Physical Education

(HKDSE)

Part V: Physiological Basis for Exercise and Sports Training

Physical Education Section
Curriculum Development Institute
Education Bureau
The Government of the Hong Kong Special Administrative Region

2024

(last updated in Sep 2024)

Contents	Page

Learning Objectives

This part equips students with knowledge about physical performance and sports training. It enables students to understand the general principles and the effects of physical training which are fundamental in exercise and acquisition of physical skills. These should be referred to when students engage in the practicum (Part X) to develop an active and healthy lifestyle.

Expected learning outcomes: Students will be able to

1. explain with examples various physiological factors affecting sports performance;
2. explain the basic principles and important points of training;
3. compare and contrast the mechanisms of various factors and their applications to the following four training principles: resistance training, circuit training, continuous training, and interval training; and
4. make recommendations for enhancing the training effects after analysing sports training plans.

Glossary

	Term	Description
1.	Blood volume 血容量	The volume of blood circulating through the body; includes blood cells and plasma (approximately 5 litres for an individual of average size).
2.	Cardiac output 心輸出量	The volume of blood pumped out of the left ventricle of the heart in one minute (litre/min). Cardiac output (Q) is the product of heart rate (HR) and stroke volume (SV), i.e. Q = SV × HR. The average cardiac output for both athletes and untrained people at rest is 5 – 6 litres; during exercise it can exceed 30 litres for a trained endurance athlete or 20 – 22 litres for an untrained college student.
3.	Cardiovascular fitness 心血管適能	The ability of the heart and blood vessels to supply nutrients and oxygen to tissues during sustained exercises.
4.	Creatine 肌酸	A protein derivative found in muscle tissue. It is essential for energy conversion.
5.	Fast-twitch muscle fibre 快縮肌纖維	A type of muscle fibre that can reach peak tension quickly. It has a high ability to respire without oxygen during anaerobic metabolism but fatigues quickly. Fast-twitch motor units are much stronger than slow-twitch motor units.
6.	Glycogen 糖原 / 肝醣	A storage form of carbohydrates in the body. Glycogen is stored in the skeletal muscle and the liver, and it is a highly branched molecule made up of glucose units bonded to one another. Depletion of this substrate as a result of prolonged (generally > 2 hours) high-intensity exercise is associated with fatigue.

Glossary

	Term	Description
7.	Haemoglobin 血紅蛋白 / 血紅素	The part of the red blood cells that carries oxygen.
8.	Hereditary factor 遺傳因素	The passing of genetic characteristics from one generation to the next through genes.
9.	Muscle hypertrophy 肌肉增大 / 肌肥大	An increase in bulk by thickening of muscle fibres which leads to excessive development of an organ or body part.
10.	Kilocalorie 千卡	A unit of energy used to express the energy yield of foods or energy expenditure by the body. One kilocalorie (kcal) is the amount of heat required to raise the temperature of 1 kilogram (kg) of water by 1° C.
11.	Lactate threshold 乳酸閾	The workload or oxygen consumption level where lactate production by the working muscles exceeds the rate of lactate removal by the liver, at approximately 50% to 80% of VO_2max. An increased lactate threshold is associated with increased endurance performance.
12.	Lactic acid 乳酸	A waste product of glucose and glycogen metabolism produced in the muscles during intense exercise. Accumulation of a large amount of lactic acid will cause acute muscle soreness.
13.	Mitochondrion 線粒體 / 粒線體	Primary functions of mitochondrion include the production and regulation of energy.
14.	Muscle fibre 肌纖維 / 肌肉纖維	A band or bundle of fibrous tissue in a human or animal body that can contract, produce movement or maintain the position of body parts.

Glossary

	Term	Description
15.	Myoglobin 肌紅蛋白 / 肌紅素	It helps transport oxygen within muscles, resembling the function of blood haemoglobin. It is also a site for storing protein in the muscles.
16.	Nerve impulse conduction 神經脈衝傳導 / 神經衝動傳導	The electrical signal conducted along a neurone. It is the means by which information is transmitted in the nervous system from one neuron to another, or from a neuron to an effector organ (for example, a group of muscle fibres). A nerve impulse in a single neuron obeys to the all-or-none law.
17.	Overload 超負荷	It refers to the increase of working loads (intensity and time) when compared with previous training.
18.	Plyometric training 增強式訓練	Also known as jump training or plyos, are exercises in which muscles exert maximum force in short intervals of time, with the goal of increasing power (speed-strength). This training focuses on learning to move from a muscle extension to a contraction in a rapid or "explosive" manner, such as in specialized repeated jumping.
19.	Resistance training 阻力訓練	A type of training which develops power and strength. Resistance training may involve static (isometric) actions, dynamic (ballistic or isokinetic) actions, or both. Dynamic actions include weight-training (with free weights or on a machine, such as a variable resistance device or an isokinetic machine), plyometrics and all other forms of training that involve the overloading principle.

Glossary

	Term	Description
20.	Slow-twitch muscle fibre 慢縮肌纖維	A type of muscle fibre characterised by a relatively slow contraction time, low glycolytic or anaerobic capacity, and high oxidative or aerobic capacity. It makes the fibre suitable for low power and long duration activities. Slow-twitch muscle fibres have a high density of mitochondria, high myoglobin content, and a rich blood supply.
21.	Stroke volume 每搏輸出量 / 心搏量	The volume of blood pumped out of the left ventricle of the heart per beat. It is the difference between the end diastolic volume and the end systolic volume. Typically, the stroke volume is 75 ml for an untrained man at rest, and 105 ml for a trained athlete at rest.
22.	Sub-maximal workload 亞極量負荷 / 次最大負荷	A work load below the maximum effort. In sub-maximal tests, extrapolation is used to estimate the maximum capacity.
23.	Tapering 減量	The act of a gradual reduction in size or amount. In sport, it refers to a reduction in training load to achieve peak performance during an upcoming event.
24.	Work to rest ratio 運動休息比	The use of a fraction or a scale to express the ratio between exercise time and resting time. For example, a ratio of three workout minutes to two resting minutes in a training session is expressed as 3/2 or 3:2.

