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The Exercise Effect on the Anaerobic Threshold in Response to Graded Exercise

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Abstract

Introduction: Anaerobic Threshold (AT) is often expressed as a percentage of VO2 max (50% - 60% for the general population, 75% and above for athletes). The higher the AT, the higher intensity the athlete can sustain without producing lactic acid. Therefore, AT is a better predictor of performance than VO2 max in elite athletes. AT is often expressed as the heart rate at the ventilatory breakpoint. The heart rate at the AT can then be utilized in designing training and interval programs for athletes. **Purpose:** The purpose of this study was to determine the exercise effect on anaerobic threshold from the VO2 max. **Methods:** Eight non-athlete subjects (age 23.25±2.55 yrs, height 177.79±9.9 cm, weight 81.36±11.13 kg) of the University of Texas at Arlington volunteered to participate in this study. Each subject had their weight, height and age for entry into a metabolic cart and on a data sheet. Each subject was outfitted with the headgear, mouthpiece and nose clip. Each subject sat at rest for five minutes to collect metabolic resting data. Next, each subject performed a graded exercise test on the treadmill with increasing speed and elevation until exhaustion. During each test heart rate (HR) and rate of perceived exertion (RPE) were recorded along with the maximal values measured by the metabolic cart, relative maximal oxygen consumption (VO_{2max}) and minute ventilation (V_E). At the end of the exercise data was collected. **Results:** Multiple categories were measured. The average maximal values: VO2 L/min (3.39±.9), VO2 ml/kg/min (41.41±8.58), VE L/min (94.35±25.2), RQ (1.04±.18), Q L/m (23.67±5.0), SV ml/bt (125.75±25.26), a-vO2 vol% (14.1±.99), HR (187.4±14.38), SBP (175±17.5), DBP (72.5±16.2), RPE (16.62±1.6). **Conclusion:** The results of this study indicated that there are some significant differences found within our population sample in terms of overall cardiovascular conditioning. It is likely there were some significant differences in the subjects' levels of conditioning before having begun the exercise. We can predict data in the measured categories will be closer to the high end of average or nearing "elite" levels of performance in subjects with more training experience compared to subjects who entered the study with a lack of conditioning. The AT and VO2 max will be achieved more rapidly in the less conditioned subjects.

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Introduction

The domain of fitness testing is typically perceived as an area usually reserved for competitive athletes. The image of the lab environment with hoses, mouthpieces, and so on connected to athletes undergoing maximal exertion testing is often what we see depicted in the popular media. However, increasing health concerns related to heart and weight related diseases has focused new attention on the value and practice of fitness testing and exercise prescription for the general population. And whereas fitness testing in the disease environment has a distinct clinical element, one should note that the outcome measures are essentially the same for the clinical population as for the athletic population. Examples of these outcome measures include functional capacity, strength, respiratory function, heart rate (HR) and so on. From a comparison point of view, the practice of fitness testing, be it in competitive athletes, research-based studies, or diseased populations, is not really any different with regard to the procedures and objectives (Mathews, 2012). A common area of testing in the athletic and medical world is the determination of one's maximal oxygen up take level. Maximal oxygen uptake (VO2 max) represents the maximal rate of oxygen consumption during exercise testing to volitional fatigue. It is commonly measured in response to incremental exercise during which ventilation and pulmonary gas exchange data are collected.

