

Physiological adaptations in response to training

- Resting heart rate
- Stroke volume and cardiac output
- Oxygen uptake and lung capacity
- Haemoglobin level
- Muscle hypertrophy
- Effect on fast/slow twitch muscle fibres

Syllabus

- Need to relate back to principles of training and use your knowledge from types of training also (aerobic, anaerobic, strength).

- physiological adaptations in response to training
 - resting heart rate
 - stroke volume and cardiac output
 - oxygen uptake and lung capacity
 - haemoglobin level
 - muscle hypertrophy
 - effect on fast/slow twitch muscle fibres

- examine the relationship between the principles of training, physiological adaptations and improved performance

Resting Heart Rate

- **Resting heart rate** is the number of heartbeats per minute while the body is at rest.
- The average persons resting HR is between 60-80 beat per minute (BPM)
- This figure can vary significantly based on age, fitness levels and even stress levels the individual is experiencing when they are tested
- The adaptation of aerobic training is that resting heart rate will decrease over time. Resistance (strength) training also lowers resting heart rate but NOT as significantly as aerobic training.

Resting HR (cont)

Google resting HR it says: “For athletes or people who often perform cardiovascular activity, “a normal resting heart rate may be closer to 40 beats a minute”, with the most noted example being that Lance Armstrong reportedly had a resting pulse of 32 BPM when he was in peak conditioning.”

What does a resting HR of 32BPM actually mean?

It means Lance’s heart does not have to work as hard as a person with a higher resting HR. His heart is pumping the same amount of blood but with fewer beats. Elite athletes have a stronger cardiac (heart) muscle.

Resting HR (cont).

- When we undertake aerobic training the heart becomes stronger and more efficient over time.
- This leads to a lower resting HR.
- Using the principles of training if you apply the progressive overload and training threshold principles this will lead to a lower resting HR.

Resting HR (cont)

- A benefit of having a lower resting HR is the heart is able to return to its resting HR quicker after exercise.

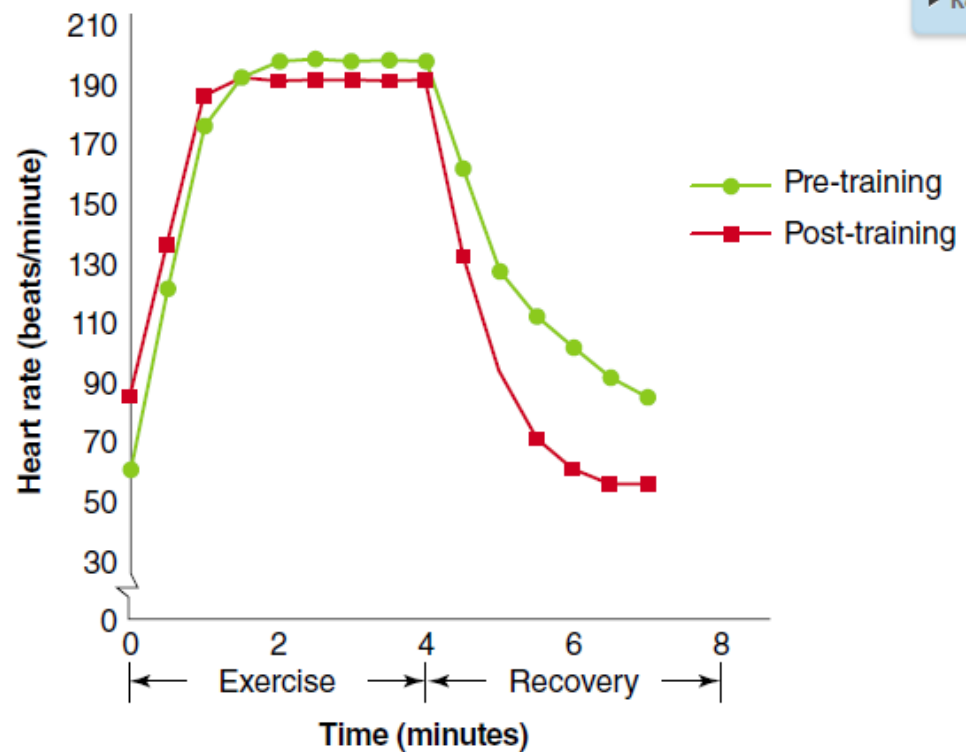


Figure 5.34: The effect of training on heart rate (Source: JH Wilmore and DL Costill, op. cit. figure 9.7, p. 281.)

