Maximum Oxygen Consumption

\( \text{VO}_{2}\text{max} \)
**VO_{2max}**

- Maximum oxygen consumption, also referred to as \( VO_{2\max} \) is one of the oldest fitness indices established for the measure of human performance.

- The ability to consume oxygen ultimately determines endurance capacity.

- A high \( VO_{2\max} \) score indicates that a person has a high aerobic fitness level and has the ability to endure exercise for long periods of time.

- Some people are born with an enhanced endurance capability but everyone can improve their aerobic capacity by as much as 20% with appropriate training.
Determinants of Maximal Oxygen Consumption

3 major factors determining maximal oxygen consumption:

• Cardiac output (the volume of blood pumped by the heart in one minute)

• The oxygen carrying capacity of the blood (determined by hemoglobin in red blood cells)

• The amount of exercising skeletal muscle and the ability of muscle to utilize supplied oxygen
Cardiac Output

- **Cardiac output** \((Q)\) is defined as the mathematical product of **heart rate** times **stroke volume**. Heart rate is the number of times the heart contracts per minute. Stroke volume represents the amount of blood ejected by the heart with each beat.

- Cardiac output in a resting individual of average size is about 5 liters/minute. In an untrained individual heart rate is about 72 beats per minute so stroke volume is about 70 milliliters.

- Maximal heart rates are related to age and appear to be unrelated to the level of fitness. The rule of predicting maximum heart rate by subtracting age from 220 is good for a rough index of maximum heart rate but it is far from precise, and may differ by 20 beats or more for individuals of the same age!
• Stroke volume increases with exercise, and maximal cardiac output in highly trained individuals may attain 40 liters/minute.

• The ability to generate high maximal cardiac output is a major determinant of the ability to have a high maximal oxygen consumption.
Oxygen Carrying Capacity

• Red blood cells, the principle component of blood, carry an iron containing protein called hemoglobin.

• Hemoglobin has binding sites for oxygen, and during exercise it off loads oxygen for consumption by the working muscles.

• In most individuals, the amount of hemoglobin in the blood is about 15 grams/100 milliliters of blood.

• Depending on the speed with which blood passes through metabolically active tissues, oxygen levels in the blood can drop (from 20mls after passing through the lungs) to below 3 mls per 100 mls blood.

• This is why the body must switch from aerobic to anaerobic energy production during intense exercise.
• **Anemia** refers to a condition where red blood cell mass is reduced and the blood carries less oxygen as a result.

• Anemia can lead to a reduction in maximal oxygen consumption due to a decreased supply of oxygen to the working muscle, but is usually manifest through a feeling of malaise during everyday activity and workouts.
Blood Doping

• **Blood doping** is the term applied to the artificial augmentation of red blood cells.

• Blood is taken from an athlete before competition, allowing enough time for the body to restore normal blood levels. The removed blood is then reinfused shortly before competition.

• This allows the body to carry more red blood cells, and consequently more oxygen, than it normally would.

• Elite athletes have died by this practice because the blood becomes very viscous or thick and is difficult for the heart to pump around the body.
• Erythropoietin is a hormone made by the liver and kidneys that regulates the production of red blood cells in the body.

• Erythropoietin (EPO), has been produced synthetically for use in subjects with chronic anemia or renal failure.

• EPO has been used for illegal performance enhancement by athletes particularly long distance cyclists (Tour de France).
• Living at high altitude also increases the amount of erythropoietin made by the kidneys and dwellers at high altitude (typically greater than 7000 feet) have more red blood cells per volume of blood.

• Adaptation takes two weeks to one month to take place.

• Short daily exposures to high altitude (low barometric pressure and resultant decreased oxygen content of the air) will not cause an increase in red blood cell count.
• For haematological (blood) changes the optimal altitude is around 2500m. Studies looking at the effects on running economy and muscle buffering have shown that there may even be better results with altitude exposures of around 3000m.
• Studies have also shown that it takes approximately 14 days minimum for an athlete to acclimatise to the effects of training at altitude above 2000m,

• optimal benefits are obtained after approximately 3 weeks of exposure.

• little gain from extending the exposure period beyond 4 weeks, although there may be certain individuals who benefit from longer exposure times.
Fatigue, breathlessness, headache and are just a few of the symptoms of altitude exposure.

There has been more recently a strategy of “live high, train low” has been used by athletes. With this method the athlete spends the majority of their day at high altitude, but descends to train at sea level for the high intensity sessions.

This tricks the body into believing it is living at high altitude & allows the athlete to perform better quality training at higher intensities.
Some athletes continue hypoxic training back at their sea level base by using hypoxic chambers or tents. Athletes spend several hours per day (including sleeping) in a low oxygen environment whilst continuing to train in their normal sea level environment.

Not as effective as spending time at “natural” high altitude. May need to spend as much as 20 hours per day in order to achieve the desired result.
Skeletal Muscle Mass

• The larger the mass of exercising skeletal muscle the more oxygen the body will consume.

• Endurance training causes key enzymes in aerobic metabolism to increased so that the body is more efficient at burning fat at higher intensities.

• Endurance trained muscles have a greater ability to extract oxygen from the blood because they use it faster, and have more capillaries supplying oxygen.