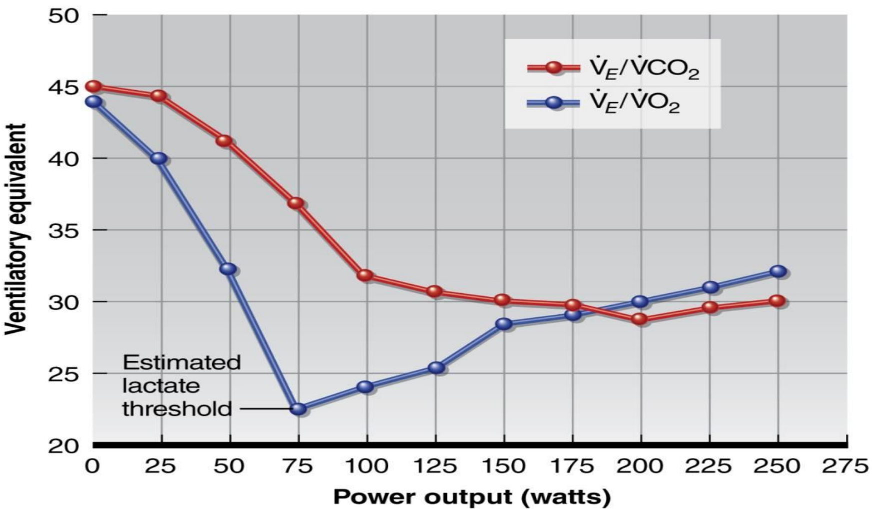


Figure 1: Exercise Intensity and Lactate Threshold

A physiological measure often used to detect metabolic changes during exercise is measurement of blood *lactate* concentration ([La]). Lactate is produced by working muscle and is the end-product of anaerobic, or fast, glycolysis. Some of it diffuses into the blood, and during exercise, heart muscle fibers and slow twitch (ST) fibers in working muscle take up most of the lactate and convert it back into pyruvate, which then enters the Krebs cycle (aerobic system). During exercise recovery, however, most of the lactate is removed from blood by the liver. Certainly, blood lactate concentrations reflect exercise intensity. However, the rapid accumulation of lactate in the blood, which is sometimes called the anaerobic threshold, is not an indication that there was a sudden shift of ATP production away from aerobic to anaerobic metabolism. Rather, it reflects that lactate production by working muscle finally exceeded the ability of the tissues to remove it from the blood (Wilson). Lactate threshold is defined as the point of nonlinear increase in blood lactate or the onset of blood lactate (OBLA). It reflects the balance between lactate entry into and removal from the blood. The ventilatory threshold test based on gas exchange rather than LA response criteria, is also a true physiological test. However, it was devised to determine LT, not AT, and suffers from many validity and reliability issues. The lactate-minimum test (LMT) begins with a short, high-lactic exercise bout followed by a typical incremental protocol. Consequently, La initially diminishes before rising again with the increasing exercise intensity (Dotan, 2012).

Whether or not lactate threshold truly reflects the beginning of anaerobic metabolism is debated. Researchers also noted that CO_2 production demonstrated a nonlinear increase during graded exercise testing, as well. The increased CO_2 production is thought to reflect a shift toward anaerobic metabolism. Often called the ventilatory breakpoint, this sudden increase in CO_2 production has been utilized to noninvasively estimate lactate threshold. The term anaerobic threshold was suggested by Wasserman and McIlroy to describe the sudden increase in CO_2 production which generally occurs at the same point in time as the lactate threshold. However, individuals incapable of increasing blood lactate levels due to a genetic enzyme deficiency, demonstrate a clear ventilatory breakpoint. Also, depleting muscle glycogen stores prior to exercise changes the relationship between lactate and ventilatory threshold.

The ventilatory breakpoint is defined as the point at which ventilation increases without an increase in oxygen consumption.

Utilizing indirect calorimetry, anaerobic threshold (AT) can be identified by several methods: 1) nonlinear increase in V_E or 2) a systematic increase in V_E /VO_2 without a concomitant increase in V_E /VCO_2.

Anaerobic Threshold is often expressed as a percentage of VO_{2max} (50% - 60% for the general population, 75% and above for athletes). The higher the AT, the higher intensity the athlete can sustain without producing lactic acid. Therefore, AT is a better predictor of performance than VO_{2max} in elite athletes. AT is often expressed as the heart rate at the ventilatory breakpoint. The heart rate at AT can then be utilized in designing training and interval programs for athletes.

Pyruvate ($C_3H_4O_3$) + NADH + H^+ ⇄ lactic acid ($C_3H_6O_3$) + NAD^+

Lactic acid is produced in the muscle then diffuses into the blood and dissociates in the plasma into $lactate^-$ and H^+. Following intense exercise, blood lactate usually peaks around 5 min into recovery.

The purpose of this study was to determine the exercise effect on anaerobic threshold from the VO2 max. This study also aimed to discover any inconstancies with commonly known and expected responses to graded exercise in blood lactate levels among its subjects compared to previous studies.

Methods

Subjects

Eight non-athlete subjects (age 23.25±2.55 yrs, height 177.79±9.9 cm, weight 81.36±11.13 kg) of the University of Texas at Arlington volunteered to participate in this study. Each subject had their weight, height and age for entry into a metabolic cart and on a data sheet. Each subject was outfitted with the headgear, mouthpiece and nose clip. Each subject sat at rest for five minutes to collect metabolic resting data. All testing took place in the cardiovascular laboratory of the kinesiology department.

Instrumentation

Equipment used was a Polar-Heart Rate monitor was attached to the subject’s chest which constantly monitored their heart rate.