Resting HR (cont)

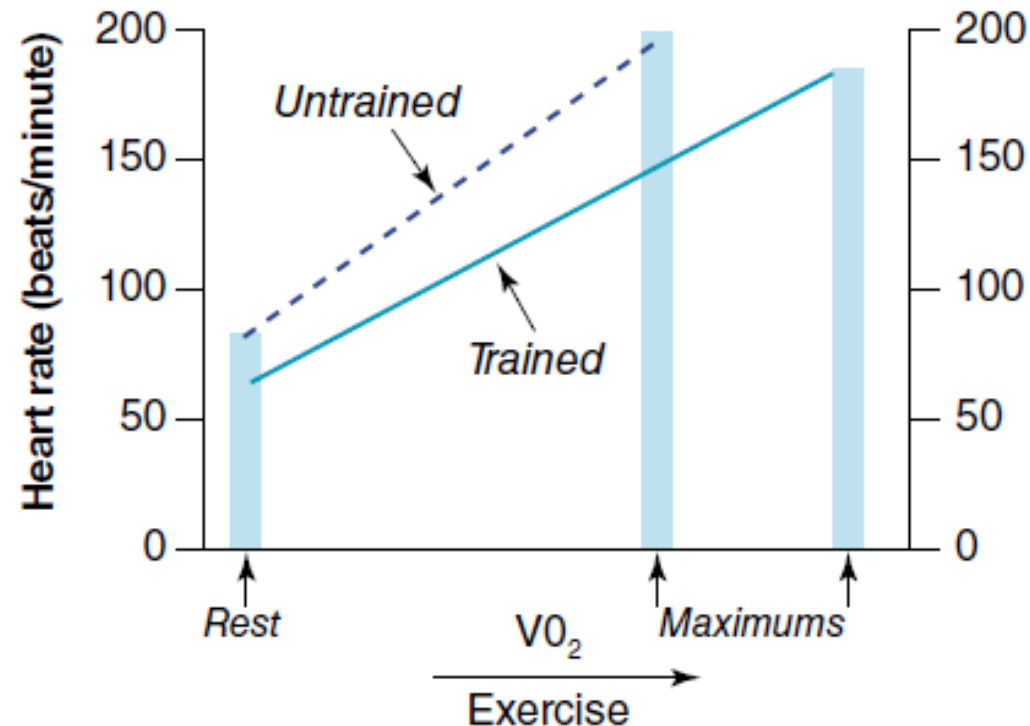


Figure 5.35: The effect of exercise on maximal heart rates of trained and untrained people (Source: E Fox and D Matthews, *The Physiological Basis of Physical Education and Athletics*, 4th edn, 1989, The McGraw-Hill Companies, Inc., Iowa, p. 250.)

2014 HSC Paper

12 What is cardiac output?

- (A) The volume of blood ejected by the heart per minute
- (B) The volume of blood sent to the lungs for oxygenation
- (C) The volume of deoxygenated blood returning to the heart
- (D) The volume of blood sent by the left ventricle of the heart during each contraction

Stroke Volume and Cardiac Output

- **Stroke volume** is the amount of blood ejected by the left ventricle of the heart during a contraction. (1 SQUEEZE) It is measured in mL/beat.
- **Cardiac output** is the amount of blood pumped by the heart per minute. It is determined by $SV \times HR$. It can be expressed as $CO = SV \times HR$ (mL/min)

