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The Accuracy of Recreational Athletes in Self Detecting Ventilation Threshold During a Maximal Exercise Test

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The Accuracy of Recreational Athletes in Self-Detecting Ventilatory Threshold During a Maximal Exercise Test

A Research Project

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Abstract:

INTRODUCTION: Ventilatory threshold (VT) is where minute ventilation (VE) increases nonlinearly with increasing exercise intensity. Prior studies have shown that subjects can recognize VT by changes in breathing during exercise. Teaching recreational athletes to use VT as a training method could result in better quality training. **PURPOSE**: Determine if recreational athletes can accurately perceive changes in ventilation associated with VT during maximal exercise testing. **METHODS**: Subjects were recruited (n=20, age= 20.5 ± 1.7 yrs.) to participate in the study. Subjects performed a modified maximal treadmill protocol with gas analysis. Subjects indicated when they noticed a considerable change in breathing and were recorded as perceived ventilatory threshold (PVT). Actual VT was calculated from maximal exercise test results. Pearson product correlation and independent samples t-tests were used to test relationships and mean differences between ventilatory frequency (VF), minute ventilation (VE), and tidal volume (Vt) at PVT and VT. Separate paired sample t-tests were used to assess the differences in perceived and actual ventilatory threshold (VT) for oxygen consumption (VO2)(mg/kg/min) and time (min). Mean differences were accompanied with their 95% confidence intervals (CI) and Cohen's d values. The assumption of normality was tested using the Shapiro-Wilk test. Significance was set at $p < 0.05$. **RESULTS**: There were no violations of normality for either paired comparison. There was no statistical difference in VO2 between actual and perceived VT, t(19) =0.807, p =0.429; Actual =37.90±7.26 and Perceived =36.49±7.07. There was a statistical difference of 2.00(0.21, 3.80) min between actual and perceived VT, t(19) = 0.2.332, p = 0.431, d =.521 with actual VT at 6.03±3.11 and perceived VT at 8.03±2.73. A strong positive correlation was found between actual VT and PVT with TV (r=.88). No statistically significant differences for mean difference between %/VO2max, VF, VE, and Vt at PVT versus VT were found. **CONCLUSION**: In the current study, recreational athletes were unable to accurately detect changes in their breathing associated with VT. Better recognition of PVT might be possible with more exercise experience. If this is achieved, PVT could be useful in prescribing exercise for this population.

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Introduction

Success in sports and competition is possible with training. In countless sports, athletes must have elite cardiorespiratory fitness to excel. Recreationally, athletes are not commonly taught how to train their cardiorespiratory system. In juxtaposition, most recreational athletes could tell you how they are training their lower and upper bodies with regard to muscle fitness. When it comes to recreational athletes' cardiorespiratory system, there is a distinctive lack of knowledge that leads athletes to a submaximal performance on the pitch, court, field, or whatever other surfaces on which they compete.

What most recreational athletes do not understand is that having top-notch cardiorespiratory fitness will elevate their performance within any sport at any level. In training, the improvement of cardiorespiratory fitness can only be attained when athletes work at a certain intensity level. While aerobic training aids mainly improvements in the aerobic system, anaerobic training has been shown to improve both the aerobic and anaerobic energy systems, specifically ventilatory threshold and increasing the capacity to do work at higher intensities (Dupont et al., 2005). Ventilatory threshold (VT) is where minute ventilation (VE) increases nonlinearly with increasing exercise intensity. Prior studies have shown that subjects can recognize VT by changes in breathing during exercise (Carey et al., 2005).

Most recreational athletes train without a coach, trainer, or guide therefore the intensity of a workout varies drastically. If recreational athletes were able to accurately detect the intensity that was at or above their anaerobic threshold, they would be able to train at the precise level needed to increase their cardiorespiratory fitness directly. This would allow for recreational athletes to train efficiently without supervision.

Statement of Purpose

The purpose of this study was to determine whether or not recreational athletes can accurately perceive changes in ventilation associated with VT during maximal exercise testing.

Definitions

Anaerobic threshold (AT)**:** The level of work or oxygen consumption at which there is an increase in lactate concentration, a decrease in arterial blood bicarbonate and pH, or an increase in the respiratory gas exchange ratio (RER) (Wasserman & McIlroy, 1964).

Lactate threshold (LT): The time or point during the progressive exercise test at which blood lactate accumulates non-linearly and its concentration in the blood increases steadily from resting levels (Wasserman et al., 1973).

