICATION

A field test of cardiorespiratory endurance — the multistage fitness test

Equipment

CD player, multilevel fitness test CD, firm surface with two lines marked 20 metres apart

Procedure

1. Form a group of no more than 10 subjects to one supervisor.
2. Divide the group into two. Half the group is to perform the test while the remaining half observes and records the results.
3. Use a general purpose warm-up including leg stretching exercises before commencing this test.
4. The subjects in group one should move to the start line and listen to the introductory remarks on the CD, which tell them when to start and how to judge pace.

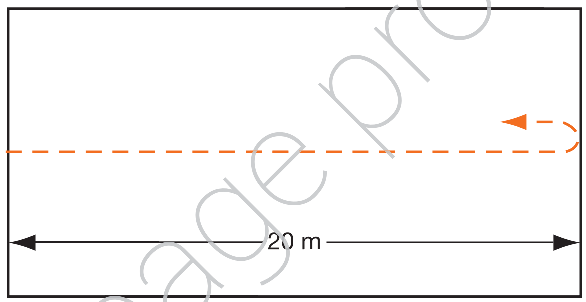

Figure 5.3: Lines for multistage fitness test

5. Subjects begin by walking to the end line, aiming to reach it on the 'beep'. Both feet must cross the line. They then turn and walk back aiming to reach the start line on the next 'beep'. Gradually the tempo is increased necessitating a jog and then a run to reach the other line by the sound of the 'beep'. When subjects fail to stay in time with the 'beep' they are given a warning. Failure to catch up or a second warning means the subject must stop the test.
6. Recorders should note the level at which their subject was unable to continue the test. Record the level and note the oxygen uptake in the table below.
7. Relate the oxygen uptake level to the aerobic capacity rating in table 5.3 to establish the rating for your cardiorespiratory endurance.

Table 5.3: Oxygen uptake according to levels

Level	Oxygen uptake
4	26.0–29.9
5	30.0–32.9
6	33.0–36.9
7	37.0–39.9
8	40.0–43.9
9	44.0–46.9
10	47.0–49.9
11	50.0–53.9
12	54.0–57.9
13	58.0–60.9
14	61.0–64.9

Level	Oxygen uptake
15	65.0–67.9
16	68.0–71.9
17	72.0–74.9

INQUIRY

My cardiorespiratory fitness level using the multistage fitness test

1. What was your rating for the cardiorespiratory endurance test? If you have completed another of the tests of aerobic capacity, how did your readings compare? Were there any factors that limited your performance?
2. What was your heart rate and breathing rate at the end of the test? Describe how your legs felt during the last few shuttles and immediately following completion of the test. Can you suggest why you felt this way?
3. Discuss the advantages and disadvantages of this test for use in a team training situation.

Muscular strength

Muscular strength is the ability to exert force against a resistance in a single maximal effort.

Body requirements of **muscular strength** vary between sport, activity and general living. There is considerable variation in strength requirements within particular sports, with some playing positions requiring more strength than others. Strength is particularly important in activities such as weight-lifting and gymnastics, and games such as rugby. High levels of overall body strength improve performance and reduce the risk of injury.

Muscular hypertrophy relates to an increase in the size of the muscle resulting from an increase in the cross-sectional area of the individual muscle fibres.

When we increase our strength, there is also an increase in the size of the muscle. This is referred to as **muscular hypertrophy**.

Figure 5.4: Muscular strength improves performance and reduces the risk of injury.

APPLICATION

Determining muscular strength

Figure 5.5: Position for grip strength test

Equipment

Hand dynamometer

Procedure

1. Pick up the dynamometer and push the arrow back to zero.
2. Let your arm hang vertically with the dynamometer comfortably gripped in the hand.
3. Gradually lift the dynamometer to shoulder height, squeezing the grip as hard as you can with the arm extended.
4. Read the result and record it in table 5.4. Repeat with the left hand.
5. Allow three tests on each hand, and record the best. Determine your rating, using table 5.5.

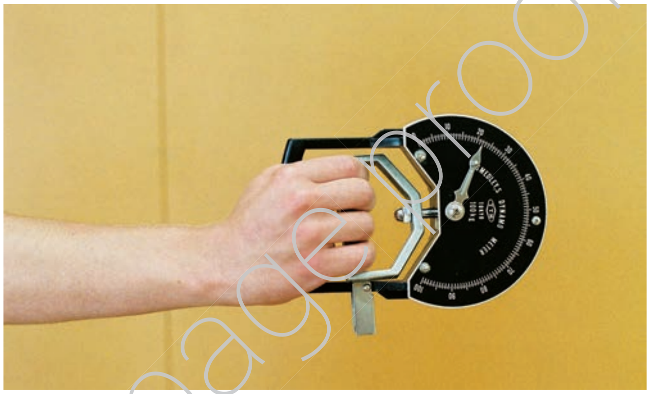

Figure 5.6: Gripping the hand dynamometer

Table 5.4: Results for muscular strength using a hand dynamometer

	Result (kg)	Rating
Right		
Left		
Best		

Table 5.5: Ratings for muscular strength using a hand dynamometer

	Strongest hand	
Classification	**Boys**	**Girls**
Super	>65.0 kg	>40.0 kg
Excellent	60.0–64.9	36.0–39.9
Good	53.0–59.9	32.0–35.9
Average	48.0–52.9	29.0–31.9
Fair	44.0–47.9	25.0–28.9
Poor	38.0–43.9	20.0–24.9
Very poor	<37.9	<19.9

Source: Adapted from D. Davis, T. Kimmet and M. Auty, *Physical Education Theory and Practice,* Macmillan, Melbourne, 1986. Reproduced by permission of Macmillan Education Australia.

INQUIRY

Activity, training and muscular strength

1. Is strength important in the type of sport or activity in which you participate?
2. Were you satisfied with your muscular strength rating? Why?
3. Do you feel this test reflected your overall body strength? Explain.
4. Do you use strength training to complement your sport or activity? Explain the strength training program you use.
5. What type of contraction was performed in the application above?
6. Why is adequate strength important in daily life?
7. As a class, discuss any differences between the strength results of girls and boys in this application.

Muscular endurance

Muscular endurance is the ability of the muscles to endure physical work for extended periods of time without undue fatigue.

The development of **muscular endurance** is very important in activities where contraction of the same muscle or group of muscles is repeated for periods of time without rest. It is a measure of the ability of the muscle to contract repeatedly over a period of time, thereby delaying the onset of fatigue.

Muscular endurance is local in that it is specific to a muscle or a group of muscles. It depends on the condition of the muscle that is performing the repeated contractions; for example, the rectus abdominis during continuous sit-ups. Muscular endurance is improved by programs that focus on maximum repetitions with low to moderate levels of resistance.

Muscular endurance is important in activities such as cycling, cross-country running, skiing, sports carnivals, bushwalking and rowing. In each of these activities, specific muscle groups must contract repeatedly to perform the skill. If the muscle group tires, the ability to continue to perform the skill is adversely affected.

Figure 5.7: Muscular endurance is important in activities where the same muscle group is involved in repetitive movements.

APPLICATION

Measuring muscular endurance

Equipment

Stopwatch, recording sheet

Procedure

1. Work in pairs. Nominate who will be the first subject and who will be the first counter.
2. The subject should lie on the floor with knees bent and feet flat on the floor. Arms are folded across the chest. Palms are open and rest on the front of the shoulders. Elbows are close together. The counter should hold their partner's feet firmly on the floor. The angle at the knees should not be less than 60°. In the sit-up, the trunk is raised and the elbows brought to a position between the knees. The body then returns to the floor. The total movement counts for one sit-up.

Figure 5.8: Sit-up test

3. Have a number of practices to warm up and ensure the technique is correct. Disallow any sit-ups performed incorrectly.
4. Perform the test, counting the number of correctly executed sit-ups in two minutes for boys and in one minute for girls.
5. Change roles and repeat the process.
6. Determine the rating for each person, using table 5.6.

Table 5.6: Muscular endurance ratings for sit-ups

Classification	Number of sit-ups	
	Boys	**Girls**
Excellent	>79	>38
Very good	69–78	33–37
Good	62–68	28–32
Average	52–61	23–27
Fair	44–51	17–22
Poor	35–43	12–16
Very poor	<35	<12

Source: Adapted from D. Davis, T. Kimmet and M. Auty, op. cit.

INQUIRY

Activity and muscular endurance

1. Are you satisfied with your rating in the sit-up test?
2. What problems did you incur with this type of test?
3. How can you improve muscular endurance?
4. In what type of activities would you expect to see a relationship between muscular endurance and cardiovascular endurance?
5. List five sports where a significant amount of muscular endurance is essential for a good performance.
6. What activities in our normal lifestyle require muscular endurance?

Flexibility

Flexibility is the range of motion about a joint or the ease of joint movement.

Isometric exercises are muscular contractions where tension is created in the muscle, but its length remains the same; for example, trying to lift a weight that is too heavy to be moved.

Maintenance of joint **flexibility** not only helps sport performance, but contributes significantly to quality of life. Flexibility is joint specific; that is, the level of flexibility found in one joint will not necessarily be uniform throughout the body. In other words, a person who is quite flexible in the shoulders may not be quite as flexible in other joints throughout the body.

Flexibility is an important health-related fitness component because it directly affects personal health and athletic performance, both now and in the future. For example, it is known that muscle length decreases with age, progressively decreasing our range of movement. Routine flexibility programs delay and restrict the effects of this process. Flexibility is improved by safe stretching programs which, in addition to increasing mobility, also:

- help prevent injury
- improve posture
- improve blood circulation
- decrease the chance of lower back pain later in life
- strengthen the muscle if combined with **isometric exercises**.

Figure 5.9: Improved flexibility allows us to participate in a greater range of activity with less discomfort and less chance of injury.

APPLICATION

Measuring flexibility

Equipment

Sit-and-reach measuring device, box for mounting

Procedure

1. Divide into pairs. Set up the box with a sit-and-reach measuring device placed horizontally on top.

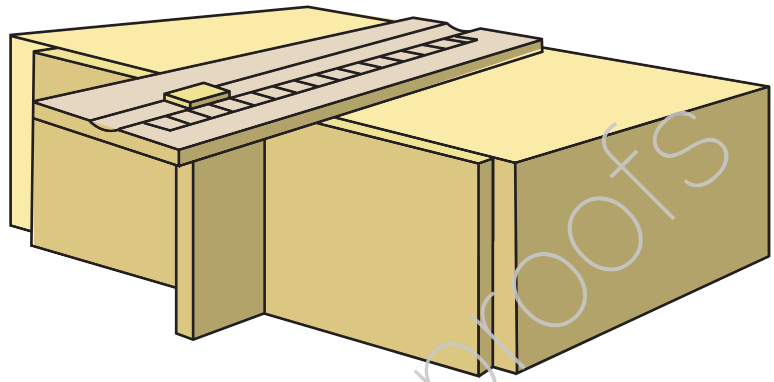

Figure 5.10: Setup for sit-and-reach test

2. The first subject sits on the floor with both legs straight, as in figure 5.11.
3. The second subject holds the first subject's knees firmly on the floor and sets the markers. Feet level corresponds to zero on the measurement rule.
4. The first subject should reach forward slowly (no jerky movements allowed) and push the markers forward as far as possible with the fingers. Fingers remain extended with palms down.

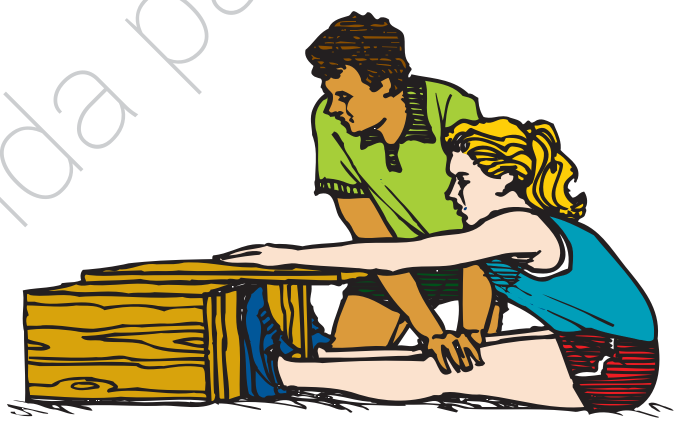

Figure 5.11: Sit-and-reach test for flexibility

5. The best of three attempts should be recorded.
6. Determine the rating for each person, using table 5.7.

Table 5.7: Sit-and-reach ratings

Classification	Boys 16–17 years	Girls 16–17 years
Excellent	>10+	>15+
Good	6–9	13–14
Average	2–5	11–12
Fair	–5–1	6–10
Poor	<–5	<5

Source: Adapted from B. Leelarthaepin, op. cit.