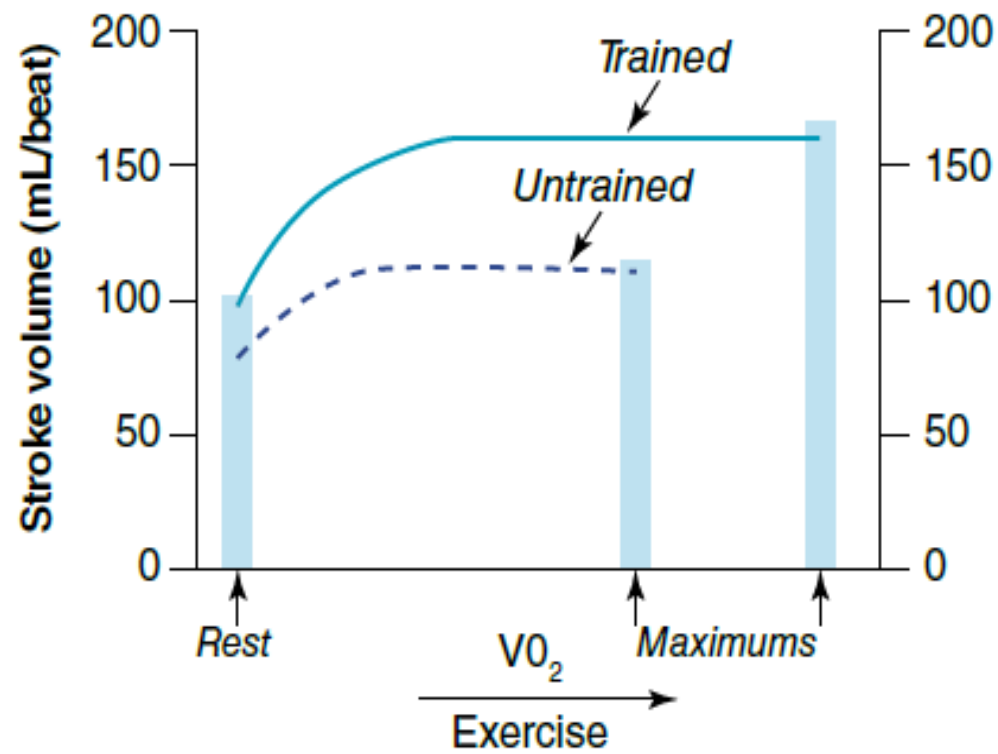
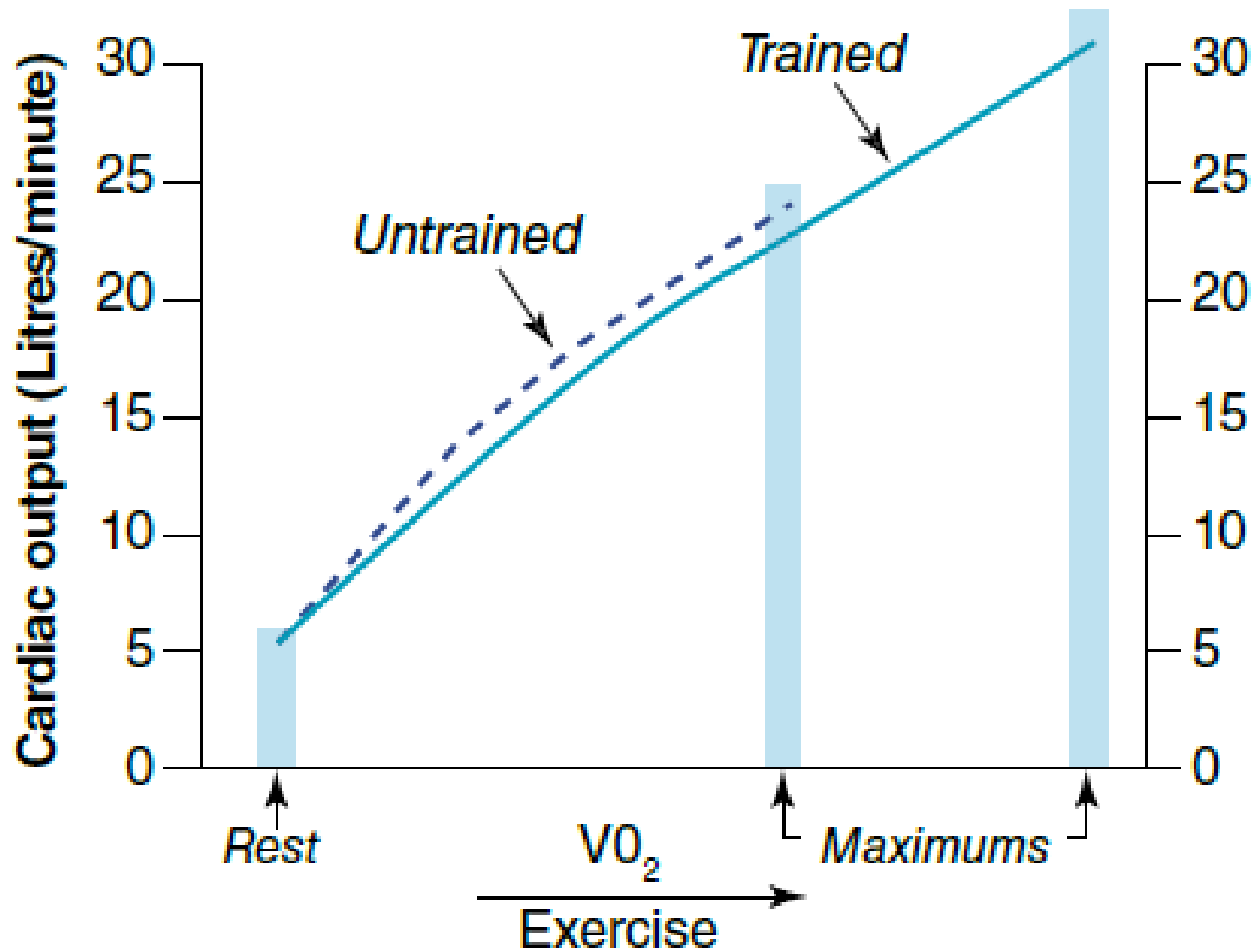