Maximal oxygen consumption (VO_2max): The maximal rate at which oxygen can be consumed per minute, the power of the aerobic system (Joakimsson, 1989).

Minute ventilation**:** The amount of air breathed in one minute (Wasserman et al., 1973).

Oxygen debt**:** Accumulation of debt of oxygen during exercise, that must be replenished post-exercise (Whipp & Wasserman, 1972).

Oxygen deficit**:** The difference between the predicted and actual amount of oxygen required to do work at a certain intensity (Whipp & Wasserman, 1972).

Oxygen uptake rate (VO_2): The volume of oxygen consumed each minute expressed in liters per minute or milliliters per kilogram per minute (Whipp & Wasserman, 1972).

Perceived ventilatory threshold (PVT)**:** The time or point during the progressive exercise test at which the subject perceives the increase in expired ventilation rate described above as the ventilatory threshold (Lieberman, 1994).

Respiratory exchange rate (RER)**:** The ratio of the volume of carbon dioxide expired per minute to the volume of oxygen consumed per minute (VCO_2/VO_2) (Wasserman & McIlroy, 1964). It will also be referred to as the respiratory quotient.

Tidal volume (TV)**:** Volume in liters of air in one breath.

Ventilatory frequency (VF)**:** Number of breaths measured in one minute.

Ventilatory threshold (VT): The level of work at which minute ventilation changes from a linear to a nonlinear increase in incremental tests or a systematic rise in the fraction of expired oxygen. The point at which VCO_2/VO_2 (RER) exceeds 1.00 (Whipp & Wasserman, 1972).

Review of the Literature

The review of the literature will first examine the significance of the anaerobic threshold (AT), its relationship with exercise intensity, and traditional ways to measure it. Next, it will look at the ability and means of different populations to perceive the AT, and it will explore the specificity required to maximize the accuracy of VO2max testing. It will examine past studies on cardiovascular training for recreational athletes. Finally, the review of the literature will be summarized and related to the current study.

Significance of the Anaerobic Threshold

Anaerobic threshold has long been used as a means to gauge intensity of cardiovascular exercise. Initial research into the topic of AT was based on the idea that the acid-base balance in the body changes with exercise. Hill, et al. (1924) experimented with gas collection on themselves and colleagues as they ran and walked around a grass track at increasing speeds. The gas was collected for approximately one minute in which they measured volume of expired oxygen and volume of expired carbon dioxide. Hill et al (1924) found that with increasing intensity, ventilation increases and so do both oxygen and carbon dioxide expiration, and they noticed that the ratio of CO2 to O2, the respiratory quotient, also increased with increasing intensity. Hill et al.,(1924) were some of the first scientists to show that during low intensity exercise, ventilation and the respiratory quotient are low, and lactic acid (LA) does not accumulate in the body, whereas during high intensity exercise ventilation and the respiratory quotient are high and LA accumulates.

Margaria et al. (1933) continued this early research into how LA and VO2 react with increasing exercise intensity. Their study consisted of one subject running on the treadmill for periods of 10 minutes at different speeds. After these 10-minute periods, blood was taken from three different arteries and analyzed for LA. They showed similar results as Hill, et al.(1924) in that LA accumulated in the body when the supply of oxygen in the muscles fell below demand, as in higher running speeds (Margaria et al., 1933). They also found that with exercise that does not result in increased LA, the oxygen debt was reduced back to normal in a matter of three minutes post-exercise, whereas with exercise moderately high to highly strenuous exercise that resulted in increased LA, the oxygen debt took 1.5 to over 2 hours to reduce back to normal (Margaria et al., 1933). The increased time to recover had implications on the amount of time the body needs for recovery when training below the lactate threshold as compared to above. Margaria et. al (1933) were able to discern the possibility that the body could increase its work capacity by increasing the capacity of the body for LA. Therefore, training above the LT increased the body's ability to do work. Finally, in their 1934 study on exercising mice, Margaria and Edwards confirmed that the speed of removal of LA from the body depended on the amount of LA accumulated. This showed that recovery post-exercise was dependent on the intensity of the training, and how high that intensity was relative to the LT.

As technology and gas analysis techniques improved, exercise physiologists were able to examine new means of measuring AT. In the 1960s and 1970s, several studies were conducted that showed the dynamics of oxygen through a range of exercise intensities. Wasserman (1967) measured blood lactate, oxygen consumption (VO2) and respiratory exchange ratio (RER) for ten medical students during three separate bouts of 50 minutes on the cycle ergometer at three different steady-state work rates: moderate (below lactate threshold), heavy, and very heavy. Oxygen debt was then measured post-exercise (Wasserman, 1967). He found a positive relationship between the change in arterial LA concentration and the oxygen debt at each of the different exercise intensities. Additionally, he demonstrated that at the start of exercise for each intensity, LA increases relative to the difficulty (greater increase with greater difficulty), but then levels off as the subject achieves steady-state (Wasserman, 1967). This showed that LA was affected by the exercise intensity, and more LA accumulates with greater work.