INQUIRY

Activity and flexibility

1. List three sports or activities that take up a lot of your recreational or training time (for example, surfing).
2. List three joints that undergo a full range of motion in performing the skills associated with the sports or activities listed in question one (for example, the shoulder joint).
3. Do you think your flexibility rating is good enough to avoid injury considering the demands made on your joints?
4. How would additional flexibility be an advantage?
5. Why is flexibility important in all sport and game situations?

Body composition

Body composition refers to the percentage of fat as opposed to lean body mass in a human being.

Body composition is an important health-related component because it takes account of the level of storage fuel required for muscle activity. Having too little or too much storage fuel (fat) can significantly affect health and physical performance.

All people need a certain amount of body fat. This is called *essential fat* and surrounds vital organs such as kidneys, heart, muscle, liver and nerves. Absence of fat in these areas would lead to chronic health problems because fat in these regions helps to protect, insulate and absorb shock to these organs. Additional fat is called storage fat and it too has an important role, mainly as a source of stored energy. Storage fat is used for fuel during times of rest and sleep and in extended exercise of more than an hour or so, when our supplies of **blood glucose** are exhausted.

Blood glucose is blood sugar. It represents the immediate supply of fuel for the working muscles.

Lean body mass is often called fat-free mass and comprises all of the body's nonfat tissue, including bone, muscle, organs and connective tissue. While the characteristics of body tissue are genetically determined, the size of the muscle can change with the use of resistance training (weight training) programs.

Body composition can be changed by diet and exercise. For example, a lifestyle that combines regular high activity and resistance training with a well-balanced, but not excessive, food intake will result in a significant decrease in body fat and improved body tone. The recommended amount of body fat as a percentage of body composition is 15 to 20 per cent for men and 20 to 25 per cent for women.

Figure 5.12: Exercise patterns and eating habits largely determine our body composition.

APPLICATION

Determining body composition

Equipment

Skin fold callipers or slide measure, recording sheets

Procedure

There are four sites on the body at which body fat is measured using callipers. Subjects should wear T-shirts and relax while measurements are being taken. Flexing the muscles does not decrease the amount of fat, it simply makes measurement more difficult.

1. Divide into pairs, threes or fours, depending on the number of callipers available.
2. Take the callipers in the preferred hand (usually the right) and practise opening the arms of the instrument. Repeat until you can do this both comfortably and smoothly. If using a slide measure, practise pushing the slide and letting it come back.
3. Take a vertical (that is, skinfold will be up and down) skinfold measurement at the four sites — (i) biceps, (ii) triceps, (iii) subscapular and (iv) suprailiac.
   (a) The biceps is located on the front of the arm in the middle of the biceps muscle (that is, halfway between the elbow and shoulder — see figure 5.13(a)).
   (b) The triceps is located on the back of the arm halfway between the elbow and shoulder (see figure 5.13(b)). The vertical skinfold should be taken from the middle of the triceps muscle (see figure 5.14).

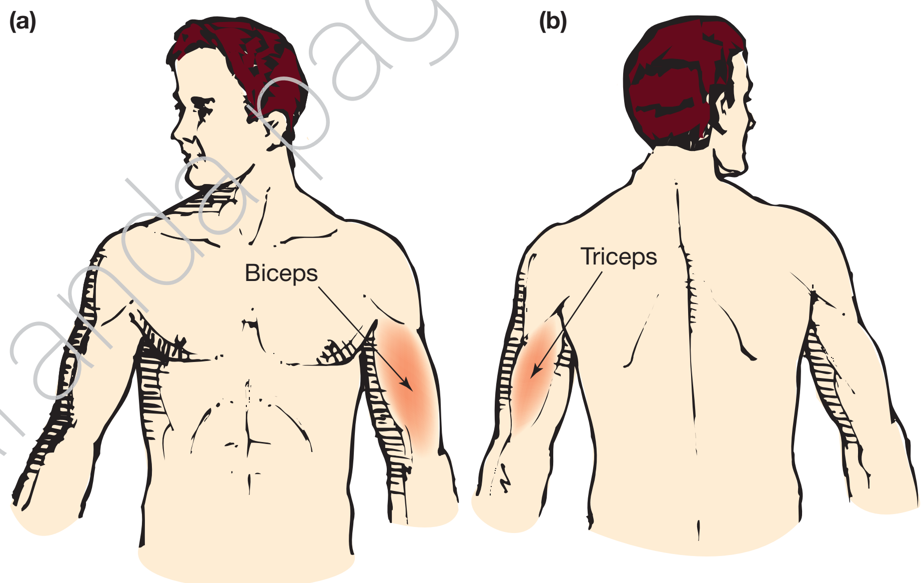

Figure 5.13: Location of **(a)** biceps, **(b)** triceps

   (c) Push your arm up your back and the shoulder blade (scapula) will protrude. Locate this bone and then have the subject drop the arm. Take a vertical skinfold approximately two centimetres below the bottom tip of the bone (subscapular — see figure 5.15).
   (d) Feel the hip bone. The top is the iliac crest. Take a vertical measurement approximately two centimetres above this point (suprailiac — see figure 5.16).
4. The first subject should stand and let his/her arms hang loosely.
5. With callipers in the preferred hand, the assistant gently pinches the skin between their index finger and thumb using the other hand. Then, slide off the muscle that can be felt underneath and gently hold the skinfold. Place the

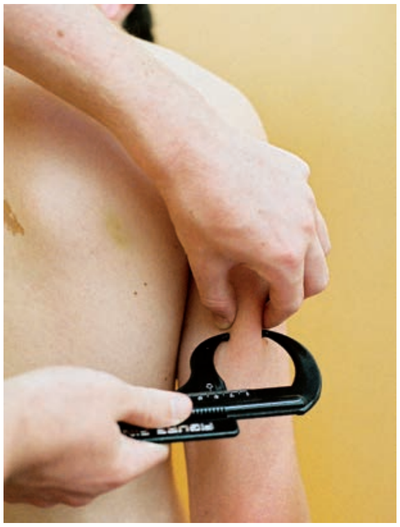

Figure 5.14: Skinfold test on the triceps

Figure 5.15: Skinfold test on the subscapular

Figure 5.16: Skinfold test on the suprailiac

callipers over the fold and let the arms of the calliper close in (see figures 5.14, 5.15 and 5.16).

6. The assistant then reads the skinfold measurement. The callipers should not be left on for too long as fat cells will compress, causing inaccuracies.
7. Callipers should be removed and the pinch of skin gently relaxed.
8. Repeat the measurement twice. If two readings are the same, record the reading. If all are different, record the mean (average) reading in table 5.8.

Table 5.8: Measurement of body fat

Site	Measurement (mm)
Biceps	
Triceps	
Subscapular	
Suprailiac	

9. Repeat for each subject.
10. Total the measurements from the four sites for each individual and check your body composition rating using tables 5.9, 5.10 and 5.11.

Table 5.9: Body composition rating

Sum of four skinfolds (mm)	Percentage body fat from sum of four skinfolds (age 16–17 years)	
	Boys	Girls
10	4.8	6.3
15	8.6	11.6
20	11.4	15.3
25	13.5	18.2
30	15.2	20.6
35	16.7	22.6
40	17.9	24.3
45	19.0	25.9
50	20.2	27.2
55	20.9	28.5
60	21.8	29.6
65	22.5	30.6
70	23.2	31.6
75	23.9	32.5
80	24.5	33.3
85	25.1	34.1
90	25.6	34.9
95	26.1	35.6
100	26.6	36.1
105	27.1	36.6
110	27.5	37.3
115	27.9	38.0
120	28.3	38.6

Table 5.10: Ordinary rating scale for body fat composition

Classification	Boys 16–17 years (%)	Girls 16–17 years (%)
Lean	12	24.1
Acceptable	12.1–19.6	24.2–28.4
Moderately obese	19.7–23.2	28.5–33.3
Obese	23.3+	33.4+

Table 5.11: Athletes' rating scale for body fat composition

Classification	Males (%)	Females (%)
Lean	6.9	11.0
Acceptable	7.0–14.9	12.0–24.9
Obese	15	25.0

Source: Adapted from B. Leelarthaepin, op. cit.

INQUIRY

Evaluating body composition

1. What percentage of body fat should you aim for?
2. How can a desirable amount of body fat be achieved and maintained?
3. What are the advantages of having a desirable percentage of body fat?
4. What problems could be incurred in calculating percentage of body fat using the skinfold measurement method?

SKILL-RELATED COMPONENTS OF PHYSICAL FITNESS

Muscular power is the ability to combine strength and speed in an explosive action.

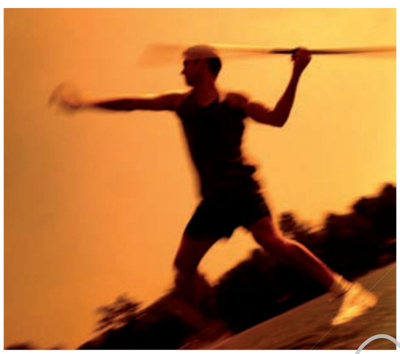

Figure 5.17: Power is important in activities that require explosive movements.

Skill-related components of physical fitness do not impact specifically on health but are important in the performance of activities, games and recreational pursuits. An improvement in skill-related components improves performance in activities that utilise that skill. For example, effective rebounding in basketball requires an ability to jump high. The fitness component required to jump high is leg power.

Power

Muscular power is determined by the amount of work per unit of time. People who are strong are not necessarily powerful.

The amount of power relative to the amount of strength varies according to the type of activity. *Speed-dominated* power is power generated through a greater emphasis on speed and is essential in activities such as sprinting and throwing. *Strength-dominated* power is power generated through a greater emphasis on strength. It is important in activities such as weight-lifting and throwing the shot or javelin. Effective programs aim to develop the required amounts of strength and power in each individual according to the needs of the sport.

APPLICATION

Measuring muscular power

Equipment

Vertical jump board or tape measures attached to wall

Procedure

1. Divide into pairs. One person is the subject and the other is the recorder.
2. The subject should dip their middle finger in chalk dust, face the wall, extend both hands upwards and make a mark. Record the height of the mark in centimetres.

3. The subject should then turn sideways to the wall, spread their feet, take a deep squat and jump vertically (see figure 5.18). No feet movements are allowable in preparation for the jump.
4. At the height of the jump, the subject should mark the wall adjacent to the tape. Record the difference between the first and second marks.
5. Allow three jumps and record the best.
6. The subject and recorder should now change roles and repeat steps 2–5.
7. Take the best jump for each person and determine their power rating using table 5.12.