Essential Concepts and Theories

A. Factors affecting sports performance

i) Cardiorespiratory fitness

It refers to the ability of the circulatory and respiratory systems to transport oxygen to the tissue cells during sustained exercise. Therefore, the cardiorespiratory fitness is an important indicator of the aerobic exercise. For example, long-distance runners usually have high level of cardiorespiratory fitness.

ii) Muscular fitness

Muscle is the major organ that produces movement, so muscular fitness is one of the crucial factors affecting sports performance. Muscular fitness comprises muscular strength and muscular endurance. Muscular strength refers to the amount of work done by a muscle or a group of muscles in a single maximal contraction, for example, the strength in a throwing event. Muscular endurance refers to the ability of a muscle or a group of muscles to work for a long period of time at sub-maximal level, for example, the endurance of leg muscles during a long-distance run. Performance in different sport will be determined by the related muscular fitness of the athletes.

iii) Flexibility

It refers to the ability of a joint or a series of joints to move within its range of motion. Good flexibility can lower the risk of sports injuries, like muscle tearing and strain during vigorous activities, and help athletes execute skills efficiently and effectively. For example, gymnasts need high flexibility to perform skills with high stability.

iv) Age

Age has an influential effect on sports performance. Aging also increases greater stress on oxygen transport and cardiorespiratory function. The rate of adaptation to training and regaining strength and power in older people are lower than those of the younger individuals. From 25 to 75 years of age, the maximal oxygen uptake (VO_{2max}) of a person declines steadily. The Maximal heart rate also decreases almost by one beat per year. As a result, the maximal heart rate can be estimated by $HR_{max} = 220 - age$. For example, the HR_{max} of a 25-year-old athlete is estimated to be 195 beats / minute whereas a 60-year-old man is 160 beats / minute. Meanwhile, there are different

equations for estimating the maximum heart rate based on different research. In general, the drop in the maximal heart rate will cause a drop in the cardiac output. Therefore, older athletes will have a lower ability of aerobic performance.

The flexibility of the joints tends to decrease from early childhood onwards and this limits the range of movement. Muscular strength reaches its peak between 20 and 30 years old. Then, it will start to drop. One of the reasons is that the body synthesises less protein as one gets older, so this weakens the muscles and they gradually decrease in size.

Peak performance at different growth periods varies a lot among different sports events. For example, female gymnasts are usually younger, throwers are usually mature adults, and marathon runners can reach their peaks in their thirties.

v) **Sex**

Physiological differences between sexes and the related athletic performance of females may be summarised as in *Table 5.1*. For example, females usually have better flexibility. However, their athletic performance is limited by their specific physiological characteristics.

Physiological Factors	**Female characteristics**	**Sports Performance**
Body structure	Broader and more tilted pelvis bones, Lower centre of gravity	Lower jumping ability
Body fat	More	Reduced sports performance
Bone density	Lower	Less strength in explosive events
Muscle mass	Smaller	
Heart volume	Smaller	Smaller VO_2max
Haemoglobin content	Less	
Range of joint movement	Larger	Greater flexibility, more suitable for the sport that require agility

Table 5.1 Influence of physiological characteristics on females' sports performance.

vi) **Heredity**

A gene is the basic physical and functional unit of heredity. Athletic performance is a complex trait that is influenced by both genetic and environmental factors. The initial ability of sports performance is genetically predetermined. The distribution of different types of muscle fibres (fast or slow-twitch muscle fibres) is primarily determined by heredity but can also be affected by training. Although heredity is unchangeable, it is evident that our physiological qualities can be improved by regular physical activities. For example, prolonged aerobic exercise will increase the aerobic capacity of slow-twitch muscle fibres.

vii) **Body composition**

Generally, the physical build of an individual can be classified into three different somatotypes, namely endomorph, mesomorph and ectomorph, which are genetically predetermined. A person's body type, in terms of size and strength, may be an advantage for certain sport. For example, in endurance activities, energy expenditure is directly proportional to the body weight and excessive body fat or muscle can affect performance. Hence, athletes in endurance activities usually have a lighter body (i.e. ecto-mesomorphs).

Body composition refers to the ratio of body fat to lean body mass. The energy consumption is directly proportional to the body weight. There is a positive relationship between the energy consumption and body composition. Thus, there is a close relationship between the body composition and sports performance. When the consumed energy is more than the intake, we lose weight. When the intake is more than the consumed, we gain weight. The excessive body fat adds weight and is unfavourable to sports performance. Participation in regular exercise is useful to reduce the excessive body weight.

viii) **Doping**

Though various drugs may have positive effects on sports performance, they have detrimental effects on athletes. Drug doping violates sportsmanship. Hence, the International Olympic Committee bans drug doping for enhancing sports performance.

Prohibited Substances	Potential Effect of Enhancing Sports Performance	Potential Side Effects
Anabolic agents e.g. Anabolic Steroids	Increasing protein synthesis, stimulating muscle and bone growth.	➢ Increasing the risk of cardiovascular disease, liver disease, and high blood pressure. ➢ Common psychological/behavioral changes include mood swings, aggression, mania, depression, and dependence.
Stimulants e.g. Amphetamine, Cocaine	Increasing athletes' alertness, reducing tiredness, increasing competitiveness and aggression.	➢ Leading to dehydration, anxiety, insomnia. ➢ Leading to increased heart rate. Affecting coordination and balance. ➢ Prolonged use may increase the risk of cardiovascular problems and stroke.
Erythropoietin (EPO)	Stimulating the bone marrow to produce more red blood cells in order to increase the oxygen carrying capacity of the blood. The use of EPO can increase exercise endurance and reduce the recovery time.	➢ Making the blood more viscous and causing blood pressure to rise. ➢ It will increase the risk of heart attack, stroke and pulmonary embolism.
Narcotics	Increasing pain threshold and causing a failure to recognise injury.	➢ Weakening immune system, decreasing heart rate and suppressing respiratory system ➢ Loss in balance, coordination and concentration ➢ Highly addictive leading to physical and psychological dependence

Table 5.2 Examples of Prohibited Substances

ix) **Environment**

Environmental factors may have different effects on people. As the oxygen concentration is lower at high altitude, a person will experience "high-altitude" disease which is the inability to intake enough oxygen. This will stimulate the body to increase the number of haemoglobin and red blood cells to increase our ability to carry oxygen. Therefore, some athletes choose to train at high altitude to improve their sports performance.

* For more information, please refer to the theory about flexibility in Part IV.