Whipp and Wasserman (1972) tested six subjects on a cycle ergometer at constant workloads from 50 to 175W for a minimum of six minutes. They found that at work rates up to 100W, the subjects reached steady state within the time of exercise and VO2 rapidly returned to its pre-exercise value during recovery, while at the workloads of 125W, 150W, and 175W, steady-state was not reached in the time lapsed, and at these higher workloads, VO2 took longer to return to its pre-exercise value, and the measured VO2 underestimates the true O2 required for exercise (Whipp & Wasserman, 1972). While they didn't directly measure it, they showed that this supply of energy must come from anaerobic sources of glycolysis and high-energy phosphates by demonstrating the quantitative difference as O2 deficit at high workloads. When taken in this context, all of these factors show that training at higher workloads, or above AT, requires more from the body's energy systems during work and more time to recover afterwards.

Whipp and Wasserman (1972) were also able to show differences in O2 kinetics between "fit" and "unfit" subjects. At higher work rates, the VO2 of fitter subjects was greater than that of the less fit subjects at every moment before steady state was attained (Whipp & Wasserman, 1972). This shows a greater efficiency for fitter subjects to utilize oxygen, and it also demonstrates that less fit subjects needed to rely more on anaerobic means to maintain their work at higher rates. Fitter subjects also have higher AT's, so they are able to do more work before the accumulation of LA. Later, Wasserman et al. (1973) used similar methods and found that changes in minute ventilation (VE) could also be used reliably to detect this threshold. Breathing rate increases nonlinearly at this point, and if graphed in conjunction with VO2, can be helpful to pinpoint the VT. In the same study, Wasserman, et al. (1973) also investigated whether the duration of each stage in the incremental tests affected the rate of LA accumulation. They tested time periods of 1-min and 4-min for each stage, and they found that while there was a slight difference in total LA accumulation, the relative rate of change of LA accumulation remained constant. This suggests that rate of LA accumulation is based on intensity of exercise rather than duration.

Perception of Anaerobic Threshold and Intensity

After the relationship between the ventilatory and LA changes at AT were solidified, researchers began to look into the subject's perception of intensity at and near these thresholds. Joakimsson (1989) looked at the reproducibility of ratings of perceived exertion (RPE) at ventilatory threshold (VT) of fifteen well trained middle-long distance runners. Using a modified treadmill VO2max protocol, he first tested his subjects to find their VT. He then had them perform two submaximal tests. The first consisted of incremental stages that got the subjects up to the workload corresponding to their VT. The second had alternating interval stages above and below the workload corresponding to VT. For each test, the subjects reported their RPE during each stage. Analysis of the results showed that middle and long-distance runners were able to reproduce RPE at VT for identical workloads in the two different protocols. A limitation of this study was that it included only distance runners, who would be more likely to self-detect their intensity due to their training specificity of the sport. A strength of this study was its testing protocol. Unlike many treadmill protocols, there were not many changes in grade, and instead relied more on changes in speed to increase intensity. Testing subjects on a level surface and with speed is more closely related biomechanically to many team sports that are played on flat ground.

Lieberman (1994) tested twelve recreationally trained young adult males to see whether or not they could perceive the abrupt changes in ventilation associated with their AT during a maximal cycle ergometry test. Subjects were read pretest instructions that directed them to raise a finger to the ceiling when they noticed a sudden increase in the breathing rate or depth. Lieberman (1994) found a high correlation between the perceived ventilatory threshold (PVT), actual ventilatory threshold (VT), and lactate threshold (LT). He showed that PVT can be a useful indicator of AT in recreationally trained males because there was a close link between the time at which ventilatory changes are perceived and when they actually occurred (Lieberman, 1994). Two limitations of this study are that they only used minute by minute gas analysis, and males subjects.

Mertens (1998) investigated this concept further when he tested young male subjects on whether there was a significant difference in the intensity chosen by participants at which they "could hear their breathing" versus "could readily hear their breathing". Subjects performed three trials of cycle ergometry with increasing resistance to maximum. They were asked to indicate the moment when either they could "hear" or when they could "readily hear" their breathing. He found no significant differences between the two phrases, and also determined that subjects responded to both phrases at approximately their VT, indicating that this young male population could also perceive the breathing changes associated with their AT.