Figure 5.36: The effect of training on stroke volume (Source: E Fox, RW Bowers and M Foss, op. cit., p. 250.)

Figure 5.37: Changes in cardiac output with endurance training



SV & CO (cont)

- The heart (a muscle) becomes stronger with aerobic training and can therefore pump more blood to the working muscles, which improves performance.
- The physical adaptation of aerobic training on Stroke Volume is that it increases.
- The physical adaptation of aerobic training on cardiac output is that it increases.

SV and CO (cont).

- Applying the principles of progressive overload and training thresholds to an aerobic training program over a sustained period of time will lead to improvements in stroke volume and cardiac output. The principle of reversibility will take effect with any extended breaks in training which will lead to a decrease in SV and CO.

2011 HSC Paper

- 20** Why is the maximal cardiac output of a trained athlete different from that of an untrained athlete?
- (A) The untrained athlete has a higher cardiac output due to a lower resting heart rate.
 - (B) The untrained athlete has a lower cardiac output due to a lower resting heart rate.
 - (C) The trained athlete has a higher cardiac output due to a larger stroke volume.
 - (D) The trained athlete has a lower cardiac output due to a lower stroke volume.

Oxygen uptake and lung capacity

- **Oxygen uptake (VO_2)** is the ability of the working muscles to use the oxygen being delivered.
- The most significant improvements in response to aerobic training are in **oxygen uptake (VO_2)**.
- Maximal oxygen uptake, or $\text{VO}_{2\text{max}}$, is regarded as the best indicator of cardiorespiratory endurance because it indicates the maximal amount of oxygen that muscles can absorb and use at that level of work.