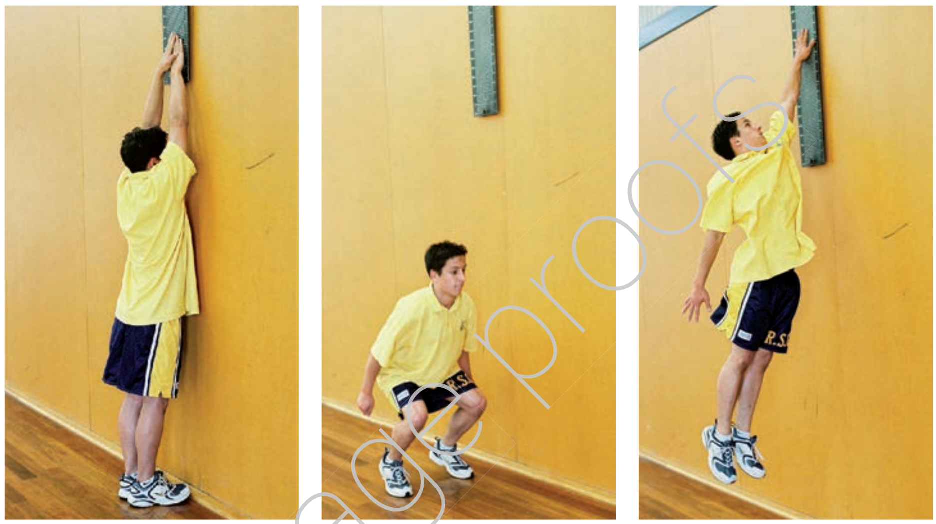

Figure 5.18: Vertical jump test

Table 5.12: Muscular power rating

Classification	Height (cm)	
	Boys	**Girls**
Super	64.1	44.1
Excellent	60.1–64.0	41.0–44.1
Good	57.1–60.0	35.1–40.9
Average	53.1–57.0	31.1–35.0
Fair	49.1–53.0	28.0–31.0
Poor	44.6–49.0	22.1–27.9
Very poor	<44.5	<22.0

Source: Adapted from D. Davis, T. Kimmet and M. Auty, op. cit., pp. 146–7.

INQUIRY

Evaluating muscular power

1. Were you satisfied with your muscular power rating in the previous application? Why or why not?
2. How might you increase your power to improve your performance in a re-test of the vertical jump?
3. List three movements in your preferred sport or activity for which power is essential; for example, jumping in basketball.

4. Is your power sufficient to be able to perform these movements as well as you would like?
5. In what aspects of daily life is power an advantage?

Speed

Speed is the ability to perform body movements quickly.

Because it is largely an innate quality determined by fibre type, **speed** is not as responsive to training as other fitness components such as cardiorespiratory endurance, strength and power. This explains why some people naturally appear to be 'quick' while others, no matter how much they train, do not make significant gains.

Sprinters still need to train to improve speed. However, while some improvements will be made as a result of increased power, considerable changes result from improvements in technique, including reaction time at the start, form, alignment, balance and the utilisation of energy for a powerful finish.

APPLICATION

Measuring speed

Equipment

Tape measures, stopwatches

Procedure

1. Measure a 45.7 metre straight on flat ground.
2. Divide into pairs. Choose who will be the first runner and who will be the first timer.
3. Have a general warm-up with emphasis on leg stretches.
4. Practise 'on the mark', 'set', 'go', allowing about two seconds between 'set' and 'go'.
5. Practise starting the stopwatch on the 'go' movement; that is, the first movement forward. As sight is quicker than sound, this will give a more accurate reading.
6. The starters should now go to the starting line and the timers to the finish line.
7. Start the runners and time them over the distance.
8. Allow three runs and select the best time.
9. The subjects and recorders should change over and repeat steps four to eight.
10. Take the best time for each person and determine their speed rating using table 5.13.

Table 5.13: Speed rating

Classification	Boys	Girls
Excellent	<6.0	<7.0
Very good	6.1–6.3	7.1–7.4
Good	6.4–6.5	7.5–7.6
Average	6.6–6.7	7.7–8.0
Fair	6.8–7.4	8.1–8.9
Poor	>7.4	>8.9

Source: Adapted from P. Hunsicker and G. Reiff, *AAHPER Youth Fitness Manual*, AAHPER, Reston, Virginia, 1976.

INQUIRY Evaluating speed

1. Why is speed an advantage in sport?
2. Were you satisfied with your rating in the application above? Why or why not?
3. How could you improve your speed?
4. List three sports that you play or have played that involve use of speed. How important is speed to good performance in these sports?
5. Where might speed be important in normal life?

Agility

Agility is the ability to move the body from one position and direction to another with speed and precision.

Agility combines a number of fitness components including balance, coordination and speed. Because agility is comprised of a number of components, any test that measures agility will be performed at speed and will reflect a degree of balance and coordination. Improved fitness in any one of these aspects subsequently improves agility and the ability to resist fatigue. Activities that require a high degree of agility include skiing, most team games and ice skating.

Figure 5.19: Agility is the ability to move with speed and precision.

Editor Note: 4 Line short

APPLICATION Testing agility

Equipment

Tape measure, six markers (chairs or witches' hats), stopwatches, recording sheets

Procedure

1. On a football field or suitable flat surface, mark two parallel lines 10 metres apart. Place four witches' hats 3.3 metres apart as per figure 5.20. Place two witches' hats 1.83 metres each side of the first line marker.
2. Divide into pairs. One person is to complete the course and the other is to time and record the results. Ensure that you warm up and stretch before completing the course.
3. The first subject from each pair must lie face down flat on the ground in a push-up position just behind the line at the start.
4. On the instruction 'go', the first subject runs to the end line and back, then in and out of the markers, to the end line again, then back to the finish (see figure 5.20).
5. During the run, each end line must be crossed. The marker cannot be jumped or knocked.

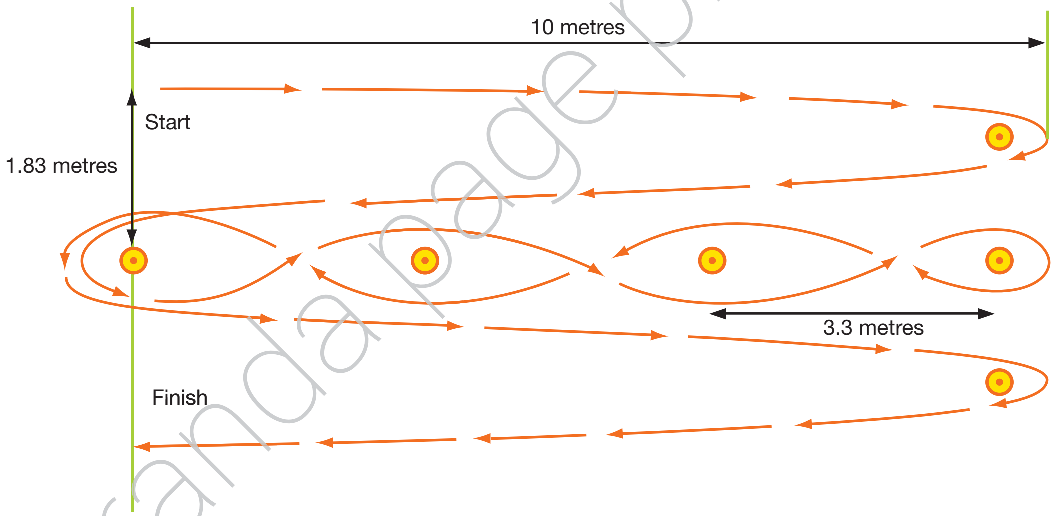

Figure 5.20: Field for agility test

6. The second subject records the time for completion of the course.
7. Allow two attempts, with recovery time between each. Then repeat the test for the second subject.
8. Check your agility rating, using table 5.14.

Table 5.14: Agility rating

Rating	Boys 16–17 years	Girls 16–17 years
Excellent	<15.2	<17.0
Very good	16.1–15.2	17.9–17.0
Average	18.1–16.2	21.7–18.0
Poor	18.3–18.2	23.0–21.8
Very poor	>18.3	>23.0

INQUIRY

Evaluating agility

1. Why do you think the test in the previous application may or may not be a good test of agility?
2. What other components of fitness will contribute to a good agility score?
3. Write a list of activities that you could use to improve your agility.
4. Are you satisfied with your rating?
   (a) If not, what do you believe contributed to this performance?
   (b) If so, to what do you attribute your success?
5. List five activities in daily life where agility is essential.
6. List five sports or activities in which above average levels of agility are essential.

Coordination

Coordination is the ability to harmonise the messages from the senses (such as sight, feel and sound) with parts of the body to produce movements that are smooth, skilful and well controlled.

Coordination requires good interaction between the brain and the muscles, resulting in efficient body movement. Coordination is important in games, in movements that require throwing and activities such as dancing. It is not a specific skill such as power or speed. Rather, we see it in the way a motor skill is executed. Performers whom we consider to be skilled, such as professional tennis players, exhibit excellent coordination. This contributes to the aesthetic quality of movement.

People who are well coordinated acquire new movements readily. As a result, they adapt quickly to learning new sports and activities. Well-coordinated players are less prone to accidents and injury when involved in physical activity.

Figure 5.21: Good coordination helps us to learn new motor skills quickly.

APPLICATION

Determining coordination

Equipment

Sticks (three per person per test), approximately 60 centimetres long, two centimetres in diameter and painted at one end

Procedure

The half-flip stick test

1. Work in pairs.
2. The first subject holds a stick in each hand at waist level so that the sticks are horizontal.
3. The second person places the third stick across the two hand-held sticks (figure 5.22(a)).
4. The first subject attempts to flip the stick so that it turns one half of a rotation and lands again balanced on the two hand-held sticks (figure 5.22(b)).

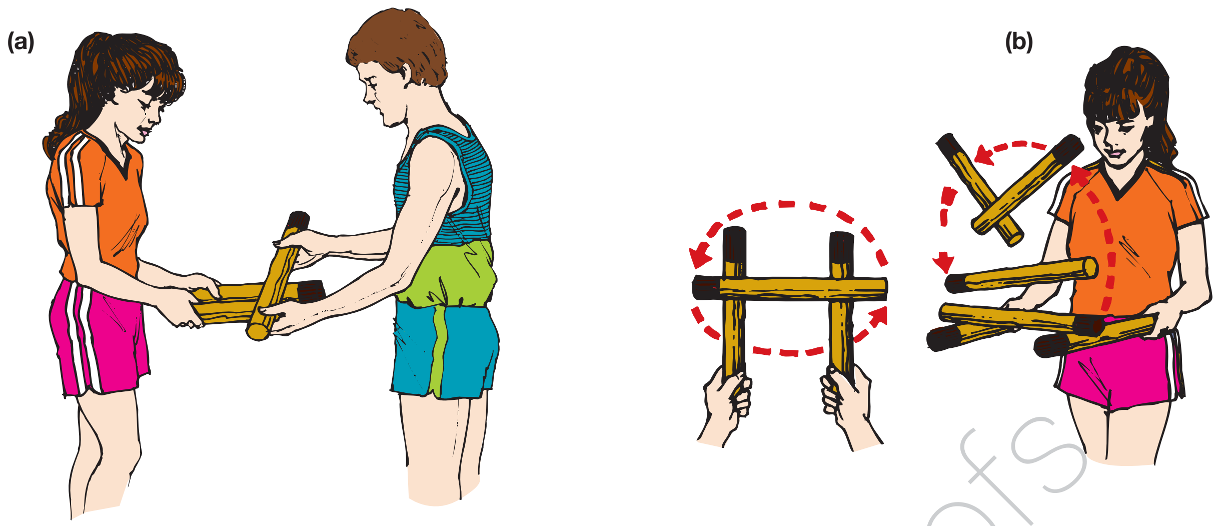

Figure 5.22: **(a)** Setting up the half-flip stick test; **(b)** flipping the sticks

Figure 5.23: Full-flip stick test

5. Allow three practice attempts.
6. In the test, the subject should attempt five half-flips. One point is scored for each successful attempt. The flip is unsuccessful if the stick is not flipped through the half rotation or is dropped.
7. Record the results of this test in table 5.15.
8. Repeat the test for the second subject.

Table 5.15: Record of flip test

Test 1	half flip	No. of successes from five attempts × one point: _____ × 1 = _____
Test 2	full flip	No. of successes from five attempts × one point: _____ × 1 = _____

The full-flip stick test

1. Repeat steps one, two and three of the half-flip stick test.
2. In this second test, a full flip is attempted. The stick must go through a full rotation and land balanced across the other two sticks (see figure 5.23).
3. Allow three practice attempts. Attempt five full flips and award two points for each successful attempt. Record your results.
4. Repeat the test for the second subject.
5. Tally your results for the two tests and find your coordination rating, using table 5.16.

Table 5.16: Stick test rating

Classification	Boys	Girls
Excellent	14–15 points	13–15 points
Very good	11–13 points	10–12 points
Fair	5–10 points	4–9 points
Poor	3–4 points	2–3 points
Very poor	0–2 points	0–1 point

Source: C. Corbin and R. Lindsay, op. cit.