** For more information, please refer to the theory about body types in Part II

Fig 5.1 Factors affecting sports performance

B. Concepts and principles of training

i) Aerobic training and anaerobic training

- **Aerobic training**

- Aerobic training refers to the participation in prolonged periods of sub-maximal exercises such as swimming, running, cycling, etc. The energy for aerobic exercises comes mainly from the oxidation of glycogen, fat and protein. When the muscles are supplied with enough oxygen, plenty of ATP will be re-synthesised and a little lactic acid will be generated.
- Improved oxygen intake ability will help athletes enhance their performance in aerobic exercises. The ability is determined by the tidal volume of the lungs, blood oxygen capacity of the blood, cardiac output and the metabolic rate of the skeletal muscles. We usually use the "Maximal Oxygen Uptake" (VO_{2max}) as the indicator for measuring the oxygen intake. Higher VO_{2max} means better cardiorespiratory fitness. The VO_{2max} of non-athletes is 30 – 40 ml / kg / min and 50 – 60 ml / kg / min for athletes. The VO_{2max} of elite marathon runners may be higher than 70 ml / kg / min.
- To improve the oxygen uptake, the target heart rate for training should be 60 – 85 % of the maximum heart rate with a duration of at least 30 minutes.

- **Anaerobic training**

- This involves the short "all-out" exercise efforts. If the exercise duration is longer than 30 seconds, our body generates a large amount of lactic acid which causes fatigue, making the exercise not sustainable. 800m run is a typical example. This type of anaerobic activity uses glucose as the main source of fuel for glycolysis. If the exercise duration is less than 10 seconds, our body will use the ATP－PC system to supply energy and this will not generate a large amount of lactic acid.

- Improved anaerobic capacity will help athletes enhance their performance in anaerobic exercise. The anaerobic capacity is determined by the anaerobic glycolysis ability of the muscle groups and the body's ability to buffer and tolerate lactic acid accumulation in the blood stream.
- To improve the ATP－PC system, the duration of exercise should be short and the rest should be long (minimum work to rest ratio is 1:3 or above). Besides, the training intensity is high.
- To improve the anaerobic glycolysis system, the duration of exercise should be relatively longer (about 1 – 2 minutes) and the rest is about 2 times of the exercise time (work to rest ratio is about 1:2). This aims to generate a large amount of lactic acid and helps muscles get accustomed to high concentration of lactic acid during exercise. Besides, the training intensity is high.
- The workload or oxygen consumption level where lactate production by the working muscles exceeds the rate of lactate removal by the liver; at approximately 50% to 80% of VO_{2max}. An increased lactate threshold is associated with an increased endurance performance (Fig 5.2).

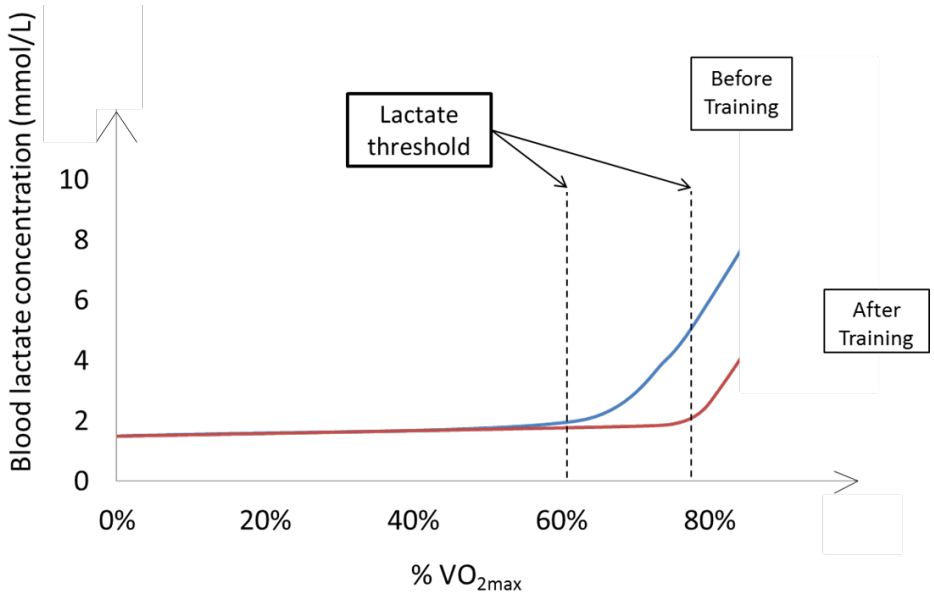

Fig. 5.2 An example of change in lactate threshold after certain period of training

ii) **Principles of training**

- **Specificity** - Training must be specific to the sport concerned. For example, specific anaerobic training such as sprinting will bring about specific anaerobic adaptations, whereas endurance exercise training such as long-distance run will bring about specific aerobic adaptations. The principle of specificity, however, does not only refer to the energy systems. The muscle groups utilised, fibre type, actions performed, environmental conditions and duration should all be taken into consideration. An athlete should identify the fitness components, the major muscles and joints required for a particular activity. These muscles and joints should be trained so that they can be used effectively in competitions. Any specific variable that can be manipulated in a training programme should be seriously considered. To sum up, tailor-made training exercises should be used to get the greatest benefits. Quite simply, specific exercise elicits specific adaptations leading to specific training effects.
- **Overload and progression -** When adaptations occur as a result of training, an individual may experience a certain degree of stress or discomfort. Overloaded training increases the stress and the body as a whole will function more efficiently. Once the body has adapted, the training intensity can progress up to the next level where further improvements and adaptations can take place. The workload should be increased only when some adaptations have occurred. It is therefore important to monitor the performance of training closely so that the body is not put under too much stress too soon.
- **Reversibility -** Performance can regress if the training intensity is reduced or the training is stopped. Significant decreases in cardiorespiratory and strength performance are obvious after an inactivity for an extended period. For example, after detraining for seven weeks, the stroke volume and cardiac output will

decrease by up to 30% and the maximum oxygen uptake by up to 27%. In general, only by continuous training can an individual maintain a high standard of performance throughout the year.

