

The Science Behind Training

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There are three key physiological areas that contribute greatly to endurance performance and aerobic capacity. These areas are:

1. $VO_2\max^1$
2. Running economy
3. Lactate threshold

Improvement in any of these areas will result in an improvement in running performance.

However, it has been shown that emphasising training on running economy and lactate threshold will result in better improvement in performance than concentrating on improving $VO_2\max$.

1. $VO_2\max$

Definition

$VO_2\max$ means the maximum amount of oxygen a person can utilize.

The amount of energy used during exercise is directly related to the amount of oxygen consumed because the breakdown of glycogen and fat for energy requires oxygen.

Oxygen consumption increases in a linear relationship to running speed. During rest, our body only requires around 0.2-0.3 litres of oxygen per minute - this is expressed as VO_2 . (Volume per minute: V and oxygen: O_2) During maximal exercise, this term becomes $VO_2\max$.

Maximum oxygen uptake is measured in either litres/minute or scaled to body weight and expressed in millilitres per kilogram per minute ($ml/kg/min$ or $ml\cdot kg^{-1}\cdot min^{-1}$).

Benefits of improving $VO_2\max$

- The heart can work more effectively, allowing more intense workouts
- Improved performance in events, slashing personal bests
- Greater ability to call upon a wider range of speeds

Some physiological factors

It has been shown that a person's $VO_2\max$ depends to a large extent on the efficiency of the cardio-respiratory, vascular and cellular metabolic system. The implication is that training to improve $VO_2\max$ can lead to increased cardiac muscle performance and increased aerobic capacity of skeletal muscle before the onset of blood lactic acid accumulation (OBLA).

Genetics: However, $VO_2\max$ is largely genetically determined and research findings have shown that whatever level of aerobic capacity an individual possess, it can be improved, with training, by about 25%.

Aerobic capacity is also closely linked with the genetic composition of aerobic muscle fibres. Aerobic capacity is affected by the carriage and delivery of oxygen from the lungs to the working muscles and thus there might be a link between the oxygen carrying capacity of the blood and $VO_2\max$.

Gender: Oxygen uptake in females is usually 65-75% of those of males. A recent survey of 1700 men and women revealed typical $VO_2\max$ values of 55 $ml/kg/min$ and 40 $ml/kg/min$ for men and women respectively for the age category 16-24 years. $VO_2\max$ also declines with age.

Elite runners typically have values exceeding 80 $ml/kg/min$.

Altitude training: Altitude training causes an increase in the haemoglobin content of the blood and since haemoglobin molecules carry oxygen to the muscles, athletes who have trained at altitude then compete at sea level seem to have an enhanced aerobic performance.

Of course there are many factors such as technique, running economy and psychological factors which have a major influence on aerobic performance and it is for these reasons that $VO_2\text{max}$ alone does not predict performance.

Measuring $VO_2\text{max}$

There are essentially two methods of measuring an individual's maximum aerobic capacity, a direct and an indirect method.

Direct method: The direct method to determine $VO_2\text{max}$ takes place in the controlled conditions of a physiological laboratory using some kind of ergometer, such as a treadmill, that controls the intensity of exercise and where the athlete's expired air is measured for oxygen and carbon dioxide content.

There are many different protocols that can be used but the aim is to take the athlete to exhaustion and monitor expired air at intervals along the way. Often capillary blood samples are also taken at regular intervals so that the point at which the athlete is producing more lactic acid than can be used up, is determined.

Indirect method: The indirect method of determining maximum aerobic capacity is based on the assumption that there is a direct relationship between heart rate and oxygen uptake. In other words as heart rate increases so does oxygen uptake. Maximum oxygen uptake can be predicted from heart rate values of an individual performing sub-maximal exercise.

Some tests involve exercises such as stepping up and down onto a bench, running at different speeds and inclines on a treadmill or the distance covered on a track in twelve minutes. These methods can be used in a fitness centre or on the track because little equipment is required.

Of course, predicted maximum oxygen uptake values are less accurate than those directly determined but are perfectly adequate as a guide to training status.

Heart rate

Since heart rate is directly related to oxygen uptake and much more convenient to measure, you can use it to help you train aerobically. One of the best ways to monitor your heart rate while running is to use a heart rate monitor. But what heart rate should you use?