INQUIRY

Evaluating coordination

1. Why do you think the stick test may or may not be a good test of coordination?
2. What other fitness components (for example, speed) may have contributed to your score?
3. In what way did you benefit (or not benefit) from the pre-test practice?
4. What is the relationship between practice and improved coordination?
5. List five sports or activities where coordination is important.
6. In what aspects of daily living is coordination important?

Balance

Balance is the ability to maintain equilibrium while either stationary or moving.

Balance is our ability to maintain equilibrium. It depends on our ability to blend what we see and feel with our balance mechanisms, which are located in the inner ear.

There are two types of balance: *static* and *dynamic*. Static balance means maintaining equilibrium while the body is stationary. Dynamic balance means maintaining equilibrium while the body is moving.

We use balancing skills virtually every moment of our lives. For instance, we are balancing while walking and running. However, in some situations, a higher degree of balance is required for the proper execution of the skill. The gymnast performing a handstand, the ballerina on her toes and the skier all need exceptional balance to execute their sporting skills.

Balance can be improved by practice. As a person learns to control their centre of gravity both when moving (as in running) and with a narrow base of support (as in a pirouette or handstand), balance improves. When the centre of gravity falls outside the base of support with stationary activities, balance is lost.

Figure 5.24: Balance is the ability to maintain equilibrium while standing or moving.

APPLICATION

Static balance

Equipment

Stopwatch, recording sheet

Procedure

1. Divide into pairs, one to perform the test and the other to time, judge and record the attempt.
2. The first subject removes his/her shoes and stands erect on a flat surface with hands on head.
3. One foot is then lifted and placed behind the calf of the other leg. At this point, the stopwatch starts.
4. The stopwatch is stopped when one or more of the events below occur:
   - the time on one leg exceeds 20 seconds
   - the foot comes away from the calf of the other leg
   - the hands come away from the head
   - the supporting foot changes position on the floor
   - the subject jumps.
5. Allow one minute's practice. Then record the best of three attempts on the right leg followed by the best of three attempts on the left leg. Record the total time.
6. Repeat the test for the second subject.
7. Determine your static balance rating using the **Static balance** weblink in your eBookPLUS.

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INQUIRY

Evaluating balance

1. What is the difference between static and dynamic balance?
2. Were you satisfied with your ratings in the two balance applications?
3. What problems did you have in trying to maintain balance in each of the tests?
4. Describe an activity in your daily life where balance is essential.
5. List three skills from a sport or activity that you participate in or have participated in that require a degree of balance.

Reaction time

Reaction time is the time taken to respond to a stimulus.

Reaction time is very important in sports such as sprinting, shooting and swimming. The stimulus could be a sound such as a starter's gun, a movement, or a target fired into the air. In each case, there is a period of time between the mind realising the presence of the stimulus and the body making the appropriate response.

The time taken between stimulus and response is called reaction time. It will vary from one person to another. Reaction time can be improved with practice and concentration. The average reaction time in human beings is 170 milliseconds. Successful athletes in sprint events will probably have faster reaction times due to practice.

Editor Note: 5 Line short

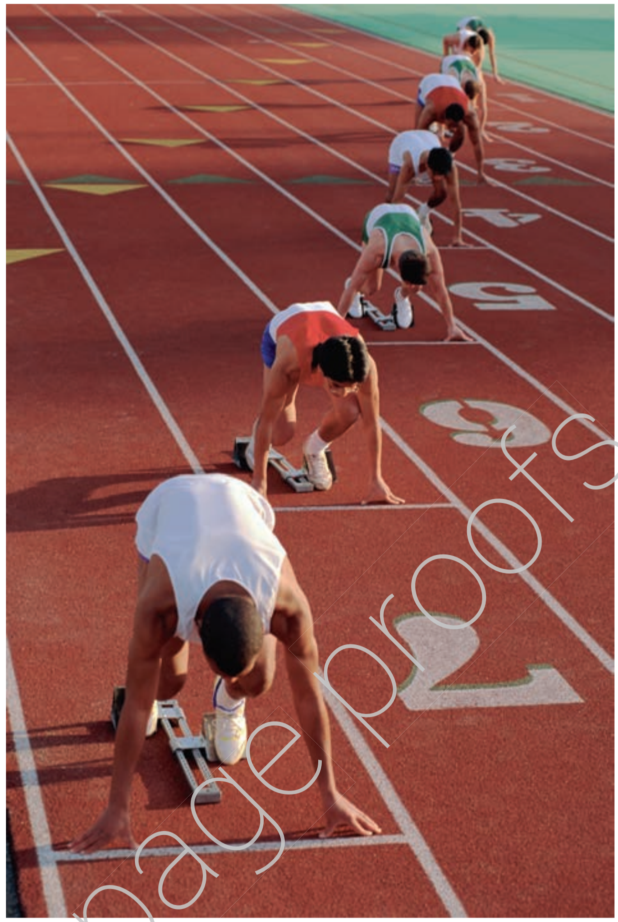

Figure 5.25: Reaction time is the time taken to respond to a stimulus.

APPLICATION

Determining reaction time — vision and hearing

TEST ONE

Equipment

One 1-metre ruler, desk and chair, recording sheets

Procedure

1. Divide into pairs. Nominate one person as the subject and the other to conduct the experiment and record the result.
2. The subject sits at the desk and places his or her preferred forearm across the desk so that the hand extends beyond the edge of the desk. Fingers and thumb point away and have a gap between them, approximately two centimetres wide.
3. The recorder stands beside the subject's hands and suspends the ruler just beyond the far edge of the desk. The bottom edges of the ruler should be level with the thumb and index finger of the subject.
4. After the recorder says 'ready' the ruler is dropped.
5. The subject should try to catch ruler. The score is read in centimetres and is the point at which the thumb and index finger grasp the ruler.
6. Allow three trials prior to testing. Then record three attempts and use the average value for assessment.
7. Repeat the test for the second subject.

8. Use table 5.17 to determine your reaction time rating.

Table 5.17: Reaction time rating

Classification	Ruler reading (cm)
Excellent	<7.5
Very good	7.5–15.9
Satisfactory	15.9–20.4
Fair	20.4–28.0
Poor	>28

TEST TWO

Equipment

As for test one

Procedure

As for test one. However, this time the subject's eyes are closed and only one hand is used at a time. The recorder should say 'ready' and then 'go' within a period of 10 seconds.

TEST THREE

Equipment

As for test one

Procedure

As for test one. However, this time the subject's finger and thumb are placed just against the side of the ruler with absolutely no pressure on the ruler itself. The recorder drops the rulers alternately as in test one, and the subject responds when the movement is felt.

TEST FOUR

Equipment

As for test one

Procedure

As for test one. However, this time the subject's eyes are closed and he/she responds to the words 'right' or 'left', describing which ruler is to be dropped. The subject has to interpret these data and respond by reacting with the correct hand.

INQUIRY

Evaluating reaction time

1. What is reaction time? How did your reaction time vary from one test to another?
2. List three sporting events where reaction time is important.
3. Describe three situations in your daily life where reaction time is important.
4. How can you improve your reaction time?
5. Why is reaction time important?
6. Good reaction time can play a significant part in avoiding car accidents. What may be the effect of the following conditions on reaction time:
   - a small amount of alcohol (say 0.04 per cent)?
   - a large amount of alcohol (say 0.10 per cent)?
   - a lack of sleep?
   - influenza?
   - caffeine?

INQUIRY

Fitness test comparisons

eBook*plus*

Use the **Fitness tests** weblink your eBookPLUS to access a website showing some well-known tests of fitness.

Scroll to *Tests for fitness components*. Open the link to each of the recognised tests and input your own results in the assessment area. Was your assessment much the same as those you calculated yourself? If there was considerable variation, explain why this might occur.

INQUIRY

Fitness components

1. Summarise what you have learned about the components of physical fitness by copying and completing a web diagram similar to the one in figure 5.26.
2. For each component of physical fitness, give an example illustrating how it applies to a particular physical activity or sport.

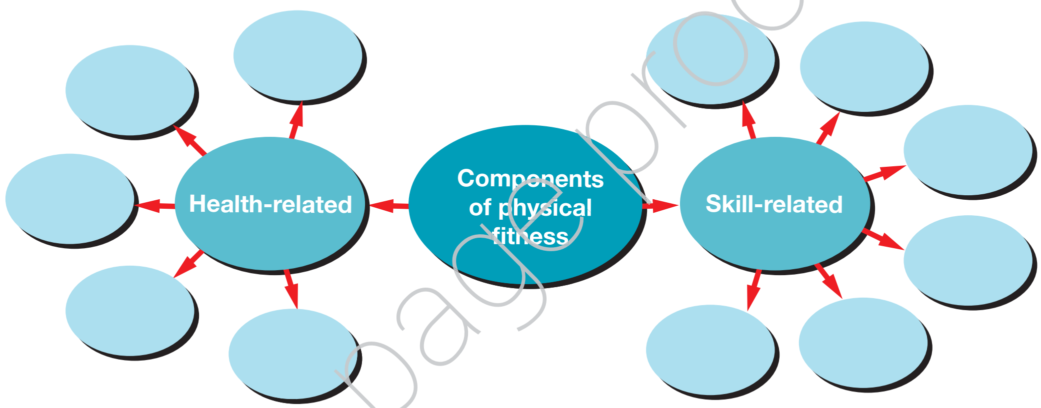

Figure 5.26: Web diagram for the components of physical fitness

APPLICATION

Compiling my physical fitness profile

Equipment

Results and classification of each physical fitness component tested in the applications on pages 178–201, recording sheet (figure 5.27, page 203)

Procedure

1. In red pen, place a circle in the appropriate column on the recording sheet that best indicates your rating for each of the physical fitness tests. Join the circles, thus plotting a graph.
2. Using another coloured pen, assess your chosen sport or activity and graph the fitness requirements for it from the information you have learned in this chapter.
3. Compare the two graphs and answer the questions in the following inquiry.

INQUIRY

My physical fitness profile

1. (a) Which fitness components fall below the requirements of your chosen sport or activity?
   (b) Which fitness components for which you tested were better than the basic fitness requirements for your chosen sport or activity?

2. Analyse the differences (if any) between the two graphs. What do you think this profile is attempting to show?
3. Design a program to:
   (a) maintain the fitness components that meet the requirements of your sport or activity
   (b) improve those areas that fell below the requirements of your chosen sport or activity.

INQUIRY

Fitness as a predictor of performance

Use the following table to assist you in examining the question: 'To what degree is fitness a predictor of performance?'

The fitness components are listed in the left column and a range of activities are listed in the centre column. Examine each of the listed activities and identify the amount of each fitness component that you believe to be necessary for movement efficiency (smoothness/aesthetically pleasing/coordinated) and good performance.

Your answer in the right column will include your selection of the most important fitness components for each activity and an analysis of why each component has been selected.

Fitness components	Activity	Your analysis
Cardiorespiratory endurance Muscular strength Muscular endurance Flexibility Body composition Power Speed Agility Coordination Balance Reaction time	Surfing	
	Marathon running	
	Weight lifting	
	High jumping	
	Sprinting	
	Basketball — guard	

INQUIRY

The purpose and benefits of testing physical fitness

Use the following ranking chart to explore the benefits of testing physical fitness. Ten benefits are listed below. Rank the benefits by writing in the column on the left. Use the right column to explain each benefit and justify its ranking.

Benefits:

- predict future performance
- place in appropriate training group
- indicate strengths
- indicate weaknesses
- identify special talents
- monitor progress
- measure improvement
- training program evaluation
- provide incentives
- motivate the athlete

Physical fitness profile					
Name			Chosen sport		
	Very low/ very poor	Low/poor	Medium/average	High/very good	Very high/excellent
HEALTH-RELATED FITNESS					
Cardiorespiratory endurance					
Bicycle ergometry					
Multistage fitness					
Muscular strength					
Hand dynamometer					
Muscular endurance					
Sit-up test					
Flexibility					
Sit and reach					
Body composition					
Body fat percentage					
SKILL-RELATED FITNESS					
Power					
Vertical jump test					
Speed					
Sprint test					
Agility					
Agility test					
Coordination					
Stick test					
Balance					
Static balance					
Dynamic balance					
Reaction time					
Reaction time test					

Figure 5.27: Recording sheet

Ranking	Explanation of benefit and justification of ranking

AEROBIC AND ANAEROBIC TRAINING

An **energy pathway** is a system that converts nutrients to energy for exercise.