- **Individual difference -** It is essential that a coach is fully aware of how their athletes react to different types of training methods. An exercise that is of benefit to an individual may not be so good for another. The possible reasons include differences in initial fitness level, injury, diet, lifestyle and genetics. A coach should never insist that all athletes of the same team train the same way or with the same exercise intensity. For example, student A resumes training after recovering from an injury whereas student B resumes training after representing the Hong Kong team in an international competition, there should be two different training plans for them because of their differences in physical fitness.
- **Variance -** To avoid boredom and staleness, a variety of training methods should be adopted to achieve the same goal during the course of any training programme. Variance of training can arouse an athlete's interest and motivation resulting in a positive psychological effect. For example, it may be quite an enjoyable break for the school cross-country team to take a training session in the swimming pool once a month. In this manner, the athletes will still be training their aerobic systems, while at the same time taking a break from their normal routine.

iii) **Basic considerations in training**

It is generally advisable to consider the **"Frequency-Intensity-Time-Type (FITT)"** principle in designing a training programme.

- **Frequency (F) -** This will depend on the training purpose and the training components. For elite athletes, it is fine to take aerobic exercises five or six times per week, but no more than three times for strength or speed work. At a recreational

level, health benefits can be gained by taking 30 minutes of exercises three times a week. No matter how low the frequency is, some exercise is better than none. Although higher training frequency will result in greater training effects on fitness, the training effects of several training sessions a day may not be necessarily better than a training session a day. There will be significant training effects for an accumulation of endurance and strength training three times a week.

- **Intensity (I) -** It depends on the types of training. There are a number of ways to gauge the training intensity:

- Training zone **-** This involves training within a specific range of heart rate. For example, training at 60 – 65% of an individual's maximum heart rate is recommended for burning fat, and 60 – 85% for enhancing cardiovascular capacity. Other than the maximum heart rate, we can use "the heart rate reserve method" to estimate the target heart rate zone *(See Table 5.3)*.

Maximum heart rate method	**Heart rate reserve method**
Target heart rate = Training intensity (in %) × HR_{max}	Target heart rate = Training intensity (in %) × HRR + HR_{rest}
HR_{max} : Maximum heart rate (220 – age) HR_{rest} :Resting heart rate HRR : Heart rate reserved (HR_{max} – HR_{rest})	
Example 1： An athlete is 20 years old and the training intensity is 70%. **Target heart rate** = 70% × HR_{max} = 70% × (220 – 20) = 140 (Remark: During training, the heartbeat of the athlete should reach at least 140 beat/minute.)	
Example 2： An athlete is 20 years old with resting heart rate at 65 and the training intensity is 70%. **Target heart rate** = 70% × HRR + HR_{rest} = [70% × (220 – 20 – 65)] + 65 = 160 (Remark: During training, the heartbeat of the athlete should reach at least 160 beat/minute.)	

Table 5.3 Two commonly used methods in estimating target heart rate zone

- Percentage of VO_{2max} - The indicator is more commonly used among elite athletes. The athlete exercises at a certain percentage of his calculated maximal oxygen uptake. The exercise intensity of the elite athletes is usually at above 70% of their $VO_{2max.}$
- Respiratory Exchange Ratio (RER) - This is used to determine the type of fuel is being used to produce energy. It is calculated by dividing the expired carbon dioxide (CO_2) by the inspired oxygen (O_2) per minute. An RER of 0.70 shows that fat is the primary fuel source. An REF of 0.85 shows that the fuel source is a mix of fat and carbohydrates. If the value is 1.0 or above, carbohydrates is the primary fuel source. The higher the intensity is, the more likely that carbohydrates will be the primary source of fuel.

- **Time (T) -** To improve the cardiorespiratory fitness, aerobic activities should take place for a minimum of 30 minutes. The training intensity largely affects the duration of exercise.
- **Type (T) –** The type of training relates to the principle of specificity. For recreational exercise, it is important to include the elements of fun and enjoyment. This will increase the chance of exercise adherence. Each sport will have its unique training mode. For example, the training approach for a marathon race is totally different from that for gymnastics. Different training objectives will also be achieved by choosing appropriate exercises. Similarly, exercises for training cardiorespiratory fitness would be different from those for training muscular strength.

iv) **Planning of training programmes**

It is important to set out achievable goals before an athlete begins a training programme. As regards to the training programmes for the participants of recreational activities, personal preferences should be addressed and interesting sports activities should be offered for selection to ensure exercise adherence. In addition, the following important factors should also be considered when planning the training programmes.

- **Diet / Hydration** - The body needs fuel to exercise. It is essential that enough fuel is available prior to the exercise. An adequate amount of food and water is also important during and right after the training sessions.
- **Clothing** - The choice of clothes may have an effect on the sports performance depending on variables like the environmental conditions, duration and exercise intensity, etc. Comfort and heat insulation are two important factors. This is true in Hong Kong, especially for the heat and humidity in summer. One should wear lightweight clothes that will dissipate heat quickly and not prohibit sweating.
- **Time commitment -** The participant should be willing to commit an adequate amount of time to training to make the most of the benefits.
- **Location -** It is important to select suitable and convenient training venues to reduce the chance of dropping out.
- **Safety -** There should be sufficient warm-up exercises before training. Cool-down activities are also very important after the training. Warm-up exercises should include stretching the limbs, joints and muscles which are involved in the training. All training programmes should cater for individual needs and include rests during the training period.

v) **Training for different targets**

Training is a means to adapt the body to the demands of the sport, whether for the high level competitions or just participation in physical activities. Due to individual differences and distinct physical growth stages, the training programmes for individual athletes should be tailor-made even though they are competing in the same event and a similar competition environment.

- **Training programme for children**

Young children should be exposed to a wide range of physical activities. Evidence indicates that the basis of most skills is learnt by the age of twelve. To cater for the short attention span and physiological limitations of children, a variety of training programmes should be used to meet children's interest as well as their psychological and physiological needs. The specialisation in one particular sport before puberty is not recommended due to their premature in the musculoskeletal system. In addition, many factors such as safety, effectiveness, satisfaction, etc. should also be emphasised when planning training programmes for children.

The speed of limb movements is relatively slow in early childhood. Specific activities should be planned to improve this ability. During the period of rapid growth in early childhood, an intensive training may be harmful. Hence, the training for muscular strength and endurance, like weight and resistance training, is not recommended in order to avoid overtraining.

Moreover, when group work is involved in training, the matching of children of similar age and size is important. Great differences between children should be avoided. In general, the use of competitions for training purpose is not recommended for young children.

Under careful supervision, resistance training is useful for improving the muscular strength and is safe for the pre-pubescent individuals. However, maximal or near-

maximal lifts should not be used. The progress of resistance training should be closely supervised by the teacher or coach.

