International Journal of Yogic, Human Movement and Sports Sciences 2019; 4(1): 562-564

ISSN: 2456-4419
Impact Factor: (RJIF): 5.18
Yoga 2019; 4(1): 562-564

www.theyogicjournal.com
Received: 19-11-2018
Accepted: 22-12-2018

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Anaerobic threshold and maximum oxygen consumption (VO_2MAX) for distance runners - an overview

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Abstract
The amount of oxygen that can be utilized at maximal work is called aerobic capacity or VO_2 max. and is determined by measuring the amount of oxygen assimilated per kg of body weight per minute. The average man breathes approximately 6 liters of air per minute, at rest, and may consume volumes of air in excess of 150 liters per minutes during a hard 5- or 6 mile run. When increasing running pace or workload there is a point at which lactic acid begins to accumulate. This is a crucial workload, as lactic acid can inhibit muscle contraction and energy production and cause pain and a burning sensation. The lactate threshold for most males is between 165 and 180 beats per minute, with females being slightly higher, at about 175 to 185 beats per minute. Relatively high-intensity, short rest period interval work has also been found to improve the lactate threshold. Cycles of 2-3 minutes of work with 1-2 minutes of rest have been found to reduce lactate accumulation during the lactate threshold is one of the more important measurements that will be obtained during testing of an endurance athlete.

VO_2 max is the maximum capacity to transport and utilize oxygen during incremental exercise. It is also called maximal oxygen consumption or maximal oxygen uptake. It is also known as aerobic capacity, which reflects the physical fitness of a person exercise. The measurement of VO_2max is important, as in many athletic events a large amount of the energy needed to perform the exercise is produced through the use of oxygen. VO_2 max many factors must be considered by the coach and athlete.

Keywords: VO2max, Lactate threshold

Introduction

The current development in long distance running events and the enormous improvements of world records is the result of a target oriented optimization of the complex training process. In this context a number of trends are becoming evident: In the control of training more and more coaches are using lactate as a parameter to monitor training loads, although it appears that sports medicine has made rather exaggerated claims on the importance of lactate testing. In addition to lactate testing, heart rate monitoring is still used to regulate aerobic training and urea testing can be used to prevent overtraining. A significant increase of training loads and volumes at elite level has reached a stage where semi-specific training means, previously used only during injury are now employed regularly.

The amount of oxygen that can be utilized at maximal work is called aerobic capacity or VO_2 max. and is determined by measuring the amount of oxygen assimilated per kg of body weight per minute. Since oxygen has diffused into the blood stream before it can be utilized by the muscles, the volume of air breathed per minute is not necessarily a perfect correlate of oxygen consumption. However, a runner can adjust his running pace to permit a tolerable level of respiratory eustress. The average man breathes approximately 6 litres of air per minute, at rest, and may consume volumes of air in excess of 150 litres per minutes during a hard 5- or 6 mile run. The ability to ventilate to 25 times the resting rate for long periods of time during long runs is not as common among elite distance runners.

Lactate Threshold (or anaerobic threshold)

When increasing running pace or workload there is a point at which lactic acid begins to accumulate. This is a crucial workload, as lactic acid can inhibit muscle contraction and energy production and cause pain and a burning sensation. The point (heart rate or running pace) at which lactic acid begins to accumulate is called the Lactate Threshold. This measurement is also sometimes called the anaerobic threshold or onset of blood lactic acid. The lactate threshold measurement is very valuable as it is one of the more sensitive indicators of fitness level. For example, if training is ineffective the lactate threshold will be reached at a relatively low running speed; with more effective training the threshold will be achieved at a higher speed. Elite athletes reach the lactate threshold at a much higher running speed than sub-elites. The threshold is, once again, a function of effective training and also genetics. Many scientific studies indicate that the lactate threshold is one of the best predictors of distance running performance. The lactate threshold is also very valuable relative to training and competition. Training at the threshold has been found to improve performance and the capacity of the aerobic system. Interval training and "over distance" training should thus consider the running speed at which the lactate threshold is attained. The lactate threshold is one of the more important measurements that will be obtained during testing of an endurance athlete.