Anaerobic means 'in the absence of oxygen'.

Aerobic means 'with oxygen'.

Training programs aim to develop a range of fitness components together with skill development, moves and strategies. To develop an effective training program it is necessary to identify the correct **energy pathway** or body system that converts nutrients to energy.

- If we perform short sharp movements as in jumping and lifting, the body uses the **anaerobic** pathway (oxygen is absent) to supply energy.
- If movements are sustained and of moderate intensity, the **aerobic** pathway (with oxygen) supplies the bulk of energy needs.

We therefore need to closely examine the exact type of movements that will be performed in the game or activity for which we are training. This allows us to select training activities that develop the correct energy source, be it aerobic, anaerobic or a combination of both.

Aerobic training

The word aerobic means 'with oxygen'. Aerobic exercise refers to exercise that is dependent on oxygen utilisation by the body to enable muscular work. Activity that is of low to moderate intensity and continues for 90 seconds or more is generally termed aerobic because oxygen becomes available to the cells of working muscles for energy generation. Walking, marathon running and the 1500 metres in swimming are examples of activities that require a high degree of aerobic fitness.

To improve aerobic fitness we need to:

- engage in activities that are continuous and of long duration. Cross-country running, sand-hill running, cycling and jogging are examples of activities that develop our aerobic energy system.
- use the **FITT** (frequency, intensity, time, type) principle to provide guidance in developing an aerobic program to suit our needs. The principle provides guidelines for individuals who aim to improve cardiorespiratory fitness and some forms of resistance training.

FITT is an acronym for frequency, intensity, time and type. It embodies a fitness principle that ensures a program has the quantity and quality of movement necessary to produce the desired physical improvement.

Figure 5.28: Sustained effort at moderate intensity underlies aerobic training.

FITT principle

Frequency

An **adaptation** refers to an adjustment made by the body as a result of exposure to progressive increases in the intensity of training.

For improvements to occur, individuals must train on at least three occasions per week. This can be increased to five, but the benefit to be gained from sessions in excess of this is minimal.

The aim is for a training session to sufficiently stress body systems, causing a response called an **adaptation**. This is an adjustment (for example, better utilisation of oxygen by cells) made by the body as a result of exposure to progressive increases in the intensity of training. For resistance training, three sessions are sufficient while four is maximal, allowing rest days in between for muscle fibres to regenerate.

Intensity

Intensity refers to the amount of effort required by an individual to accrue a fitness benefit.

Target heart rate zone is an area surrounding the target heart rate and is calculated using percentages of maximal heart rate.

Intensity refers to the amount of effort required by an individual to accrue a fitness benefit. The most accurate way of measuring intensity during aerobic exercise is by calculating your target heart rate and using this as a guide. The target heart rate together with the area above and below is called the **target heart rate zone**. When exercising, the level of intensity needs to be sufficient to keep the heart rate within the target heart rate zone for the required period of time. This is illustrated in figure 5.29. Here a person progresses from rest, through a warm-up and into the target heart rate zone where a steady state level of intensity is maintained for an extended period of time.

The level of intensity is established in terms of heart rate, which is calculated in beats per minute (bpm). There are two important steps that need to be taken to calculate your target heart rate zone.

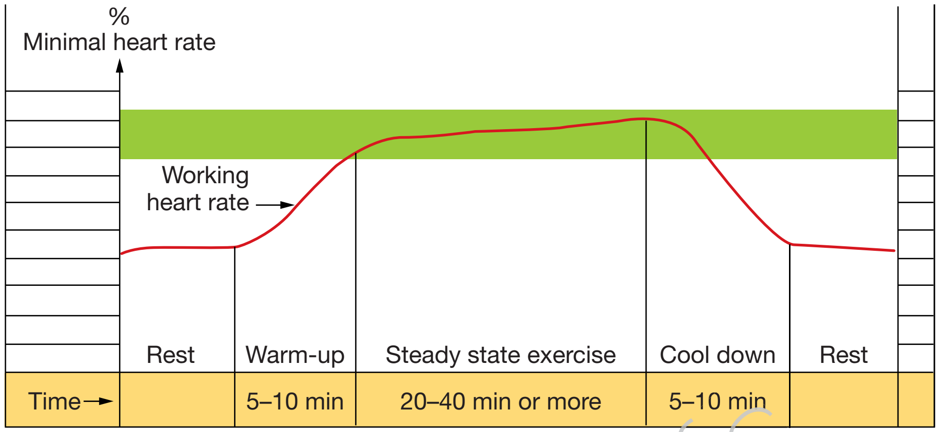

Figure 5.29: The intensity of exercise when applying FITT is moderate, sustained and within the target heart rate zone.

1. *Determine your maximum heart rate.* To do this, simply subtract your age from 220. Hence, a 20-year-old person would have a maximum heart rate of 200 beats per minute.
2. *Determine the percentage of your maximal heart rate relevant to your fitness.* If your fitness is poor, work at 50 to 70 per cent of your maximum heart rate. If your fitness is good, work at 70 to 85 per cent of your maximum heart rate. If uncertain, work at the lower level and gradually increase the level of intensity.

As an example, take a 20-year-old person of average fitness who wants to establish their training zone. Their maximal heart rate is 200 bpm, calculated by subtracting their age from 220. Using the figure 200 bpm, they calculate their lower level of intensity which is 140 bpm (70 per cent of 200) and an upper level which is 170 bpm (85 per cent of 200). The training zone is the area in between, which is from 140 bpm to 170 bpm. Figure 5.30 shows the target

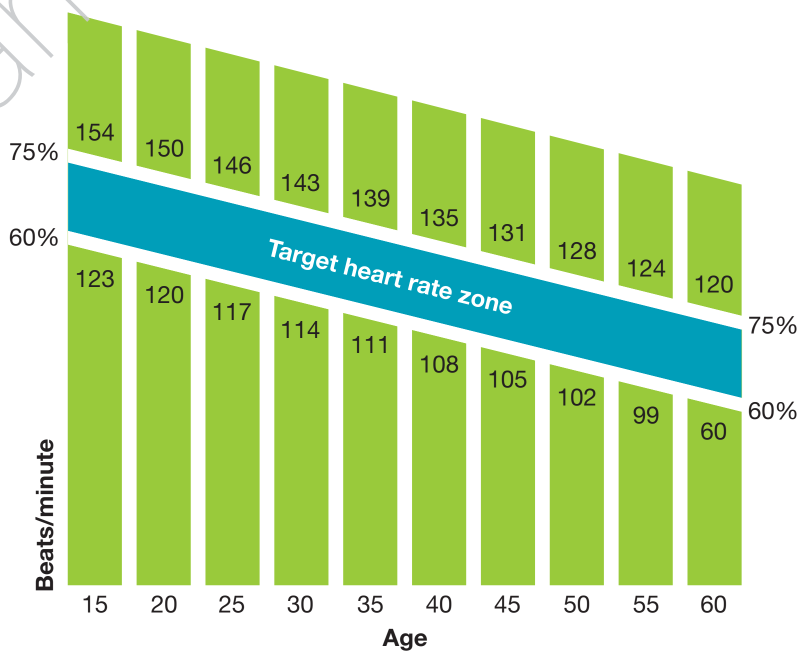

Figure 5.30: The target heart rate zone varies according to age.

heart rate zone for various age groups, based on 60 to 75 per cent maximal heart rate.

In resistance training programs, intensity is established in a number of ways but usually by varying the load, the number of times you perform an exercise (repetitions), the sets (a number of repetitions in succession) or the rest period.

Time

For people in good health, a session in which the heart rate is held in the target heart rate zone should last from 20–30 minutes and increase to 40 minutes or more if possible. There is little sense in exercising for periods longer than 60 minutes or to exhaustion as this carries the risk of overtraining and the possible development of overuse injuries (elite athletes excepted). For those beginning a program or those with lower levels of fitness, the starting point should be around 15 minutes. Note that this does not include time used to warm up and cool down.

In terms of duration, six weeks is the minimal period for the realisation of a training effect; that is, for adaptations to have taken place. In resistance training programs, 30–45 minutes is generally sufficient and will depend on the intensity of exercise.

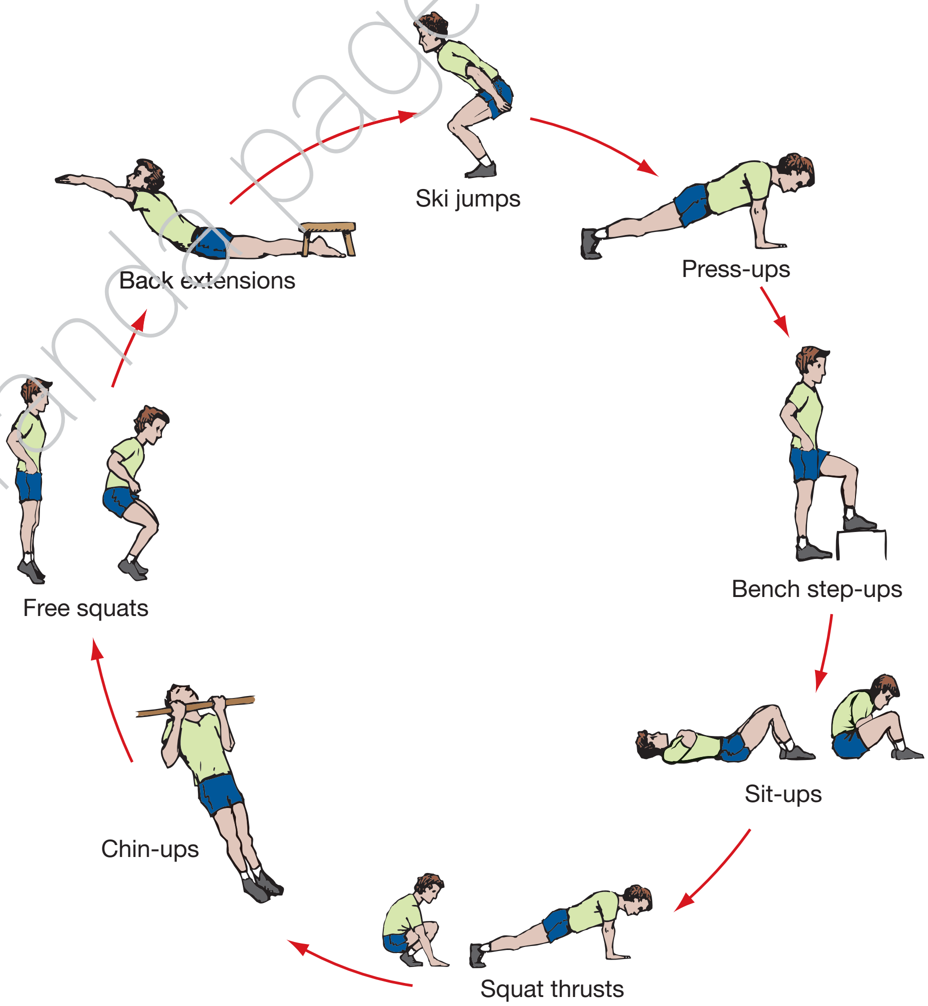

Figure 5.31: Circuits are an excellent way of improving aerobic fitness.

Type

The best type of exercise is continuous exercise that uses the large muscle groups. Running, cycling, swimming and aerobics are examples of exercises that utilise large muscle groups. These draw heavily on our oxygen supply, necessitating an increased breathing rate, heart rate and blood flow to the working muscles. Our aerobic fitness improves as the cardiorespiratory system adapts in response to the demands being made on it.

Circuit training requires participants to perform set exercises at a number of stations, working through the course in the shortest period of time.

For resistance training, low resistance with high repetitions is preferable and this can be provided using many activities such as **circuit training** and resistance bands.

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To see examples of how *type* can be varied to improve all-round fitness, use the **Circuit training** weblink in your eBookPLUS.