- **Training programme for adolescence**

Exercise can produce the most dramatic improvements in health-related physical fitness in adolescence. During the period, their muscles develop rapidly. Therefore, weight training is effective in developing strength and endurance. To ensure safety, light weights and more repetitions are preferred.

The volume of oxygen consumption usually reaches its peak for an individual between 17 and 20 years old. Hence, under normal circumstances, an adolescent is suitable to undergo aerobic fitness training. The training programmes should be safe, beneficial and provide satisfying experiences to youngsters.

- **Training programme for adults**

Regular exercise can have a significant delaying effect on the aging process. The muscular strength and cardiorespiratory fitness decrease with age. Therefore, the age factor should be considered when designing training programmes for adults.

The target heart rate should be carefully calculated as a guide for the workout intensity in endurance training. A training programme of low intensity comprising several workouts each week is usually more effective than a single workout of higher intensity.

Activities	Aerobic Fitness (1)	Muscular Fitness (2)	Flexibility Agility & Coordination	Weight & Fat Control (3)
Aerobic dance	Excellent	Good	Excellent	Good
Badminton	Excellent	Good	Excellent	Excellent
Basketball	Excellent	Excellent	Excellent	Excellent
Weight-lifting	Poor	Excellent	Fair	Fair
Bowling	Poor	Poor	Poor	Poor
Cycling	Excellent	Good	Fair	Good
Golf (18 holes)	Poor	Poor	Fair	Fair
Jogging	Excellent	Good	Poor	Excellent
Martial Arts	Good	Excellent	Excellent	Good
Netball	Excellent	Good	Good	Good
Qi Gong	Fair	Fair	Fair	Fair
Rhythmic exercise	Good	Good	Excellent	Good
Soccer	Excellent	Excellent	Excellent	Excellent
Squash	Excellent	Good	Excellent	Excellent
Swimming	Excellent	Excellent	Good	Good
Table tennis	Good	Good	Good	Fair
Tennis	Good	Good	Good	Good
Volleyball	Good	Good	Good	Good
Walking	Good	Fair	Poor	Fair

Footnote: (1) Aerobic fitness: Fitness of the heart, lungs and blood circulation
(2) Muscular fitness: Muscular strength, power and endurance
(3) Combined with judicious dieting, if necessary

Table 5.4 Effects of activities on improving the components of physical fitness

- **Training programme for the elderly**

The elderly usually have weaker muscles fitness and reduced joints mobility. Therefore, exercises of lower intensity, i.e. lighter resistance, are more suitable. The elderly in general have lower muscular endurance and are less able to sustain physical work for long periods. Hence, shorter work durations with longer rest intervals may help them recover more quickly.

The purpose of exercise for the elderly is to move all joints through their full range of motion, to improve their muscle tone, strength and flexibility, and to increase the blood circulation. The exercise benefits will be the greatest when the elderly train in the most comfortable way.

It is important to combine movement sequences that are logical in their progression. A sample programme is as follows:

1. **Warm-up exercise for 10 minutes:** to increase the body temperature, heart rate and blood circulation slowly; warm muscles, limbs and lubricate joints; and prepare the body for more demanding exercises.
2. **Muscle strengthening and flexibility exercise for 15 minutes:** to exercise the large muscle groups and major joints of the limbs and trunk such as hands and arms, upper and lower back, chest and abdomen muscles, and shoulder and hip joints.
3. **Endurance activities for 30 minutes:** to make demands on the cardiorespiratory system, to bring improvements in their strength and efficiency. Do aerobic activities that keep the elderly moving for at least 30 minutes, for example, brisk walk, comfortable walking, jogging, slowing down to walking pace towards the end so that the heart rate gradually slows down.
4. **Stretching for 5 minutes:** to bring the heart rate and breathing frequency back to normal after the demands of endurance work; stretch the tight muscle groups; and bring the body temperature down.
5. **Cool down for 3 to 5 minutes:** to relax the body and mind to promote recovery.

- **Training programme for athletes**

The training programmes for athletes should be designed to meet the specific objectives related to particular athletic events. The intensity and duration of work should be carefully adjusted with the levels of endurance or strength determined by the physical capabilities and potential of the individuals, for example, endurance, muscular strength, etc.

Modern theory of training considers training as a cyclical year-long process. It emphasises the organised division of the training year into periods of varying duration, which is characterised by the nature of activity practised in each period (periodisation). Owing to the tight competition schedule in recent years, the periodisation of training has not been so apparent compared with that of the old days. However, the basic principles are still useful for reference. (*See Table 5.5* and *Table 5.6*). The three basic objectives of periodisation are to prepare an athlete for:

1. Achieving an optimal improvement in performance (preparation period; pre-season)
2. Achieving peak performance in the competition season (competition period; in-season)
3. Facilitating a psychological rest, relaxation and physiological adjustment while keeping the appropriate fitness level (transition period; off-season)

Preparation period	Competition period (Early stage)	Competition period (Mature stage)	Transition period
Muscular fitness training of increasing intensity for strength, power, and endurance (8 to 10 weeks, 3 sessions / week)	Muscular and energy fitness sessions of high intensity, focusing on sport-specific power and speed; frequency depends on the competition schedule (1 to 3 sessions / week)	Speed is the emphasis in fast sport. Use high-speed/low-resistance movements and sprints (1 to 2 sessions / week)	Muscular fitness training to improve strength and power in sport-specific muscle groups (8 weeks, 3 sessions / week)
High-intensity energy fitness training, including intervals and sprints (8 to 10 weeks, 3 sessions / week)	Anaerobic fitness is critical; high-intensity sessions (6 to 8 weeks, 2 to 3 sessions / week)	Drills on competitive skills	Energy fitness training to improve aerobic capacity, using low-intensity, continuous exercise, Fartlek* and interval training (8 weeks, 2 sessions / week)
Strategies, techniques, and skill practice	Sport-specific skills, strategies, and drills on competitive skills	Regular competitions substitute for fitness training	Participation in other sport and recreational activities. Practise sport-specific skills. Keep body fat low.

*For more details, please refer to the description on session C (v) of this part.