The lactate threshold for most males is between 165 and 180 beats per minute, with females being slightly higher, at about 175 to 185 beats per minute. Of all the measurements obtained during testing, the speed and heart rate at which the lactate threshold is obtained are probably the most important to remember when planning training. For comparison purpose, in competitive regional and national level distance runners, the lactate threshold is reached at speeds of 6:00 to 5:00 pace per mile. The lactate threshold is perhaps the best and most sensitive indicator of distance running performance. An individual who reaches the threshold at a speed of 10 mph (16.1 km/h) would most likely defeat an individual who reaches the threshold at any lower running speed. It is thus desirable to increase the speed at which the threshold is obtained; this can be accomplished by methods outlined below.

1. Training at speeds/heart rates near or at the threshold

The above information has provided you with the approximate speed and heart rate at which the lactate threshold is achieved. Of the two, training at this given heart rate is probably the most effective method for monitoring training intensity relative to the threshold. This knowledge may greatly improve training effectiveness as training near or at the threshold provides a very effective stimulus for improving factors associated with endurance performance.

For example, it was found that when highly-trained distance runners added a weekly 20 min run at the lactate threshold the speed at which the threshold was reached increased after 14 weeks of such training (Sjodin*et al*., Eur. J. Appl. Physiol. 49:45, 1982). This research also demonstrated that the addition of this single weekly run significantly improved many of the enzymes, which produce energy in muscle. Thus, steady-state training (i.e., longer distance, continuous runs) at the lactate threshold will improve the metabolic capacity of skeletal muscle even in well-trained athletes. It was also found that the addition of the 20 min run improved running economy. Thus, relatively long-duration runs (15-30 min) at the speed or heart rate of the lactate threshold should be considered when designing an effective endurance-training program.

2. Interval work

Relatively high-intensity, short rest period interval work has also been found to improve the lactate threshold. Cycles of 2-3 minutes of work with 1-2 minutes of rest have been found to reduce lactate accumulation during exercise. As with VO_2max, the principal is that skeletal muscle and the heart adapt when the level of exercise is close or above VO_2max.

Unfortunately, this is quite intense exercise, which cannot be maintained for a long period of time (5-15 minutes) due to the accumulation of lactic acid. The lactic acid diffuses out of the skeletal muscle by allowing a "recovery" period of walking or slow running between intense work bouts. Intervals thus allow a high workload to be maintained over a longer time period which results in maximal adaptations. With shorter, intense intervals, the stress is even greater. The endurance athlete and coach should thus not shy away from the performance of relatively "sprint" type work with an active recovery between each bout. Such work has been found to increase the lactate threshold, which is a very sensitive and accurate indicator of performance potential in endurance events.

Knowledge about the lactate threshold can also help in designing workloads/heart rates for various types of training. General recommendations are

1. Over distance runs and "easy" or recovery days should be performed at 80 to 90% of the lactate threshold.
2. Intensive, continuous distance runs (15-30 min duration) can be performed at approximately 100% of the lactate threshold, as discussed above. No more than one of these workouts should be performed per week.
3. Longer interval work (i.e., 800-1000 m repeats) should be performed at approximately 110-120% of the lactate threshold.
4. For shorter, intense interval work the lactate threshold is usually not considered. Keep in mind that such work, although commonly considered "anaerobic" can maximally stimulate the aerobic systems if adequate sets are performed with rest between the sets.

VO2max (maximal oxygen consumption)

The amount of oxygen that can be utilized at maximal work is called aerobic capacity or VO_2 max. and is determined by measuring the amount of oxygen assimilated per kg of body weight per minute. Since oxygen has diffused into the blood stream before it can be utilized by the muscles, the volume of air breathed per minute is not necessarily a perfect correlate of oxygen consumption. However, a runner can adjust his running pace to permit a tolerable level of respiratory eustress. The average man breathes approximately 6 litres of air per minute, at rest, and may consume volumes of air in excess of 150 litres per minutes during a hard 5- or 6 mile run. The ability to ventilate to 25 times the resting rate for long periods of time during long runs is not as common among elite distance runners.

VO_2 max is the maximum capacity to transport and utilize oxygen during incremental exercise. It is also called maximal oxygen consumption or maximal oxygen uptake. It is also known as aerobic capacity, which reflects the physical fitness of a person

Maximal oxygen consumption, also known as VO_2max, has long been considered the "gold-standard" for determining cardiorespiratory fitness level. Your VO_2max value is dependent upon several factors:

1. The ability of your muscle to use oxygen to produce energy.
2. The ability of your lungs, heart, and circulatory system to transport oxygen to the muscle.