OU & LC (cont)

- Measurements are expressed in millilitres of oxygen per kilogram of body weight per minute (mL/kg/min). I.e. amount of oxygen used in a minute.
- Maximal oxygen uptake is relatively easy to estimate using tests such as bicycle ergometry in the laboratory, or field tests such as the 12-minute run or the multistage fitness test. (Beep test – we love it!)

OU & LC (cont)

- For example in the beep test there comes a point where you reach your maximum oxygen uptake (where you can't go on)...this is your VO2 max.
- What was your last score on the beep test?
- **Beep Test Score Calculator (Imogen 10.1)**
- <http://www.topendsports.com/testing/beepcalc.htm>

OU & LC (cont)

- The higher the VO₂ max the greater the aerobic performance by the athlete.
- For an untrained athlete the average VO₂ max is approx 40ml/kg/min
- The highest recorded value for a female, world-class, endurance athlete is 75 mL/kg/min and the highest for a male athlete is 94 mL/kg/min.

OU & LC (cont)

- Oxygen uptake increases with high intensity aerobic and anaerobic interval training.
- Physiological adaptation is that oxygen uptake increases with high intensity aerobic and into the anaerobic training zone (principle of training threshold)

OU & LC (cont)

- **Lung capacity** is the amount of air that the lungs can hold.
- Total lung capacity is about 6000 mL in males and slightly less in females due to their smaller size.
- In general, lung volumes and capacities change little with training, there is a slight increase. Why?

OU & LC

- You cannot increase the size of your lungs.
- Any increase in lung capacity that does come from aerobic training comes from an increase in the number of capillaries (where oxygen exchange happens) produced in the lungs and therefore more oxygen with each breath.
- Some research suggests strengthening core muscles around the lungs can lead to more efficient lungs.

OU & LC

- Physiological adaptation of lung capacity is an increase with aerobic training and some strength training of the core but is not as significant as some of the other adaptations (such as stroke volume or resting HR).

Haemoglobin level

- **Haemoglobin** is contained in the red blood cells of the body. It is the substance in blood that binds to oxygen and transports it around the body. I.e haemoglobin carries oxygen to the muscles.
- Therefore, if you have more haemoglobin then you can get more oxygen to the working muscles which leads to an improved performance.

Haemoglobin (cont)

- The most efficient way for the body to produce more haemoglobin is through training at high altitude.
- The air becomes thinner the higher you go above sea level so the body will start to produce more haemoglobin to transport the oxygen to the working muscles.
- Is there an illegal way?..... (Lance Armstrong)

Haemoglobin (cont)

- The physiological adaptation of aerobic training on haemoglobin levels is that it is increased and enhanced even further when training at altitude. (over 2400m is best, 2230m Mr Koziosko)

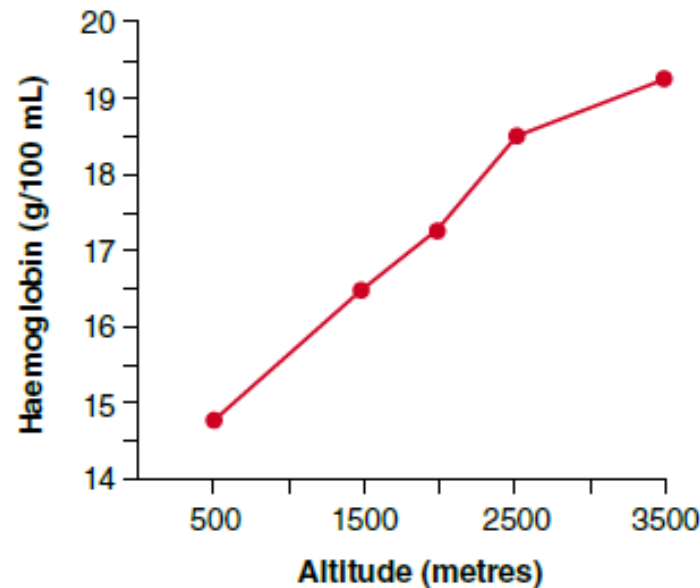


Figure 5.41: The effect of altitude on haemoglobin levels in males (Source: JH Wilmore and DL Costill, *ibid.*, fig. 11.4, p. 347.)