Table 5.5 A generalised seasonal training outline

vi) **General points on training for fitness and health**

- Before starting any programme, the participants, be they athletes or not, should have a medical check-up. For those aged over 35 who have not been exercising regularly for some time, or who already have significant medical or fitness problems, they are advised to consult a doctor before joining vigorous exercise programmes.
- A fitness programme should embrace physical activity, regeneration, nutrition, and guidelines on developing healthy living habits. A proper and good fitness programme should, on top of adhering to the basic principles of training and exercise prescription, be sufficiently beneficial with respect to the four components of fitness (i.e. cardiorespiratory endurance; flexibility; muscular strength and endurance; body composition). It should carry a minimum risk of developing medical problems.
- The fitness programme should be sufficiently enjoyable, relatively easy to do regularly and with the minimum needs for special talents, facilities, equipment and favourable environmental conditions.
- When beginning an exercise programme, one must first work on the cardiorespiratory endurance before progressing to other aspects.
- The time the participants can spend on training should be considered when planning training programmes.
- A fitness programme should include:

1. 10 minutes of warm-up activities
2. 30 minutes of continuous activity using large muscle groups at an intensity within the target heart rate zone (for developing the muscular strength and endurance)
3. 10 minutes of cool-down activities

- For non-athletes and beginners, four to six weeks of a low level and gradual

conditioning programme of mild to moderate physical activities are recommended before taking part in more vigorous activities.

A senior form student is planning to take part in a 400 m race in a competition of the upcoming season. The training plan is as follows:

- **Phase 1 (pre-season) - General development of strength, agility, endurance and basic technique:** This is a general strength and fitness phase to achieve a basic level of fitness. The training is not particularly specific at this stage and would involve exercises that train a large number of muscles at the same time, e.g. bench / leg / shoulder press**.**
- **Phase 2 (pre-season) - Development of specific fitness and advanced technical skills:** At this stage, the principle of specificity becomes important. The training goal is to improve the VO_2 max and resistance to fatigue, and to train at the speed required for the 400m run. The specific endurance sessions would involve a maximum distance of 400 metres in a single repetition with 2 to 3 minutes of rest in between. The weight training would move from general to more specific. The focus should be on speed and power (high weights, low repetitions), including plyometric exercises.
- **Phase 3 (competition) - Competition experience:** The athlete should gain some valuable race experience while at the same time focusing on the main goals for the season. The principles of overload and progression should be adhered to as the body is still adapting to the training programme.
- **Phase 4 (competition) - Technical adjustments and preparation for the main competition:** The athlete must make any necessary adjustment to the techniques and race strategies that may have arisen from the previous phases. It is very important that the athlete does not suffer from "staleness" and "overtraining".
- **Phase 5 (competition) - Competition experience and achievement of objectives:** It is at this stage that the athlete aims to achieve his / her peak performance. In the lead up to the competition, it is vital that the athlete understands the concept of tapering to remain fresh for the main events.
- **Phase 6 (transition) - Active recovery - planning and preparation for the next season:** Once the season ends, the athlete makes a note of the lessons learnt and how further improvements can be made for the following season.

Table 5.6 A sample training programme

C. Training methods

i) Resistance training

It helps strengthen specific muscles and can be used in a variety of ways. The most popular form of resistance training is weight-lifting. Before commencing a weight-lifting programme, the 1 and 10-repetition maximum (RM) tests should be carried out. These are tests to determine the maximum weight that can be lifted only once and ten times respectively. Every subsequent exercise should be performed at a percentage of these maximum figures. Depending on the weight and number of repetitions, the strength training can be divided into various training categories such as aerobic, anaerobic, strength, power and muscle hypertrophy. An athlete needs to establish the type of strength he/she wants to develop, and the kind of muscle contractions will be performed before embarking on a training programme. The lifting techniques and safety procedures are vitally important at all times.

ii) Circuit training

It involves performing a number of different exercises within a certain time limit with a view to achieving a whole body workout. Exercises are marked out at stations and usually follow a particular order of anaerobic, aerobic and local muscular endurance. Depending on the desired intensity of the session and the standard of participation, particular attention should be paid to the work to rest ratio. Circuit training is particularly good for general conditioning and enables a large group of athletes to participate together.

iii) **Continuous training**

This type of training stresses the aerobic energy system. It generally involves performing exercises which use large muscle groups at low intensity over a long period of time (between 30 minutes and two hours). The results of this type of training are an improvement in the ability to utilise energy derived through the aerobic energy system. Examples of continuous training activities include jogging, cycling and swimming. This type of training is not sport-specific, and there is an increased chance of injury, particularly to the muscles and joints due to the prolonged training duration of a particular activity.

iv) **Interval training**

This involves a combination of high-intensity exercises interspersed with periods of rest. Light or mild exercise usually constitutes this resting period. The work to rest ratio is vitally important in all interval training sessions and will vary according to the goals and objectives of the training and the type of energy systems to be stressed. The following are some general guidelines (work to rest ratio):

- To improve the ATP-PC system, exercise less than 20 seconds and the work: rest ratio is 1:3 or above
- To improve the lactate system, exercise between 20 seconds and 2 minutes and the work to rest ratio is 1:2
- To improve the aerobic system, exercise between 2 and 5 minutes and the work to rest ratio is 1:1

v) **Fartlek training**

Fartlek, which means “speed play” in Swedish, is a form of conditioning. It puts stress mainly on the aerobic energy system because of the continuous nature of the exercise. The difference between this type of training and continuous training is that the intensity or speed of the exercise varies, meaning that the aerobic and anaerobic systems can be put under stress.

Training Method	Purpose	Workout Design
Resistance training	- Improve muscular strength and endurance - Improve power	**Development of maximum strength:** - 85 – 95% 1RM - 1 – 5 repetitions per set - 2 – 4 sets - 4 – 5 minutes rest between sets **Development of strength endurance:** - 50 – 75% 1RM - 15 – 20 repetitions per set - 3 – 5 sets - 30 – 45 seconds rest between sets
Circuit training	- Improve aerobic and anaerobic capacities - Improve muscular endurance and strength - Improve power	- Working at a number of exercise stations in sequence - Usually 5 – 15 stations in each circuit - 3 – 5 circuits - Resting time between circuits can be varied
Continuous training	- Improve aerobic capacity - Improve muscular endurance	- **F**requency: 3 – 4 sessions a week - **I**ntensity: 70 – 85% of VO_2max - **T**ime: minimum 30 minutes - **T**ype: whole body activities that use major muscle groups, e.g.: running, swimming, rowing, cycling, etc.
Interval training	- Improve aerobic and anaerobic capacities - Improve power	- Consists of several bouts of high-intensity exercises, with certain rest time in between **Example: for 100m athletes** - Sprint distance: 60m - Rest time: 40 seconds - Work intensity: 95% - Repetitions: 8 times per set - Sets: 3 - Longer resting time between sets - Frequency: 3 sessions / week
Fartlek training	- Improve aerobic and anaerobic capacities	**Sample programme for a middle distance runner:** - Warm up: Stretching exercises and jog for 5 minutes; - 600 m at a fast steady pace; - Rapid walk for 5 minutes; - Alternate jog-sprint (300 m – 100 m) for 2,000 m; - Cool down: Stretching exercises and jog for 2,000 m.