3. Your body composition, which is the amount of fat and muscle you have.

The measurement of VO_2max is important, as in many athletic events a large amount of the energy needed to perform the exercise is produced through the use of oxygen. For example, it is estimated that approximately 25% of total energy comes from oxygen in short events which last 40 to 60 seconds. In events lasting 100 to 120 seconds about 50% of energy comes from oxygen and in events lasting 3-4 minutes about 65% of the energy comes from oxygen. Longer events such as distance running require greater than 90-95% of their energy from aerobic sources. A high VO_2max is indicative of an enhanced ability of the aerobic systems to provide this energy to the working muscle. Thus a measurement of the capacity of the aerobic system to produce energy is vital to assessing athletic performance. Successful athletes which participate in sports lastiing more than 1 minute generally possess a higher VO_2max then sedentary individuals or those in more short-duration, high-intensity oriented sports such as weightlifting or sprinting.VO_2max value is measured 'relatively' in the units of ml/kg/min or 'absolutely' in l/min. The VO_2max value in ml/kg/min is adjusted for your body weight while the value in l/min is your absolute maximal oxygen consumption. In many sports, such as running, the commonly used value is ml/kg/min, since the mass of the body must be moved against gravity. Absolute VO_2max is more appropriate for non-weight supported events such as swimming and cycling. Maximal oxygen consumption is determined by training and genetic endowment; the contribution of each is not known. VO_2max can indicate the potential of an athlete for participation in endurance-oriented events. VO_2max can also help determine if a specific training program is efficient in developing the aerobic system. How does your VO_2max compare to values in other athletes? Keep in mind that any one variable that is being measured as part of your evaluation does not predict athletic performance. However, there are ranges of VO_2max for many different sporting endeavours.

Ranges of VO_2max reported for International athletes in a variety of sports.

Range (ml/kg/min		
Sport	**Males**	**Females**
Nordic Skiing	69-95	56-74
Middle-distance running	70-86	55-70
Distance running	65-80	55-72
Rowing	58-74	48-68
Cycling	56-72	47-57
Swimming	54-70	48-68
Soccer	50-70	-----
Basketball	45-65	42-54
Baseball	40-60	-----
Untrained	38-52	30-46

VO2max values of some athletes (ml/kg/min):

Steve Prefontaine, middle distance runner, American record holder	84.4
Lance Armstrong, Tour de France Cycling Champion	83.8
Alberto Salazar, world record holder, marathon	78.0
Bill Rodger, world class marathoner	78.0
Grete Waitz, world class female distance runner	73.5
Frank Shorter, Gold Medalist, Munich Olympic Marathon	71.3
World Class male long-distance runners	78.7
World Class female long- and middle-distance runners	65.6
World Class male marathon runners	74.1
Elite middle-distance and male distance runners	76.9
Good national class male distance runners	69.2

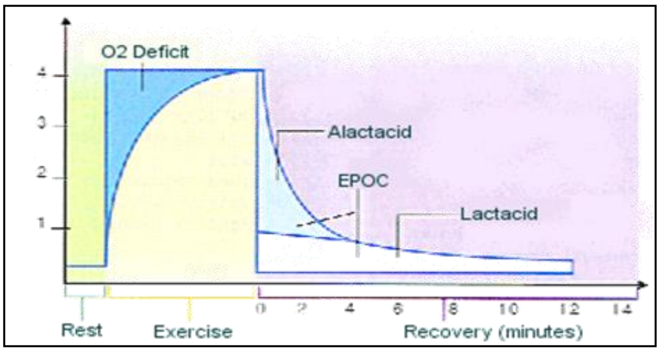

Fig 1: Representation of A lactacid and Lactacid recovery

It is evident from the above information that a high VO_2max (greater than 68-70 ml/kg/min in men and 60-65 ml/kg/min in women) must be attained for international success in many athletic events involving endurance, such as distance running. However, there is very little "separation" between VO_2max values in terms of performance; for example an athlete with a VO_2max of 70 will not always run faster than an athlete with a VO_2max of 68. Thus, for your athletic event, you should optimally be in the ranges listed in the presented tables and figures. Generally, a nationally competitive male distance or middle-distance runner will have a VO_2max of approximately 70 ml/kg/min or greater; a nationally competitive female distance runner will have a VO_2max greater than 65 ml/kg/min. To increase VO_2max many factors must be considered by the coach and athlete.

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