Ng (2004) attempted to see if children could perceive the changes in breathing associated with VT. For this study, the participants ran a modified treadmill test specific to this younger population and were asked to raise their hand at the moment their breathing became audible (Audible Breathing Threshold/ABT). After this moment, the test was stopped, and the time was recorded. On the second visit, participants performed the same treadmill protocol, but this time to maximal effort and with breath by breath analysis. After both tests, the intensity at ABT was compared to the true VT. Results showed that ABT was within 7% of VT, where subjects heard their breathing at about 71% of VO2max while their actual VT was about 76% of VO2max. This demonstrated that ABT could be used as a reliable gauge for intensity at VT for children.

The Talk Test has also been researched as a means to gauge VT. A talk test consists of participants reading a script during each stage of a maximal test. If the participant is able to read the entire script without any trouble, it is counted as a pass, whereas if they struggle or cannot read at all, it is counted as a fail. Dehart-Beverly et al. (2000) tested recreational walkers and joggers (24.1 ± 6.1 years) to see if the intensity at their VT aligned with the intensity at which they failed the talk test. Walkers performed an exercise test with the Balke treadmill protocol in which the incline increases incrementally while subjects maintain a constant walking (3.3 mph). Joggers performed an exercise test with the Astrand treadmill protocol in which subjects maintain a jogging speed (5.0 mph) while the incline increases incrementally. Each subject performed two identical tests, one with gas analysis and one without it. In the test without gas analysis, subjects were asked to speak aloud a paragraph at the last minute of each stage. Subjects were asked to assess whether they could still speak comfortably and were given the choice of three different answers: “yes,” “I’m not sure,” or “no.” They found that the subjects were able to talk comfortably at and before VT, but clearly failed to do so at an intensity above it. This demonstrated that there was a change in breathing that significantly affects our ability to speak at high intensities at or above VT.

Quinn and Coons (2011 conducted a similar study with fifteen young adults (13 males and 2 females) using the Pledge of Allegiance for their talk test and a treadmill protocol. On the first day, participants performed on the treadmill test up to their lactate threshold (LT) and a

VO2max test. On a second day, participants performed the same protocol as the LT treadmill test, but this time were asked to recite the Pledge of Allegiance at each new increase of intensity. The times were recorded where participants began to have difficulty speaking and where they could no longer speak. They compared the physiological variables of the LT test, the VO2max test, and the Talk Test and found that failure of the talk test was more closely related to LT than VT, and that the intensity point of failure of the talk test was generally higher than the intensity at VT, meaning that it was possible for participants to continue to talk when working above their VT.

Rodriguez-Marroyo et al. (2013) had similar findings in their study with of a group of 18 highly trained cyclists. Like Quinn and Coons (2011), they had their subjects perform one maximal test on a cycle ergometer with breathing analysis to attain VT and the respiratory compensation threshold (RCT), and then repeated the same protocol without breathing analysis, but with the subjects reading a paragraph aloud in each stage. When subjects could no longer speak comfortably, it was labeled as equivocal (EQ), and when they could not speak at all, it was negative (NEG) for that stage. They found a strong correlation between the workloads, heart rates, and RPEs at VT and EQ, and RCT and NEG. These results show again the correlation between the ability to talk or not during exercise and being below, at, or above the VT.

Little research, however, has investigated the ability specifically for athletes to self-select intensities for training that are at or above their anaerobic thresholds. In one study, Mandengue et al. (2005) studied nine male university athletes' ability to self-select proper intensities during their warm-up. They found that most, but not all, of these athletes were able to select an intensity within ±10% of their optimal warm-up intensity (~60-70% of VO2peak). Athletes that could select within this range were warming up at an intensity that is appropriate. However, not all athletes were able to do this, indicating that there may be some discrepancy in the ability of different athletes to monitor and self-select an appropriate intensity that is asked of them.

Haile (2010) studied recreationally active males. These participants were told to self-select an intensity for 20-minutes of cycling that was "high enough for a good workout, but not high that (they) would not prefer to exercise at that intensity daily or at least every other day" (p. 33). Most all of the participants chose an intensity that was above 50% of their oxygen uptake reserve. This showed that this sample can select an exercise intensity within the range recommended in ACSM's Guidelines for Exercise Testing and Prescription (American College of Sports Medicine, 2018). These recommendations, however, are used with the general population and so they may not be appropriate or applicable to athletes as this study was limited to males.

