

VO2 max

VO2 max at Altitude (From 'Lore of Running' fourth Edition – Prof Noakes)

The term VO2 max can be more easily understood if it is considered that it is the athlete's maximum work rate that predicts athletic performance, rather than his or her VO2 max. This maximum work rate is the result of a complex interaction of heart and skeletal muscle factors, which combine to establish the measured maximum rate of oxygen use by the muscles at that peak work rate (VO2 max). But the measured peak rate of oxygen consumption is the result, not the cause, of the peak work rate that is achieved.

VO2 max in Runners

A group of scientists between 1970 and 1979 were probably the first scientists to suggest that there may be differences, in the amount of oxygen that athletes require when running at the same speed.

In more simple terms, we could compare two athletes to two different cars, one of which uses less fuel than the other when traveling at the same speed, and is therefore said to be more economical.

To avoid confusing the concept of running economy, with that of the VO2 max, it is important to point out that running economy relates to the amount of oxygen used by the athlete when running at a constant submaximal speed, whereas VO2 max refers to the rate of oxygen used by that individual athlete when running at the maximal speed that that athlete can sustain for between 5 and 8 minutes.

The authors concluded that a high VO2 max (anything above 67ml O₂.kg⁻¹min⁻¹) helped each athlete gain membership of an elite performance group. However, within this select group, running economy, and not VO2 max was the factor controlling success in the 10 km race.

I interpret these data differently. To join the elite group of runners the athlete needs both a superior and efficient heart, which is able to achieve a high cardiac output at the maximum coronary blood flow, but also muscles with superior contractility, elasticity and fatigue resistance. A combination of superior heart and skeletal muscle function then allows the athlete to achieve a high work rate during the maximum test to exhaustion.”

The high work rate demands a high rate of oxygen consumption which is interpreted as a high VO2 max. But the exact VO2 max which each athlete

achieves (whether in the laboratory or in racing) will be determined by his or her running economy, and is independent of the peak work rate that is achieved. At the same maximal work rate, uneconomical runners will have high VO₂ max values, and economical runners will have much lower values. But the real predictor of performance is the work rate (running speed) not the VO₂ max measured at that work rate.

Exercise at Altitude

With an increase in altitude, the barometric pressure decreases and with it the oxygen content of the air. The fall in the oxygen content of the air causes a predictable fall in the VO₂ max equivalent to about 10 per cent for every 1000m above 1200m.

But the reason why climbers complain of weakness in their muscles and an inability to climb rapidly at extreme altitude are not, as discussed subsequently, those that might seem the most obvious.

The VO₂ max of Reinhold Messner, arguably the most remarkable high-altitude climber of all time is only 48.8 ml O₂.kg⁻¹.min⁻¹ (milliliters oxygen per kilogram per minute), essentially the same as that of Sir Edmund Hilary, who in 1953, became one of the first people to reach the summit of Mount Everest. These values are little better than those found in untrained but healthy young men.

In fact the key to successful climbing at altitude is an ability to sustain higher than expected oxygen tension in the arterial blood supplying both the heart and brain (and has nothing to do with the capacity of the exercising muscles to use oxygen)

Exercise at altitude provides the single best test of the Central Governor Model. Crucial findings are:-

- 1) Blood lactate concentrations **fall** progressively at peak exercise with increasing altitude.
- 2) Heart rate and heart output – the amount of blood pumped by the heart, most of which goes to the muscles being exercised – decreases at increasing altitude. Most crucial of all, recruitment of skeletal muscle also falls during exercise at altitude. Hence, neither the heart nor the skeletal muscles become anaerobic at extreme altitude when the oxygen content of inspired air is so low that it is barely able to sustain human life.

But according to the Cardiovascular/Anaerobic Model, the skeletal muscle and the heart must surely become anaerobic under these conditions.

If the muscles were able to work normally, as at sea level, the oxygen content of the blood supplying the (heart and brain) would drop so low that the normal functioning of the heart and brain would be impossible, inducing unconsciousness. Without the Central Governor, mountaineers would risk death from heart and brain hypoxia whenever they ascended above 5000m. Indeed, we can safely predict that if the human had been designed by exercise physiologists according to the Cardiovascular/Anaerobic model, no human would have survived a climb above base camp at Mount Everest, much less have reached the summit.

There are differences between people living at altitude and those living at sea level. Altitude natives whose VO₂ max is almost the same as residents at sea level, have substantially higher VO₂ max at altitude.

The Sherpa's superior performance at altitude, is not explained by the capacity of their leg muscles to use oxygen, but would result from:

- A higher red blood cell concentration:
- An increased ventilatory function which would allow more oxygen to be transferred from the lungs to the blood during exercise at altitude:
- A more extensive network of blood vessels in the heart, which is able to accommodate a larger coronary blood flow:
- An increased volume of mitochondria in the heart and :
- As a result, superior myocardial efficiency so that an even larger cardiac output can be achieved at these high levels of blood and oxygen supply to the heart.