Table 5.7 Purpose and design of various training methods

Training Method	Training Effect			
	Aerobic	Anaerobic	Power	Strength
Resistance	✓	✓	✓✓	✓✓
Circuit	✓✓	✓	✓	✓
Continuous	✓✓	✖	✖	✖
Interval	✓	✓✓	✓	✓
Fartlek	✓	✓	✓	✓

✖: Not Suitable, ✓: Suitable, ✓✓: Very Suitable

Table 5.8 Training effects of different training methods

D. Training and detraining effects

i) Cardiovascular system

- The heart is enabled to work more efficiently because of cardiac hypertrophy, which is an increase in the thickness of the cardiac tissue. This allows for a more forceful contraction of the heart. As a result, the heart does not have to pump as many times to achieve the same amount of blood flowing to the working muscles. The resting heart rate then falls.
- The improvements in the efficiency of constriction and dilation of arteries as well as the development of new capillaries within the muscles allow for a greater supply of blood to the working muscles.
- An increase in the water component of the blood allows it to flow around the body more easily.
- The haemoglobin content of the blood increases, which further facilitates the transport of oxygen around the body.

ii) **Metabolism**

- The size and number of mitochondria increase, which enhances energy production.
- The amount of oxidative enzymes increases, which can oxidize and dissolve food more effectively. This leads to an increase in stores of glycogen and fat, which allows exercise to be performed for a longer period of time.
- The myoglobin content increases. This enables more oxygen to be brought to the cells, resulting in more efficient aerobic energy production.
- The activity of the ATPase increases, which is responsible for breaking down the ATP. The efficiency of the energy system is enhanced.
- The activity of glycolytic enzyme increases. This helps the body break down glycogen in the absence of oxygen, enabling us to exercise longer without fatigue.
- The tolerance of the accumulation of lactic acid (lactate threshold) increases, which enhances an athlete's stamina.

iii) **Lactic acid level**

During the energy production process, lactic acid is formed as a waste product in the muscles. The accumulation of lactic acid may hinder the contraction of muscle fibres and affect sports performance negatively. Training diminishes the rate of lactic acid formation, raises the athlete's lactic acid tolerance and improves their sports performance.

iv) **Muscular fitness**

After the training of the muscle, the muscle fibres will increase in size, which is known as muscle hypertrophy. In addition, more motor nerve units will be involved in the movement, thus increasing the muscle that can be used. Hence, sports performance is improved.

v) **Detraining**

When the training ceases, the detraining effects may occur. This results in a reversal of many of the positive adaptations that took place during the training programme. Generally, most elements of fitness decrease at about the same rate as they increase. A study[1] shows that 2 - 4 weeks after the training has been stopped, the VO_{2max} will decrease by up to 10%, the blood and stroke volume will decrease by up to 12%, the resting heart rate will increase by up to 10%, the muscle glycogen levels will decrease up to 30%. Regular training is required in order to maintain the effects of training. However, if we need to reduce the training frequency, the training intensity should be maintained as far as possible. Without practice, the size of muscle will decrease, resulting in muscle atrophy.

Examples of Enquiry Activities

Themes		Activities
1.	Physiological factors affecting performance	Information collection: ● Identify a sport event that you are most interested in; describe the physiological characteristics (for example, physical fitness, age, body type, etc.) of those high level athletes who perform at their peak. ● Learn about the relative importance of heredity and training. ● Learn about the effects of environmental factors (for example, temperature, humidity, amount of oxygen in air, etc.) on sports performance. ● Learn about the doping effects on sports performance and its damage to one's body.
2.	Training programme	Information collection and analysis: ● Students in groups of 3 to 5; collect 8 to 12 samples of training plans from interviews, internet, documents / books and journals, etc. ● The plans should be different in training purposes, formats, designs, etc. for achieving the best learning outcomes. ● Add notes to the plans, showing the functions of individual training activities (For example, to enhance aerobic capacity, muscular strength, skill proficiency, etc.). P-I-E (Planning–Implementation–Evaluation)**:** ● Students develop an individualised 12-week training programme based on a selected plan; individual plans are then circulated in the group for comments. ● The training plans must contain the following:

Examples of Enquiry Activities

Themes		Activities
		- The long-term goals (goals to be accomplished by the end of the training programme) - The short-term goals (smaller goals broken down from the long-term goals; to be accomplished at different stages of the training programme) - The date, time, venue and content of each training session - The physiological and physical performance indicators to be monitored ● Put the plans into practice after gaining endorsement from the teacher. ● Before, during and after the plan, students must record the responses and changes induced by the training for the purposes of evaluation and reflection. ● On the completion of the training programme, students of the same group share the experience gained and write a report together.
3.	Training effect	Project learning – The effects of training on: ● the skeletal system ● the nervous system ● the muscular system ● the cardiovascular system ● the respiratory system ● the energy system

Reference for Teachers

Adams V., & Linke A. (2018). Impact of exercise training on cardiovascular disease and risk. *Biochim Biophys Acta Mol Basis Dis*. 1865(4):728-734. doi: 10.1016/j.bbadis.2018.08.019.

American College of Sports Medicine. (2017). ACSM's guidelines for exercise testing and prescription (10th ed.). Philadelphia, PA: Lippincott Williams & Wilkins.

American College of Sports Medicine. (2013). ACSM's resource manual for guidelines for exercise testing and prescription (7th ed.). Baltimore, MD.: Lippincott Williams & Wilkins.

Bushman, B. A. (2017). *ACSM's Complete Guide to Fitness & Health (2nd ed.)* Champaign, IL: Human Kinetics.

Faigenbaum, A., & Westcott, W. (2015). Youth Strength Training: A Guide for Fitness Professionals from the American Council on Exercise. Publisher: Coaches Choice.

Gibson, A.L., Wagner, D. R., & Heyward, V. H. (2018). Advanced fitness assessment and exercise prescription (8th ed.). Champaign, IL: Human Kinetics.