APPLICATION

Aerobic training and the FITT principle

Choose any aerobic activity, particularly a sport or game that you play. Design a training session for this sport or activity based on the FITT principle. Ensure your session addresses the following:

- warm-up
- fitness work (show activities that incorporate FITT. Draw a chart similar to the one in figure 5.31 to show how you anticipate your heart rate to respond to your fitness activities.)
- skills and strategies (small section)
- cool down.

eBook*plus*

You can find examples of aerobic activities by using the **Aerobics** weblink in your eBookPLUS.

Discuss your session with the class. Then have the class choose one session that would be challenging, interesting and convenient to run. Allow the student who designed this session to conduct it with the class.

Evaluate how well you think the session applied the principles of intensity, time and type.

Anaerobic training

Anaerobic means 'in the absence of oxygen'. In anaerobic activity, the intensity level is much higher and the effort period much shorter than required in aerobic activity.

In general, activity that lasts for two minutes or less and is of high intensity is called anaerobic because muscular work takes place without oxygen being present. When we sprint for example, the muscles respond instantly and quickly exhaust any fuel reserves in the working muscles. Our increased breathing rate delivers more oxygen to this area, but it is some time before it arrives as there is a limit to the speed of blood flow and therefore oxygen transport. Fortunately these muscles are able to use a restricted amount of stored and other fuel until oxygen becomes available.

Anaerobic exertion requires specialised training to generate the adaptations necessary for muscular work without oxygen. Training enhances the ability of muscle cells to improve their use of fuel reserves and be more efficient in converting blood sugar to energy during intense exercise.

It should be noted that anaerobic training generally requires an aerobic foundation, particularly in activities like sprinting and swimming. Other more spontaneous activities such as diving, vaulting and archery require a minimal aerobic base.

Figure 5.32: Explosive movements are enhanced through quality anaerobic training programs.

To improve anaerobic fitness, we need to:

- work hard at performing and enduring specific anaerobic movements such as lifting weights, throwing or jumping
- practise the required movements at or close to competition speed to encourage the correct adaptations to occur
- use activities such as interval training where periods of intense work are interspersed with short rests to train the anaerobic system to supply sufficient fuel
- utilise resistance (weight) training exercises to further develop the muscles required for the movement
- train to improve the body's ability to recharge itself; that is, to decrease recovery time after short periods of intense exercise
- train to improve the body's ability to tolerate higher levels of lactic acid, a performance use crippling substance that builds up in the muscles following intense exercise
- gradually develop the body's ability to utilise and/or dispose of waste that is created by intense exercise.

Table 5.18 summarises the basic differences between aerobic and anaerobic training programs.

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Table 5.18: Differences between aerobic and anaerobic training programs

Feature	Aerobic	Anaerobic
Goals	Improved stamina, endurance, lung capacity, cardiorespiratory endurance	Development of force, power, body mass and speed
Warm-up	General, short, low intensity exercise. Cool down essential	Sustained (20 minutes or more), gradual increase in intensity, must be specific to muscles required in activity
Activities	Targets endurance type activities: marathon running, cycling, 1500 metre swimming, power walking, kayaking, triathlon together with the sustained phases of games	Targets explosive type activities: track 100, 200 and 400 metre, swimming 50 and 100 metre, diving, weight-lifting, discus, javelin, shot-put and the sprint phases in games
Targeted fitness components	Cardiorespiratory endurance, muscular endurance, body composition	Speed, power, agility
Resistance training	High repetition, weights with low resistance, circuits	Low repetition weights, high resistance, fast plyometrics
Physical benefits	Improved cardiovascular system and ability to endure performance	Strength, power and speed gains, increased local muscle recovery ability
Health benefits	High	Low to medium
Liabilities	Possibly decreased muscle mass, speed and power	Possibly decreased cardiorespiratory function unless supported by an aerobic program
Foundation	Does not require anaerobic foundation	Requires an aerobic foundation, but varies according to sport

A quality training program should encompass fitness activities that directly address the requirements of the selected sport or activity. Some sports require a high level of aerobic fitness and a general level of anaerobic fitness while the reverse is true of others. Games such as touch football, soccer and netball are characterised by periods of moderate intensity interspersed with periods of high intensity.

While the amount of aerobic/anaerobic fitness varies according to the game, it is also affected by the position of the player, each individual's effort and their base fitness level. The sprint in rugby, rally in tennis and man-to-man defence in basketball are all highly demanding, causing muscles to use available fuel and then requiring cells to find other sources for energy supply.

The change between aerobic and anaerobic energy supply is gradual rather than abrupt. When engaged in activity, the body switches between systems according to the intensity of exercise, with one system being predominant and the other always working but not being the major supplier of energy. A sprint during a touch football game requires anaerobic energy due to the instant and heavy demands made on the muscles involved in the movement. During this period, the aerobic system is still functioning, but is not the major energy supplier. When we think aerobic or anaerobic training, we therefore need to think in terms of which system will predominate and the time for which it will be engaged.

INQUIRY

Aerobic versus anaerobic training

1. Listed below are six sports that may be predominantly aerobic or predominantly anaerobic. Complete the following table by comparing features that make training for each sport different. Think in terms of warm-up, time, distance, resistance work, activity types, duration, intensity, sessions per week and so forth.

Aerobic training	Anaerobic training
Triathlon • • • • •	Sprinting • • • • •
Soccer • • • •	Gymnastics • • • •
1500 metre swim • • • •	Javelin throw • • • •

2. Compare the relative importance of aerobic and anaerobic training for different sports.

IMMEDIATE PHYSIOLOGICAL RESPONSES TO TRAINING

Immediate physiological responses are the changes that take place within specific body organs and tissue during exercise. These changes are particularly observable in capacities directly related to performance, including heart rate, cardiac output, stroke volume, lactate levels and ventilation rate. When we increase our level of activity during training, the body makes specific changes to ensure that adequate oxygen and nutrients are being supplied to the muscles to meet the increase in demand. For example, aerobic exercise can require an increase in blood flow of 20 per cent or higher to the working muscles. The important responses to training are outlined below.

Heart rate

Heart rate is the number of times the heart beats per minute (bpm).

Changes in **heart rate** are the most obvious and easy to measure. Our *resting heart rate* is our heart rate when we are completely at rest. While the average resting heart rate is 72 bpm, readings of 27 to 28 bpm have been recorded in champion endurance athletes. A low resting heart rate is indicative of a very efficient cardiovascular system.

Heart rate increases with exercise. This is our *working heart rate*. Our heart rate increases according to the intensity of our exercise effort. Maximal heart rates are observed during exhaustive exercise.

During short-term (five to 10 minutes), moderate exercise or when moving from an inactive to an active state, our heart rate rises sharply. This is illustrated in figure 5.33.

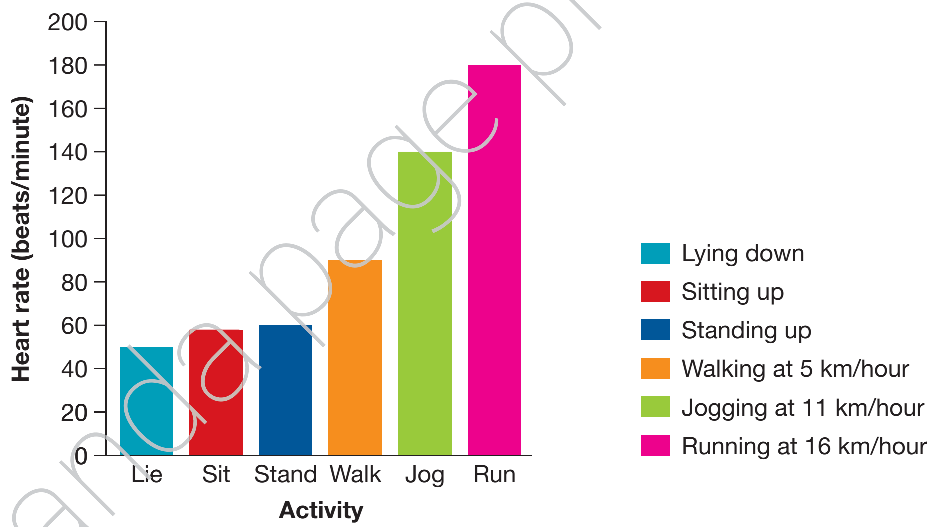

Figure 5.33: The effect of varying activities on heart rate (*Source:* J. H. Wilmore and D. L. Costill, *Physiology of Sport and Exercise*, 3rd edn, 2004, p. 230, figure 7.15a © 2004 by Jack H. Wilmore and David L. Costill. Adapted with permission from Human Kinetics, Champaign, IL.)

Steady state is a period of time during which oxygen uptake remains at a uniform level, such as swimming at a constant speed.

In a fit person, heart rate levels off during protracted exercise, reaching a **steady state**. For an unfit person, heart rate continues to rise gradually as exercise is prolonged. For both groups, cessation of exercise causes a quick decline in heart rate, followed by a slower decline as it returns to the pre-exercise level. This decline is rapid in a fit person. However, for an unfit person, it may take some time, even hours. Heart rate is therefore a good indicator of the intensity of exercise and may be used as a fundamental measure of a person's cardiovascular fitness.

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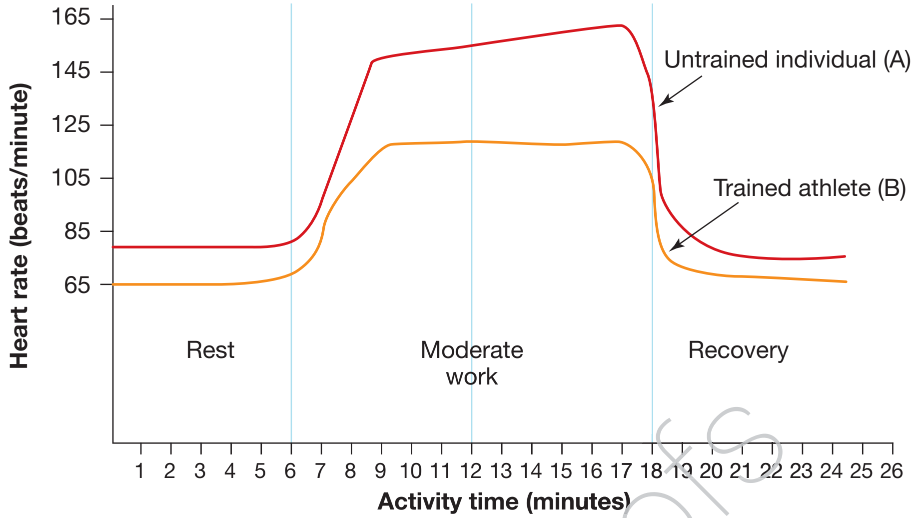

Figure 5.34: Heart rate response before, during and after moderate exercise

INQUIRY

Heart rate graph

On a graph, plot the heart rate (HR) for a 16-year-old subject with a resting HR of 55 bpm who performs the following activities over one hour: rests for 10 minutes, runs for 30 minutes at 70 per cent maximal heart rate (MHR), followed by three 100-metre sprints at 90 per cent MHR with intervals of five minutes between each. How does the heart respond to changes in exercise intensity?

Ventilation rate

Ventilation refers to our depth and rate of breathing and is expressed in breaths per minute.

When we begin to exercise, the demand for more oxygen by the muscle cells causes a **ventilation** response. Ventilation has two phases — *inspiration*, or breathing air into the lungs, and *expiration*, or the expulsion of air from the lungs. Ventilation rates are measured over a time period, usually one minute. A term commonly used is *minute ventilation* — that is, the amount of air that can be breathed in one minute. For most people this is around six litres.

During rest, the ventilation rate is about 12 breaths per minute, causing the lungs to consume around 500 millilitres of air per breath. Exercise causes many immediate adjustments in the workings of the respiratory system. The rate and depth of breathing increases moderately, even before exercise begins, as the body's nervous activity heightens in anticipation of exercise. Once exercise starts, the rate and depth of breathing intensifies. This is matched by an increase in oxygen consumption and carbon dioxide production, triggering elevated respiratory activity. At the end of exercise, breathing remains rapid for a short period of time, then gradually abates, finally returning to resting levels. Changes in ventilation rates between rest and steady state exercise are illustrated in figure 5.35.