Maximum heart rate

Calculate your theoretical maximum heart rate from the following formula:

$220 - \text{age in years} = \text{maximum heart rate (MHR)}$. This is sometimes called aged related maximum heart rate.

When starting training use a working heart rate of about 70% (i.e. $\text{MHR} \times 0.7$) of maximum and gradually increase the intensity up to about 80%.

It is very important for aerobic training that you do not exceed about 80% of your maximum heart rate because if you do then you start to work anaerobically and this is counter productive to endurance running.

2. Running economy

Definition

Running economy is a physiological measure of the amount of oxygen required to run at a specific pace (below maximum pace). The more economic the runner, the less oxygen will be needed to run at that specific pace.

Generally, a runner with good running economy will feel more comfortable at faster speeds than one with low running economy and therefore be able to run faster.

Benefits of improving running economy

- Lowered perceived effort at your current race pace
- Increased endurance at current race pace as well as generally
- Ability to run faster than current competitive speed

The test

Measurement of running economy is carried out using the same treadmill test as for VO_{2max} .

A good simple test whether a runner has improved economy is running quicker times over a set distance while exercising at the same heart rate.

Running economy is one physiological factor that can be easily enhanced and trained with the correct program.

Training Tips

Strength Training: Recently a strong link has been established between training for strength and improvement in running economy. It was concluded that resistance work enhanced economy by eliminating wasted energy in excessive movement and stabilizing the running motion.

As with any strength work or training, it is recommended that progression starts from relatively easy workouts, building gradually to more difficult efforts.

Hills: An alternative to gym strength training is hill running. Hills provide resistance as a runner works against gravity.

Hill running strengthens individual muscle cells, which means fewer fibres are needed to be activated during running and the oxygen demands are thus lowered.

Short Intervals: When carried out correctly, interval running trains muscles to use oxygen more efficiently when working hard. This means an athlete will find it easier to run at a particular pace.

3. Lactate threshold

Definition

Lactate threshold is the running speed at which large amounts of lactate (also called lactic acid) begin to build up in the blood. High lactate levels cause pain in the muscles (sometimes described as 'burning') which causes an athlete to reduce the level of exertion - for a runner, to slow down.

A runner who has a high lactate threshold will be able to run at a faster pace with less lactate build up than a runner with a moderate or low threshold. Put simply, if your lactate threshold is high, you will run faster with less discomfort.

Lactate threshold is a superb indicator of performance in endurance events from 10 km races through to the marathon. This accumulation of lactate usually occurs at just below 10 km pace.

Benefits of improving lactate threshold

- Improved speed endurance over 10 km upwards
- Speeds up marathon pace
- Stamina to run strongly towards the end of a distance event

Physiological Aspects

When muscles convert stores of glucose into energy through a process called glycolysis, a by-product is lactic acid. This process occurs after a few seconds of exercise. During low intensity exercise, lactic acid is cleared before it can build up.

As the intensity of exercise increases, more lactate is produced. If the intense activity continues the body is unable to remove this lactate, which then builds up. This build up inhibits the muscle function, preventing exercise.

Training Tips

Lactate threshold training takes place at or just below the exercise intensity where there is an accumulation of lactic acid in the muscle.

Long intervals: These intervals can vary from 1 - 3 miles at varying faster paces, but should always stimulate a degree of lactate build up in order to familiarize the muscles with lactate clearance capabilities.

When performing such threshold sessions, it is important to take at least one week in four very easy, so allowing the muscles to recover. This will raise lactate threshold.

Tempo running: Tempo running involves running a specified distance, usually ranging from 4 to 6 miles at a pace just below threshold, something like 10 seconds a mile below 10 km pace. These longer periods of strenuous exercise are excellent for building endurance and generating lactate build up.

Conclusion

The key areas for improvement are VO_2max , running economy and lactate threshold.

VO_2max

- The maximum amount of oxygen a person can utilize relative to body weight
- Best improved by interval training

Running economy

- A physiological measure of the oxygen required to run at a specified pace that is lower than your maximum pace
- Best improved by strength training, hill running and running short intervals

Lactate threshold

- The running speed at which large amounts of lactate begin to build up in the blood. The higher the threshold, the faster the runner
- Best improved by running long intervals and tempo running

Note 1: VO_2max should be written with a dot over the 'V', but it has not been possible to reliably publish this character