Every participant was fitted with headgear to hold a mouthpiece in place. A nose clip was used to ensure all expired air was analyzed. Each subject's breathing was done through the mouthpiece, which was connected to a mass flow sensor, to ensure all inspired and expired air was analyzed continuously for oxygen consumption and carbon dioxide production. Oxygen consumption was measured on the V max metabolic cart. A Borg RPE scale chart was used to allow the subjects to indicate their RPE and the end of each stage and at maximal levels. Blood pressure was taken by use of a standard blood pressure cuff and stethoscope. Capillary tubes and blood lactate analyzer device was used to extract blood from the finger of the subject exercising and report the lactate levels. Gloves were worn by the experiment administrators to prevent contact with the blood. Exercise was performed on a Parvo Met Cart treadmill.

I. Equipment List-Comprehensive

Bicycle Ergometer	Vmax Metabolic Cart	Mouthpiece	Headgear
Stethoscope	Blood Pressure Cuff	HR monitor	Nose Clip
Parvo Met Cart	Capillary tubes	Blood lactate analyzer	Gloves

Exercise Protocol

Each subject had their weight, height and age for entry into a metabolic cart and on a data sheet. Each subject was outfitted with the headgear, mouthpiece and nose clip. Each subject sat at rest for five minutes to collect metabolic resting data. Next, each subject performed a graded exercise test on the treadmill with increasing speed and elevation until exhaustion. During each test heart rate (HR) and rate of perceived exertion (RPE) were recorded along with the maximal values measured by the metabolic cart, relative maximal oxygen consumption (VO2 max) and minute ventilation (VE). At the end of the exercise data was collected.

The subjects were prepared for exercise. Their resting blood lactate levels were established along with resting blood pressure and heart rate. At the onset of exercise heart rate, blood pressure, blood lactate and RPE were measured the last minute of each 3 minute stage. Exercise administers conducted a symptom limited cycle exercise to maximal levels.

At the time of recovery, heart rate and blood pressure during minuet one, three and five were recorded. A final blood lactate level was taken at the end of the five minuet recovery.

II. Procedures

A. Prepare the subject for exercise. Obtain resting blood lactate, blood pressure and heart rate measurements and complete data collection sheet.
B. Heart rate, blood pressure, blood lactate and RPE are measured the last minute of each 3 min stage.
C. Conduct a symptom limited cycle exercise to maximal levels.
D. During recovery, record HR and BP during min 1, 3, and 5. Take a final blood lactate at the end of the 5 min recovery.

Statistical Analysis

Mean values, maximum and minimum values as well as the standard deviations of the age, height, weight, heart rate, rate of perceived exertion and maximal oxygen uptake were calculated for each of the variables. To analyze the means and standard deviations of the demographics and categories said functions were run on the Microsoft excel sheet.

Results

Multiple categories were measured. The average maximal values: VO2 L/min (3.39±.9), VO2 ml/kg/min (41.41±8.58), VE L/min (94.35±25.2), RQ (1.04±.18), Q L/m (23.67±5.0), SV ml/bt (125.75±25.26), a-vO2 vol% (14.1±.99), HR (187.4±14.38), SBP (175±17.5), DBP (72.5±16.2), RPE (16.62±1.6). Each of these relationships is depicted in the following graphs and tables.

The relationship between VO2 L/min and RQ (r=0.311). The relationship between VO2 ml/kg/min and VE L/min (r=0.412). The relationship between Systolic and Diastolic Blood Pressures Between (r=-0.150).

Table 1: Average/Standard Deviation Values for: Max VO2 L/min, VO2 ml/kg/min, VE L/min, RQ, Q L/m, SV ml/bt, a-vO2 vol%, HR, SBP, DBP, RPE

Q L/min	SV ml/bt	a-vO2 vol%	HR	SBP	DBP	RPE	VO2 L/min	VO2 ml/kg/min	VE L/min	RQ
23.665	125.75	14.1	187.4	175	72.5	16.625	3.393625	41.4125	94.35375	1.03875
4.97835	25.56085	0.994269294	14.38	17.5	16.2041	1.598	0.9051675	8.577784846	25.20087	0.179955

Figure 2: The Relationship between Stroke Volume (ml/bt) and Heart Rate (bpm)