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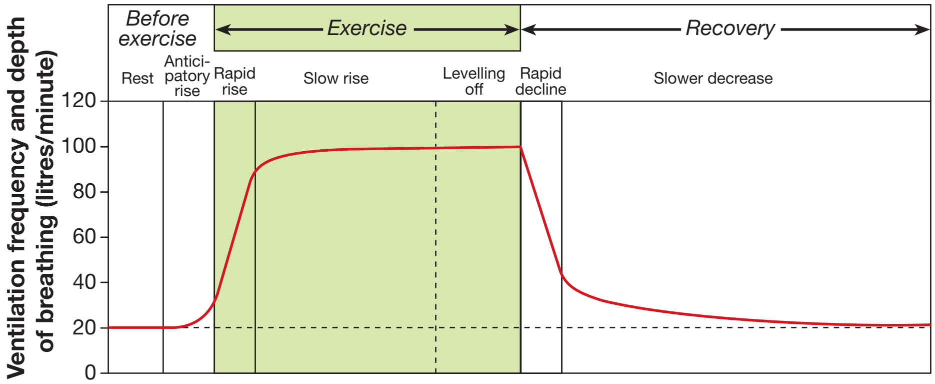


Figure 5.35: Changes in ventilation rate during moderate exercise (*Source:* D. K. Mathews and E. L. Fox, *The Physiological Basis of Physical Education and Athletics*, W. B. Saunders, Philadelphia, 1976, p. 168. Reprinted with permission, McGraw-Hill Companies.)

Stroke volume

Stroke volume is the amount of blood ejected by the left ventricle of the heart during a contraction. It is measured in mL/beat.

When exercise increases, the amount of blood that the heart discharges increases considerably. Much of this is due to an increase in **stroke volume**.

Stroke volume is determined by:

- the ability to fill the ventricles by blood volume
- the ability to empty the ventricles as a result of ventricular contractions.

Stroke volume increases during exercise, with most of the increase being evident as the person progresses from rest to moderate exercise intensity. As intensity increases to a high level, there is less change in stroke volume. The magnitude of the increases is depicted in figure 5.36.

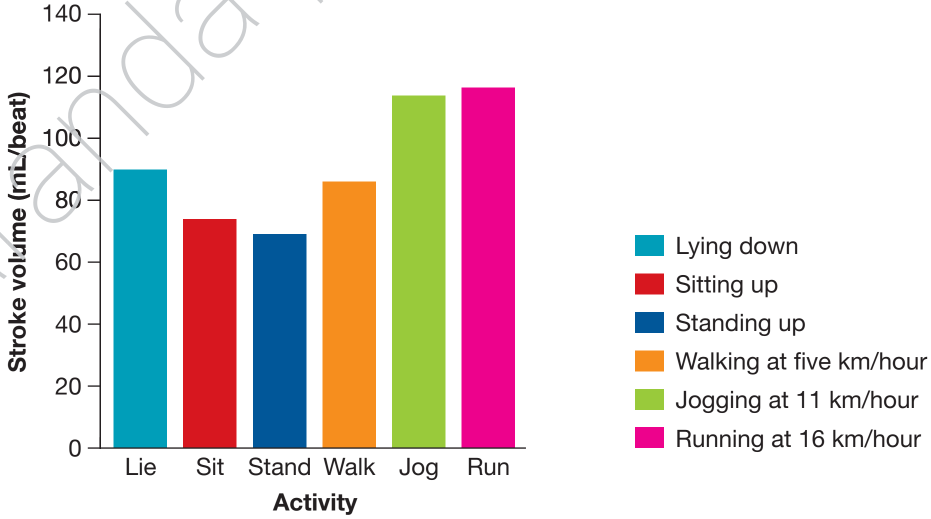


Figure 5.36: Stroke volume increases as activity increases. (*Source:* J. H. Wilmore and D. L. Costill, op. cit., figure 7.15b, p. 230.)

There is a significant difference in stroke volume between fit and unfit people. Whereas the sedentary person will maintain a stroke volume of 60 to 80 mL/beat, the well-trained athlete will reach 160 mL/beat at submaximal workloads. This large increase in the availability of oxygenated blood to the working muscles explains their superior performances. The differences are illustrated in table 5.19.

Table 5.19: Typical stroke volumes for different states of training

Subjects	SV rest (mL)	Maximum SV (mL)
Untrained	50–70	80–110
Trained	70–90	110–150
Highly trained	90–110	150–>220

Source: J. H. Wilmore and D. L. Costill, op. cit., p. 277.

It should be noted that the increase in stroke volume occurs as a result of more blood returning to the heart. This promotes a more forceful contraction and a more complete emptying of the left ventricle with each beat. A fit person usually has a greater stroke volume at rest and a significantly greater stroke volume during exercise than an unfit person. The relationship between increases in heart rate (intensity) and stroke volume is illustrated in figure 5.37.

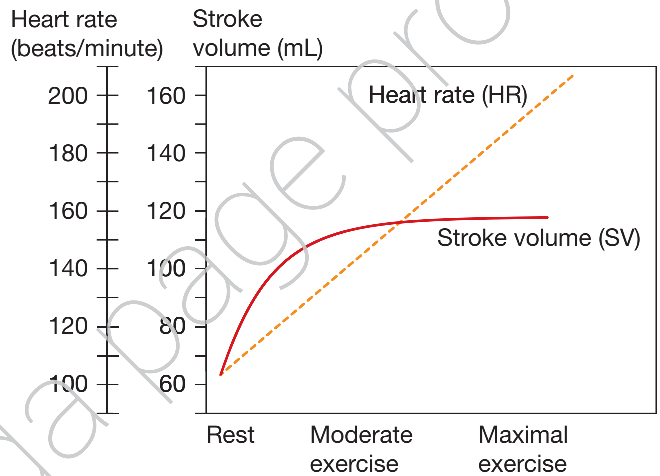


Figure 5.37: Increases in stroke volume and heart rate as a result of exercise (*Source*: Based on information from *Sports Physiology*, 2nd edition, Edward L Fox, Saunders College Publishing, pp. 184–5, Figs 8.12 and 8.13.)

INQUIRY

Heart rate and stroke volume

Examine figure 5.37. Using the information, discuss the effects of an increase in exercise on both heart rate and stroke volume.

Cardiac output

Cardiac output is the amount of blood pumped by the heart per minute.

Cardiac output increases with exercise in the same way as stroke volume. Cardiac output is a product of heart rate and stroke volume. It can be calculated in the following way:

Cardiac output (CO) = heart rate (HR) × stroke volume (SV).

If an athlete's HR is 60 bpm and their SV is 100 mL/beat, their CO is worked out in the following way:

CO = 60 bpm × 100 mL/beat
= 6000 mL/min (6 litres/min).

Cardiac output increases in response to physical demands being made on the body. Figure 5.38 shows how progressing from lying down to running causes significant increases in cardiac output.

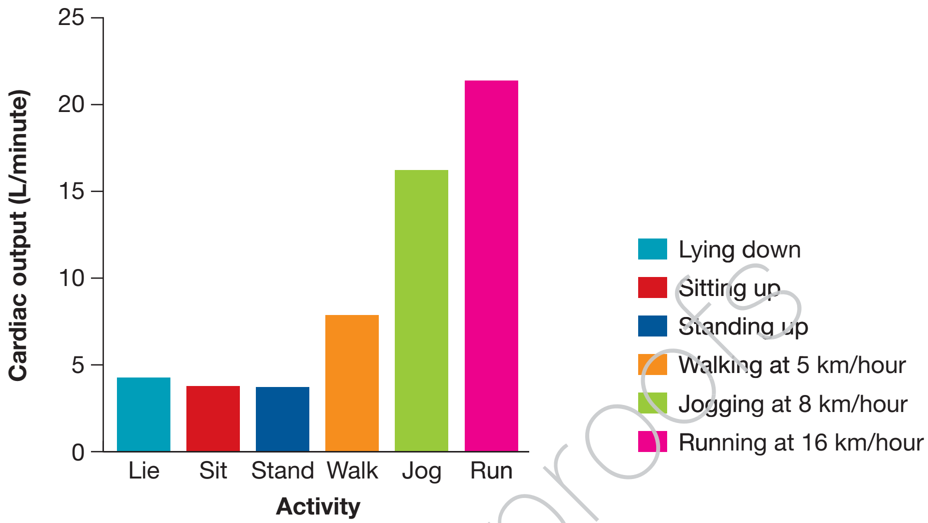


Figure 5.38: Cardiac output increases as exercise demands increase. (*Source:* J. H. Wilmore and D. L. Costill, ibid., figure 7.15c, p. 230.)

The working muscles' demand for additional oxygen causes blood flow to be redistributed within the body. While at rest, cardiac output is directed to physically inactive muscles. However, the demands of exercise mean that the body's blood must be redirected to the muscles that are now active. As shown in figure 5.38, muscles can demand around 84 per cent of blood flow during exercise.

Cardiac output for both trained and untrained people is approximately five litres per minute. This is despite trained athletes having lower resting heart rates and therefore not ejecting blood from the heart as frequently as untrained people. While the heart rate of the trained athlete is lower, their stroke volume is substantially higher.

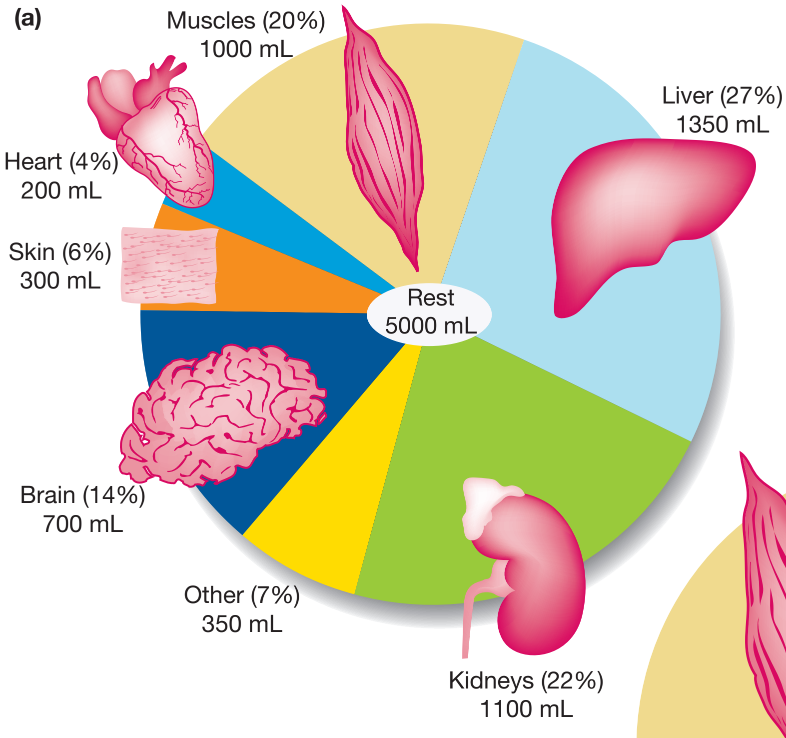
Examine the figures in the table at the top of figure 5.39. While trained and untrained people have similar cardiac output, differences are evident in the lower heart rate and higher stroke volumes of trained athletes.

The immediate response to training indicates noteworthy differences between the two groups. While untrained people are able to increase cardiac output to around 20 to 22 litres per minute during exercise, highly trained endurance athletes will have an increase in the vicinity of 35 to 40 litres per minute. In addition, this increase is achieved at a slightly lower maximal heart rate.

APPLICATION

Calculating cardiac output

Calculate the cardiac output at maximal exercise for a person with a heart rate of 190 bpm and a stroke volume of 180 mL/beat. Draw a chart to illustrate cardiac output and comment on the lifestyle of the subject. Do they have a sedentary lifestyle or are they a trained athlete?