MT. EVEREST

8848m

ALTITUDE AUSTRALIA

Up to 5000m

MT. KOSCIUSZKO

2228m

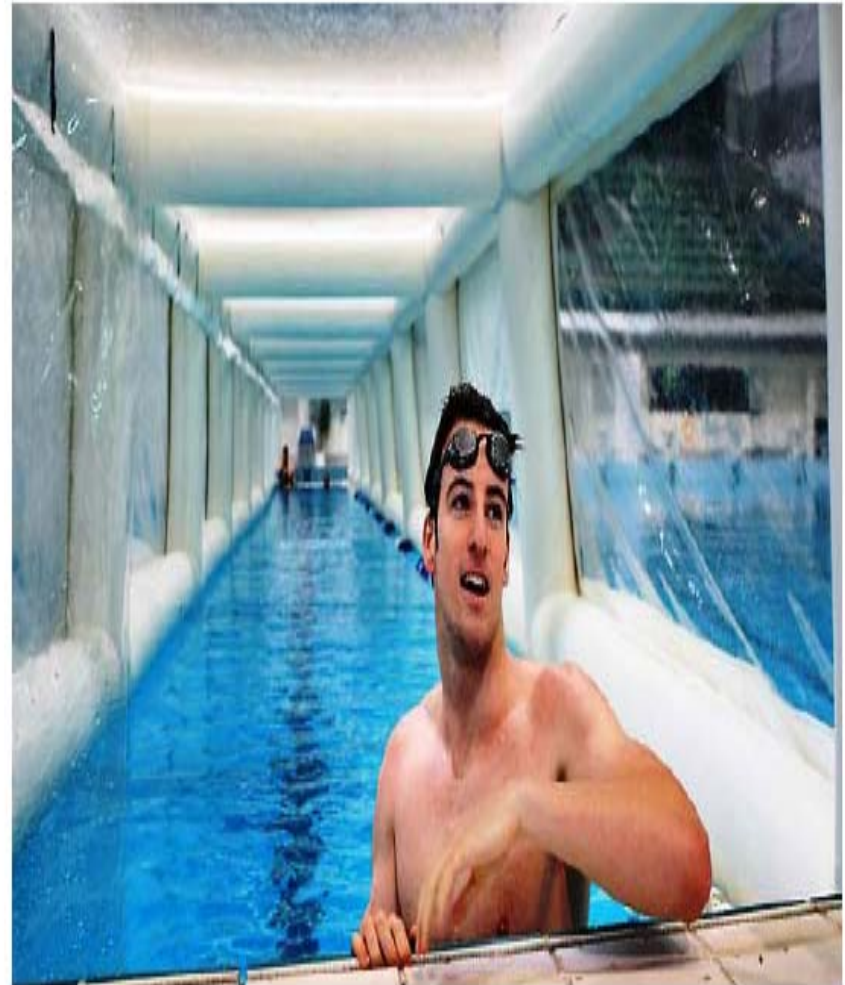
ASPEN COLORADO

2405m

ALTITUDE TRAINING GYM

CENTRAL COAST BRANCH NOW OPEN

Now anyone can become fitter, faster, stronger, improve endurance, acclimatise or simply lose weight, in less time.



Geoff Heugill and James Magnussen using the Simulated Altitude Training Pool at NSW Institute of Sport.



Muscle Hypertrophy

- **Muscle hypertrophy** is a term that refers to muscle growth together with an increase in the size of muscle cells/fibres.
- (Think hypertrophy is a BIG word...means muscles get BIGGER! Atrophy...the opposite is a SMALL word...muscles get smaller if they are not worked)
- Muscles become larger by following a resistance or weight training program

Muscle Hypertrophy (cont)

- Training causes structural changes in muscle fibres, leading to hypertrophy.
- After a workout the body repairs and replaces damaged muscle fibres and new muscle fibres (myofibrils) are formed.
- They increase the thickness of the muscle and therefore hypertrophy occurs.
- The adaptation of muscle hypertrophy occurs after the workout while the body rests. A reason why bodybuilders take protein shakes is to assist in the body's ability to repair muscle fibres after a workout to increase muscle hypertrophy.