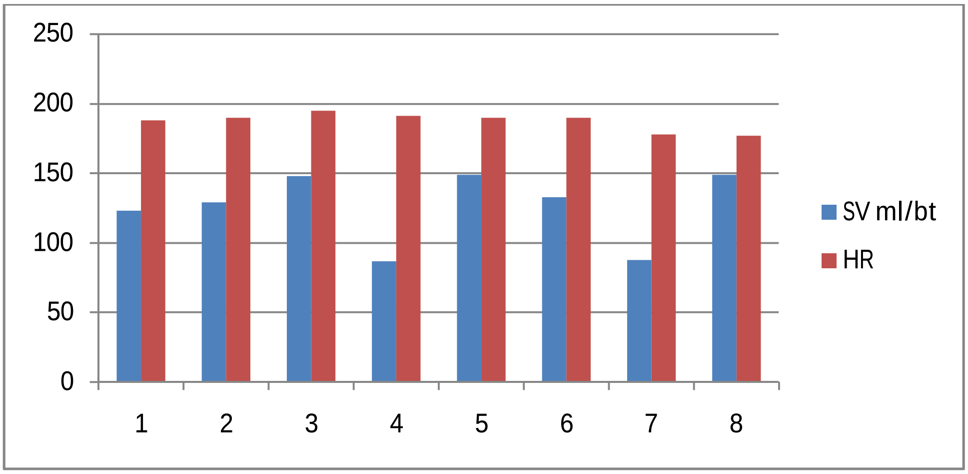


Figure 3: The Relationship between Q L/min and a-vO2 vol%

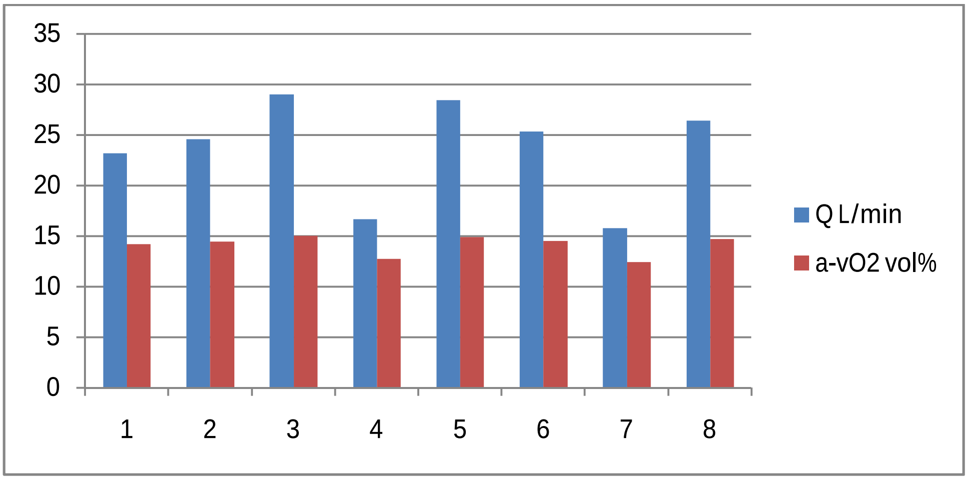


Figure 4: The Relationship between VO2 L / min and RQ (r=0.311)