Trained	Untrained
CO = HR × SV	CO = HR × SV
= 50 bpm × 100 mL/beat	= 72 bpm × 70 mL/beat
= 5000 mL/min (5 litres)	= 5040 mL/min (5.04 litres)

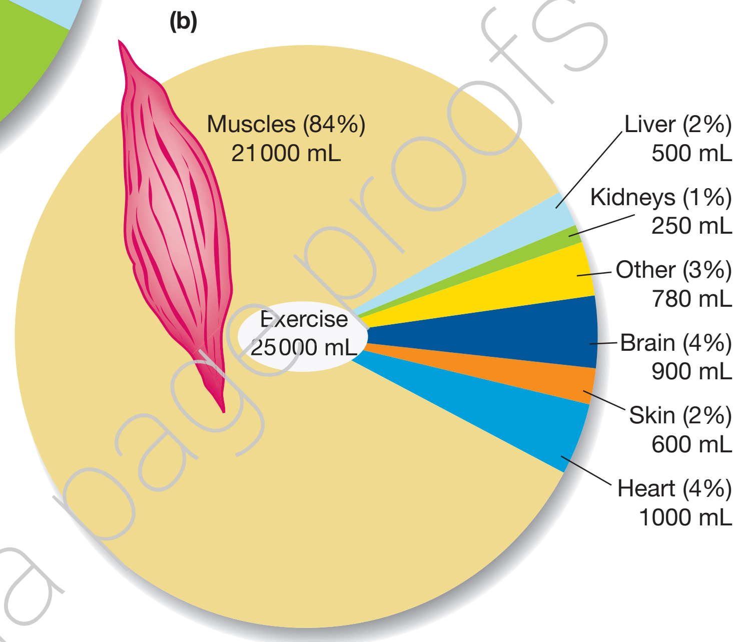


Figure 5.39: As we move from **(a)** rest to **(b)** exercise, cardiac output is redirected to active muscles. (*Source:* W. McArdle, F. Katch and V. Katch, *Exercise Physiology*, Lippincott, Williams and Wilkins, 2006, p. 357. Reproduced by permission.)

Lactate levels

Lactate is a salt formed from lactic acid that accumulates during intense anaerobic activity.

Hydrogen ion (or H+) is a hydrogen atom that has lost its electron, the concentration of which determines the pH of a solution.

Lactate is a chemical formed during the breakdown of carbohydrates in the absence of sufficient oxygen. There is always a small amount of lactate circulating in the blood — about 1–2 millimoles/litre. This lactate is continually being resynthesised by the liver to form glycogen and so is of benefit in providing the body with energy.

Generally, lactate flows freely in the blood and its concentration increases as the workload is increased. With each molecule of lactate formed, one **hydrogen ion** is also formed. It should be noted that it is the hydrogen, and not lactate, that is responsible for increasing the acidity of blood and subsequently making it difficult for muscles to function properly.

Vigorous physical exercise causes increases in levels of lactate. Lactate levels relate to the pH value of blood, which is affected by physical activity. Neutral pH is 7.0. A higher reading indicates elevated alkalinity, while readings lower than 7.0 reveal gradations of acidity. At rest, blood has a pH value of about 7.4, which means that it is slightly alkaline. However, as exercise intensity increases, the pH level drops and acidification of muscles increases.

High levels of lactate are produced when we exercise and there is insufficient oxygen available to the muscle cells. It accumulates rapidly when we exercise above the **lactate inflection point (LIP)**, which occurs at about 80–90 per cent MHR for trained athletes. The point is much lower for untrained athletes.

The **lactate inflection point (LIP)** is a point beyond which a given power output cannot be maintained. It is characterised by lactic acid accumulation and decreased time to fatigue.

Table 5.20 illustrates that lactic acid concentrations increase as exercise intensity is raised. High levels of lactate make it increasingly difficult for muscle fibres to contract. Once the LIP is reached, further exercise results in fatigue and the subsequent inability to maintain the higher work output. If intensity is increased beyond the LIP, such as by a sprint finish at the end of an endurance event, the onset of fatigue will be even more rapid.

Table 5.20: The effect of increasing intensity on blood lactate levels

Lactic acid concentrate (mmol)	Training for:	Heart rate	Percentage of maximum intensity
20.0	Maximum anaerobic power	200	
		200	
12.0		200	85–90%
8.0	Lactate inflection point	190–200	80–90%
		180	
		170	
		160	(60)–70–85%
4.0		150	
		140	
2.0	Aerobic threshold	130	60%
		120	50%
	Lactate threshold	110	
		100	
1.1	Resting state	>80	

Source: Adapted from T. Bompa, *Theory and Methodology of Training*, 3rd ed, Kendall/Hunt Publishing, Iowa, 1994, p. 305.

Although present, lactate does not cause fatigue prior to the LIP being reached. Lactate is a source of energy at low to moderate levels of intensity. However, once the LIP is reached, lactate contributes to fatigue because it cannot be removed from the bloodstream faster than it enters. The high concentration of lactate together with other factors, including high levels of hydrogen ions and the physical demands of the work being performed, contribute to fatigue and the subsequent inability to continue to work in the same manner as before the LIP was reached.

APPLICATION

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Changing patterns of respiration and heart rate

1. Use the **Home Step** weblink in your eBookPLUS to download the procedures for the Home Step Test.
2. Divide into groups of three. Choose one student to perform the test, the second to monitor and record heart rate and the third to monitor and record ventilation rate. The heart rate and ventilation rates for each student will be required before, at the conclusion of and then three minutes following the test. This should be recorded in table 5.21.

3. Students should perform the test on a rotational basis, swapping roles between performer and recorder. At the required times, measure heart rate and ventilation rate for 15 seconds and multiply by four to establish rates per minute.
4. Use the website to establish your fitness level and then use the additional information in the table to discuss questions in the following inquiry.

Table 5.21: Heart and ventilation rates

	Before test	End of test	Three minutes following test
Student 1			
Heart rate (bpm)			
Ventilation rate			
Student 2			
Heart rate (bpm)			
Ventilation rate			
Student 3			
Heart rate (bpm)			
Ventilation rate			

INQUIRY

Changing patterns of respiration and heart rate

1. Use the information in table 5.21 to draw a graph that illustrates your pattern for ventilation and heart rate.
2. Discuss reasons for the changing patterns of respiration and heart rate during this submaximal test.
3. Discuss the relationship between your fitness level as established by the test and how quickly your heart rate and ventilation rate returned to normal.

SUMMARY

- Physical fitness implies the ability to work or play without experiencing undue fatigue while having enough energy in reserve for basic movements, emergencies and activities of interest.
- Health-related components of physical fitness include cardiorespiratory endurance, muscular strength, muscular endurance, flexibility and body composition. An improvement in the health-related components will assist personal health and lifestyle, including lowering the risk of hypokinetic disease (diseases related to lifestyle).
- Cardiorespiratory endurance refers to the ability of the working muscles to take up and use the oxygen that has been breathed in during exercise and transferred to the cells. It is important in endurance events such as cycling and marathon running.
- Muscular strength is the ability to exert force against a resistance in a single maximal effort. It is important in sports such as weight-lifting and wrestling.
- Muscular endurance is the ability of the muscles to endure physical work for extended periods of time without undue fatigue. Running for long periods of time requires considerable muscular endurance because the same muscle groups are contracting repeatedly.

- Flexibility is the range of motion about a joint or the ease of joint movement. It is important for injury prevention and in slowing muscle shrinkage as a result of the ageing process.
- Body composition refers to the percentage of fat as opposed to lean body mass in a human being. A certain amount of fat is essential to protect and insulate vital organs. Excess fat is called storage fat and is useful as a source of fuel in endurance events. High levels of excess fat hinder athletic performance in most events.
- Skill-related components of physical fitness include power, speed, agility, coordination, balance and reaction time.
- Muscular power is the ability to combine strength and speed in an explosive action. It is important in events such as running, throwing and jumping.
- Speed is the ability to perform body movements quickly. It is very important in sprint events and most team games.
- Agility is the ability to move the body from one position and direction to another with speed and precision. It is important in most team games.
- Coordination requires good interaction between the brain and the muscles, resulting in the smooth and efficient coordination of body parts. It is important in most team games.
- Balance is the ability to maintain equilibrium while either stationary or moving. There are two types of balance: static and dynamic. Static balance implies maintaining equilibrium while the body is stationary. Dynamic balance means maintaining equilibrium while the body is moving. Balance is important in most team games, but it is especially important in activities such as diving and gymnastics.
- Reaction time is the time taken to respond to a stimulus. Its importance is most evident in starts in athletics and swimming.
- The components of fitness can be measured using simple tests. By compiling the results of testing for each of the components, we gain an overall impression of our level of fitness. We call this a fitness profile.
- The two basic types of training are aerobic (with oxygen) and anaerobic (without oxygen).
- Aerobic training involves exercise that is sustainable and of low to moderate intensity. The FITT principle, (frequency, intensity, time, type) is used to adapt aerobic training programs to individual needs. Marathons, 400 metre swimming and triathlons are examples of activities that draw their energy from aerobic metabolism.
- Anaerobic training involves activities where the level of intensity is high but is maintained for short periods of time; for example, sprinting and high jumping.
- Most team games require energy utilising both the aerobic and anaerobic pathways. It is therefore important to establish the main sources of energy as a prerequisite in the development of training programs.
- Training causes an immediate physiological response seen in changes to heart rate, ventilation rate, stroke volume, cardiac output and lactate levels.
- Heart rate is the number of times the heart beats per minute. When we begin to exercise our heart rate increases and reaches a steady state during sustained moderate activity such as jogging.

- Breathing or ventilation rate increases during activity to deliver more oxygen to muscles.
- Stroke volume refers to the amount of blood ejected by the heart during a contraction. It increases significantly in response to exercise.
- Cardiac output, the total amount of blood pumped by the heart per minute, increases with exercise. When muscles work, blood is drawn from many parts of the body and redistributed to muscles.
- Lactate or lactic acid increases in the blood during exercise. If exercise is vigorous, lactate increases rapidly and inhibits performance if levels rise too high.

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A summary quiz and revision test on this chapter's content are available in Microsoft Word format in your eBookPLUS.

QUESTIONS

Revision

1. **Discuss** the difference between health-related and skill-related components of fitness. (P8) (4 marks)
2. Choose a test that measures cardiorespiratory endurance. **Describe** how you would conduct it on a group of soccer players at a preseason training session and suggest what the results mean. (P8) (5 marks)
3. **Discuss** the difference between strength and power. **Describe** a simple test to measure each component. (P11) (4 marks)
4. **Discuss** the importance of body composition to both personal health and athletic performance. (P16) (4 marks)
5. You are the coach of a basketball team. Select the three most important skill-related components and **describe** how you would test these at training. (P11) (3 marks)
6. What is agility? What other components of physical fitness, if improved, would result in an improvement in agility? (P8) (3 marks)
7. What is reaction time? **Outline** a simple test to measure reaction time and suggest measures as to how this component could be improved. (P8) (3 marks)
8. **Discuss** the difference between static and dynamic balance. **Propose** three activities where static balance is more important than dynamic balance. (P8) (3 marks)
9. **Explain** the difference between aerobic and anaerobic training. (P7) (2 marks)
10. **Discuss** how the FITT principle is used to improve aerobic performance. (P10) (4 marks)
11. Work out the target heart rate zones for two people of average fitness aged 18 and 40. **Explain** why they are different. (P11) (4 marks)
12. **Explain** how anaerobic training can be enhanced. (P10) (4 marks)
13. Choose a team game such as soccer, basketball or touch football. **Explain** how you would establish a training program that would ensure appropriate fitness for the sport. Include examples of activities that could be used to enhance fitness for that sport. (P8) (6 marks)
14. **Explain** how the heart responds to an increase in exercise. (P7) (3 marks)
15. **Explain** why ventilation rate rises with increases in exercise intensity. (P7) (3 marks)
16. **Outline** the difference between stroke volume and cardiac output. Why might their levels be different in trained and untrained athletes? (P7) (3 marks)
17. **Explain** the effect of increased lactate levels on performance. (P7) (4 marks)

Extension

Choose a sport or activity. List the six most important fitness components required. **Describe** where and how these components are used. Finally, **propose** or skills to develop each of these components. (P8) (10 marks)

Note: For an explanation of the key words used in the revision questions above, see Appendix 2, page XXX.