Muscle Hypertrophy (cont)

- The physiological adaptation of resistance/strength training is increase in muscle hypertrophy

Muscle Hypertrophy (cont)

- Training needs to address the overload principle to encourage muscle hypertrophy.

	Reps	Sets
Endurance	+12	2-3
For Hypertrophy	6 to 12	3 to 6
Strength	3 to 6	2 to 6
Power	1 to 2	3 to 5

This can be done by lifting heavier weights, increasing sets and reps or a combination of all three. The MAIN focus is to increase weight.

Muscle Hypertrophy

- The principle of specificity is also important in targeting muscles or regions of the body where hypertrophy is required.
- The principle of reversibility will also come into play if the individual has an extended period of time away from training. (muscle atrophy...decrease in muscle size)

Effect on fast/slow twitch muscle fibres

- **Slow-twitch muscle fibres** contract slowly and for long periods of time. They are recruited for endurance-type activity such as marathons. (red)
- **Fast-twitch muscle fibres** reach peak tension quickly and are recruited for power and explosive movements such as throwing and lifting. (white)

Effect on fast/slow twitch muscle fibres (cont)

- The make up of a persons fast or slow twitch fibres is based on genetics, therefore it's not possible for an athlete with mainly slow twitch muscle fibres to change to fast twitch with training – one type will be predominant over the other.
- From your experience in sport, what is your dominant muscle fibre?

Effect on fast/slow twitch muscle fibres (cont)

- Training needs to be specific to the goals the athlete wishes to achieve (specificity).
- For example marathon runners have predominantly slow twitch muscle fibres so training of the aerobic energy system is important.
- Shot putters need speed and power, need to train fast twitch muscle fibres.
- Physiological adaptations will lead to increased efficiency of the fibres.

Summary Physiological Adaptations

- Resting heart rate: decreased – healthy 60bpm – can go as low as 30 bpm.
- Stroke volume: increased due to stronger and larger left ventricle in the heart.
- Cardiac output: increased due to higher stroke volume.
- Oxygen uptake: increased VO₂ max as the efficiency of many body systems improves.
- Lung capacity: small increase but greater efficiency.
- Haemoglobin level: increased oxygen carrying capacity.
- Muscle hypertrophy: strength training and anaerobic training lead to greater hypertrophy – some increase for aerobic.
- Fast-twitch muscle fibres: anaerobic leads to increased size and efficiency.
- Slow-twitch muscle fibres: aerobic leads to increased efficiency.

2010 HSC Paper

18 What are the characteristics of fast twitch muscle fibres?

- (A) Explosive activities, fatigue slowly
- (B) Endurance activities, fatigue slowly
- (C) Explosive activities, fatigue quickly
- (D) Endurance activities, fatigue quickly

19 Which option reflects the physiological adaptations expected in an endurance swimmer's training program?

	<i>Oxygen uptake</i>	<i>Haemoglobin level</i>	<i>Resting heart rate</i>	<i>Stroke volume</i>
(A)	Increase	Increase	Decrease	Increase
(B)	Increase	Decrease	Decrease	Increase
(C)	Increase	Increase	Decrease	Decrease
(D)	Increase	Decrease	Increase	Increase

2012 HSC Paper

- 20 Which physiological adaptations occur in athletes when regularly training at sub-maximal levels to improve their aerobic performance?
- (A) Increased cardiac output, decreased stroke volume and muscle atrophy
 - (B) Increased cardiac output, increased lung capacity and muscle hypertrophy
 - (C) Decreased resting heart rate, decreased haemoglobin levels and increased oxygen uptake
 - (D) Decreased resting heart rate, increased stroke volume and increased haemoglobin levels

2010 HSC Paper

Question 23 (3 marks)

Outline THREE physiological adaptations in response to aerobic training.

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