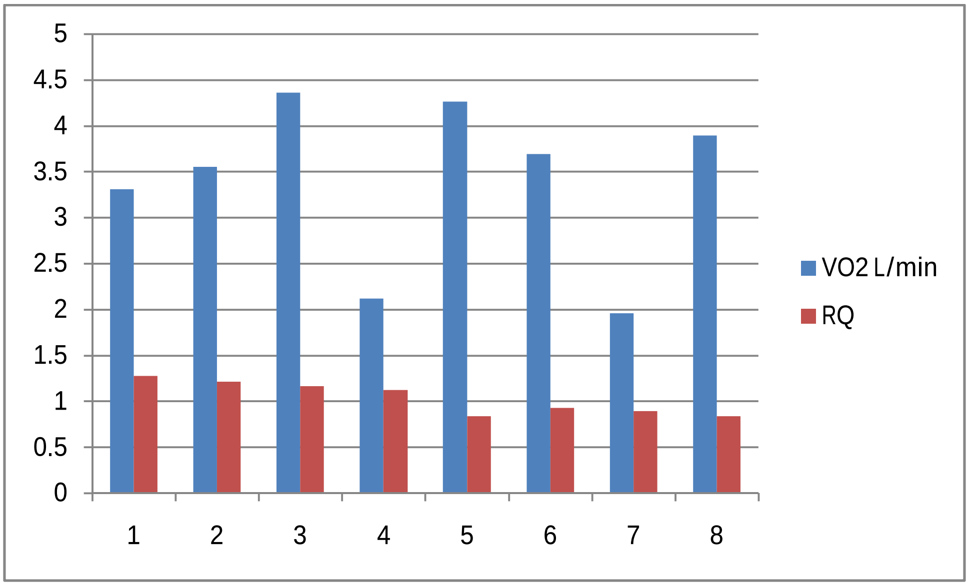
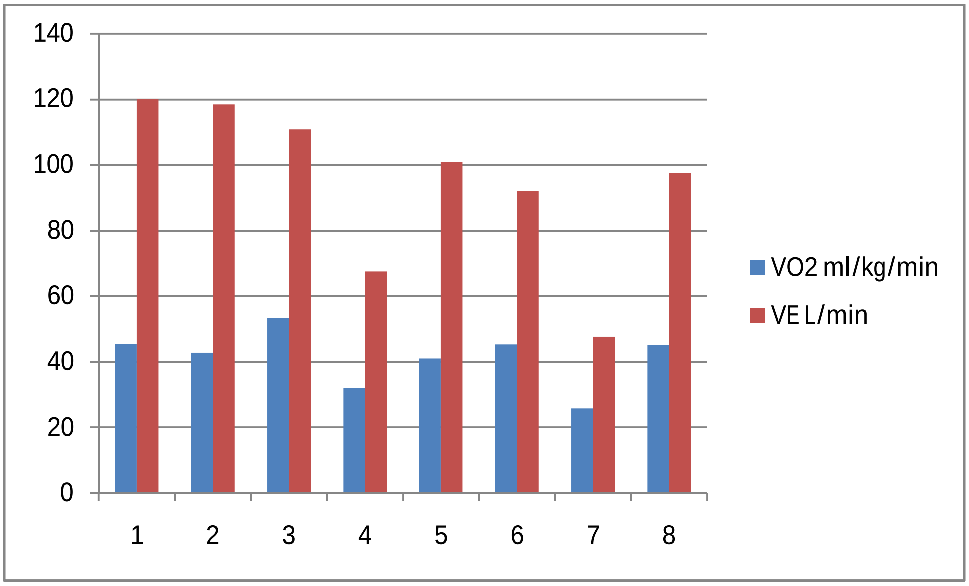


Figure 5: The Relationship between VO2 ml / kg / min and VE L / min (r=0.412)



Significant difference between subjects, for the most part did not exist. Significant differences from resting values and post-exercise values did not exist. The results of this study reflect similar studies.

The physiological response to graded exercise was expected. The results of this study indicated that there are some significant differences found within our population sample in terms of overall cardiovascular conditioning. It is likely there were some significant differences in the subjects' levels of conditioning before having begun the exercise. We can predict data in the measured categories will be closer to the high end of average or nearing "elite" levels of performance in subjects with more training experience compared to subjects who entered the study with a lack of conditioning. The AT and VO2 max will be achieved more rapidly in the less conditioned subjects.

Discussion

The purpose of this study was to determine the exercise effect on anaerobic threshold from the VO2 max. In our study and many like it subjects are either running or cycling to achieve their anaerobic threshold and VO2 max values. It is possible that developing a certain rhythm to leg stokes can be a benefit to the exercise and have an effect on breathing rhythm. This is a design limitation as this was not accounted for in the present study. Past studies have looked to see if a relationship does exist between stroke rhythm and ventilatory rhythm. Both of which may also have an influence on anaerobic threshold and potentially VO2 max. From a practical point of view, the findings from those studies allow us to establish that, when a really tight coordination exists between breathing and locomotor rhythms, the determination of the anaerobic threshold, thanks to the ventilatory method, must be used cautiously because it mainly depends on mechanical factors (Faber, 2012).

Furthermore, the stroke length also has proven to be a factor in anaerobic threshold and VO2 max. In a study where a physiological and biomechanical comparison between intermittent incremental protocols with different step lengths and a maximal lactate steady state (MLSS) test was conducted, findings showed that it is valid to use intermittent incremental protocols of 200 and 300 m lengths to assess the swimming velocity corresponding to individual **anaerobic threshold**, the progressive protocols tend to underestimate the [La-] at **anaerobic threshold** assessed by the MLSS test, and swimmers increase velocity through stroke rate increases (Fernandez, 2011).

In conclusion, to have a study which can better determine the exercise effect on anaerobic threshold from the VO2 max other factors must be considered and adjusted for. Future studies would need to include a much larger sample size of subjects and take into account the length of stride or RPM or stroke. By so doing, researcher may better be able to address the increasing health concerns related to heart and weight related diseases. They may then focus new attention on the value and practice of fitness testing and exercise prescription for the general population

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