Haff, G. G., & Triplett, N. T. (2015). Essentials of Strength Training and Conditioning (4th ed). National Strength & Conditioning Association. Champaign, IL: Human Kinetics.

Kenney, W. L., Wilmore, J. H., & Costill, D. L. (2019) Physiology of Sport and Exercise (7th ed.). Champaign, IL: Human Kinetics.

Matsuo, Tomoaki; Ohkawara, Kazunori; Seino, Satoshi; Shimojo, Nobutake; Yamada, Shin; Ohshima, Hiroshi; Tanaka, Kiyoji; Mukai, Chiaki (2012). "Cardiorespiratory fitness level correlates inversely with excess post-exercise oxygen consumption after aerobic-type interval training". *BMC Research Notes*. 5: 646. doi:10.1186/1756-0500-5-646

Maughan, R.J., & Gleeson, M. (2010). The Biochemical Basis of Sports Performance (2nd ed.). New York: Oxford University Press.

McArdle, W.D., Katch, F.I., & Katch, V.L. (2015). Essentials of exercise physiology (5th ed.). Philadelphia: Lippincott Williams & Wilkins.

Murray, B., & Kenney, W. L. (2016). Practical Guide to Exercise Physiology. Champaign, IL: Human Kinetics.

Stojanović, E., Ristić, V., McMaster, D.T. *et al.* Effect of Plyometric Training on Vertical Jump Performance in Female Athletes: A Systematic Review and Meta-Analysis. *Sports Med* 47, 975–986 (2017). https://doi.org/10.1007/s40279-016-0634-6

Silva, A.F.; Clemente, F.M.; Lima, R.; Nikolaidis, P.T.; Rosemann, T.; Knechtle, B. The Effect of Plyometric Training in Volleyball Players: A Systematic Review. *Int. J. Environ. Res. Public Health* (2019), *16*, 2960.

Vernon G. Coffey and John A. Hawley. (2017). Concurrent exercise training: do opposites distract? *J Physiol*. 595(9): 2883–2896. doi: 10.1113/JP272270

王鶴森等 (2015) 運動生理學（第二版）。台灣：新文京。

李水碧等（譯）(2016)《體適能評估與運動處方 (2 版)》。台北市：禾楓書局。

林貴福等（譯）(2017)《提升運動訓練水準及競技運動表現: 速度、敏捷及反應的運動訓練法含 260 種專項運動訓練課程》。台北市：禾楓書局。

田麥久 (主編) (2006) 《運動訓練學》。北京：高等教育出版社。

全國體育院校教材委員會 (2005)《運動生理學習題集》。北京：人民體育。

沈劍威、阮佰仁 (2006)《體適能基礎理論》(第二版) 。香港：中國香港體適能總會。

陳啓明 (主編) (1995)《運動醫學與科學》。香港：中文大學出版社。

傅浩堅、楊錫讓 (主編) (2005)《運動健身的科學原理》。香港：商務印書館。

黃玉山 (主編) (2005) 《運動處方理論與應用》。廣西：廣西師範大學出版社。

鄧樹勛、王健、喬德才 (主編) (2005) 《運動生理學》。北京：高等教育出版社。

中國香港體適能總會 (2017)。器械健體導師手冊。香港：中國香港體適能總會出版。

阮伯仁，沈劍威，鄭毓全，許世全等 (2017)。體適能導師綜合理論。香港：中國香港體適能總會。

林正常等 (2017) 《運動科學概論 (二版)》。台中：華格那出版社。

Reference for Students

American College of Sports Medicine. (2017). ACSM's guidelines for exercise testing and prescription (10th ed.). Philadelphia, PA: Lippincott Williams & Wilkins.

Bushman, B.A. (2016). ACSM's Complete Guide to Fitness & Health (2nd ed). American College of Sports Medicine. Champaign, IL: Human Kinetics.

Kenney, W. L., Wilmore, J. H., & Costill, D. L. (2019) Physiology of Sport and Exercise (7th ed.). Champaign, IL: Human Kinetics.

沈劍威、阮佰仁 (2006)《體適能基礎理論》(第二版)。香港：中國香港體適能總會。

阮伯仁，沈劍威，鄭毓全，許世全等 (2017)。體適能導師綜合理論。香港：中國香港體適能總會。

林正常等 (2017) 《運動科學概論 (二版)》。台中：華格那出版社。

陳啓明 (主編) (1995)《運動醫學與科學》。香港：中文大學出版社。

傅浩堅、楊錫讓 (主編) (2005)《運動健身的科學原理》。香港：商務印書館。

黃玉山 (主編) (2005) 《運動處方理論與應用》。廣西：廣西師範大學出版社。

雷雄德、林思為 (2019) 。《運動 x 營養：講是又講非》。 一丁文化出版社，ISBN: 978-988-78157-6-1

雷雄德 (2017)。《請問雷博士：運動科學是與非》。 一丁文化出版社，ISBN: 978-988-77200-6-5

Related Websites

1. American College of Cardiology
   https://www.acc.org

2. American Heart Association Recommendations for Physical Activity in Adults
   https://www.heart.org/en/healthy-living/fitness/fitness-basics/aha-recs-for-physical-activity-in-adults?utm_source=redirect_heartorg&utm_medium=referral&utm_campaign=301

3. Australian Institute of Sport
   https://www.sportaus.gov.au/

4. Brianmac Sports Coach
   https://www.brianmac.co.uk/index.htm
   - Principles of Training
     https://www.brianmac.co.uk/trnprin.htm

5. Gatorade Sports Science Institute
   https://www.gssiweb.org/en
   - Training & Performance
     https://www.gssiweb.org/en/sports-science-exchange/All/training-performance

6. HKPE.NET (in Chinese only)
   http://www.hkpe.net/hkdsepe/
   - Running Training (in Chinese only)
     http://www.tswongsir-runners.guide/

7. Peak Performance
   https://www.sportsperformancebulletin.com/

8. Sportscience
   http://www.sportsci.org/index.html

9. Society of Chinese Scholars on Exercise Physiology and Fitness
   http://www.scsepf.org/

10. World Athletics
    https://www.worldathletics.org/about-iaaf/documents/health-science

11. Hong Kong Sports Institute
    https://www.hksi.org.hk

12. Hong Kong Anti-Doping Committee
    https://www.antidoping.hk/