VO2max Testing Specificity

Studies have been conducted to examine the specificity of the VO2max test protocol to the mode of exercise of the participants. In a review of studies looking at the physiological responses of runners versus cyclists, Millet et al. (2009) found that runners had a higher VO2max when tested in a running protocol versus a cycling protocol. They concluded that athletes should be tested in a modality that is closest to the way that they train and compete.

Another area of interest for researchers is the effect of pain on perception of intensity during aerobic testing. Slapsinskaite et al. (2015) investigated the perception and location of pain during running and cycling VO2max protocols. They found different local pain dynamics for the two modes. For both modes, participants noted the number of pain locations gradually increased with increasing intensity. For cycling, this pain was greatest in the quadriceps and hamstrings, while it was greatest in the quadriceps and chest while running. This showed a difference in the way that pain is perceived and demonstrates that using a different exercise modality can greatly affect the way participants feel during a VO2max test.

Summary of Review of the Literature

Research on the positive effects of training at and/or above the anaerobic threshold is abundant. Several studies have been conducted looking at runners' and cyclists' perception of their AT. However, information is lacking on the ability for female team-sport athletes to detect and self-select intensities relating to AT thresholds. Differences in training practices, knowledge of individual versus team sport athletes between sexes, needs further research to investigate the capabilities of this specific population. Recreational athletes are one of the sole athletic populations that do not train consistently with a coach or trainer. This means that they should be prioritized when researching methods that could help solo training. This anaerobic threshold could be the key to unlocking a new maximum potential within these athletes.

Methods

Subjects

Convenience sampling was used for this study. Selection requirements for this research were that subjects must have been a student at The University of Akron regardless of sex, have exercised at least 3 days a week for more than 30 minutes a session, and considered themselves to be "recreational athletes." Twenty subjects were recruited using flyers, email pushes, and face-to-face conversation. Subjects had to come in once for data collection. Prior to arrival for testing, subjects were instructed to refrain from strenuous activity and all drugs/alcohol for 12 hours prior to test time. Subjects completed informed consent forms, a questionnaire on their age, activity levels, and academic level, as well as a PAR-Q (Reibe, 2018) pre-participation examination form. The paperwork was reviewed to ensure that the participants were properly cleared for activity

VO2 Max Testing Procedures

All testing was conducted in the exercise physiology lab at the university with the approval of the Institutional Review Board. Upon arrival, participants were informed of the testing procedures (verbally and in writing) and completed a consent form (Appendix A). They were then read a script (Appendix B) to explain to them what their VT is, and when to raise their hand during the maximal testing.

Lactate concentration was measured and recorded at rest using a lactate analyzer (Nova Biomedical, Watham, MA). All waste material and gloves were disposed of in the proper biohazard bin. Lactate was measured pre- and post- VO_2max testing as another means of ascertaining whether the test could be considered a true maximal test (Edvardsen et al,. 2014).

Subjects were then fitted with a heart rate monitor across their chest. They were asked to stand up and straddle the Quinton T65 treadmill (Mortara Instrument, Inc., Milwaukee, WI), where they were fitted with a mask connected to a metabolic cart (Parvo Medics, Murray, UT). The metabolic cart was calibrated prior to each test. Next, the subject warmed up on the treadmill for 3 minutes at 3.5mph and 0% grade. After the warm-up, the subjects were notified that they would begin the maximal testing and were reminded once again to give their best effort and to raise their hand when they noticed a change in their breathing.

The maximal testing consisted of modified treadmill protocol (Table 1) similar to one that has successfully been used in previous studies (Joakimsson, 1989). The treadmill parameters started at 5.0 mph and 0% grade. The speed then increased each minute by 0.5 mph. Speed continued to be increased in this manner until 9.5 mph. If participants were still running at this point, the speed would stay at 9.5 mph, and the grade was then be increased by 2% each minute. The full protocol is listed in Figure 1. This protocol with minimal change in grade was chosen in order to mimic the running involved in recreational sports as much as possible.

Table 1

Modified treadmill protocol

Time	Speed (mph)	Grade
0:00	5.0	0%
1:00	5.5	0%
2:00	6.0	0%
3:00	6.5	0%
4:00	7.0	0%
5:00	7.5	0%
6:00	8.0	0%
7:00	8.5	0%
8:00	9.0	0%
9:00	9.5	0%
10:00	9.5	2%
11:00	9.5	4%
12:00	9.5	6%
13:00	9.5	8%
14:00	9.5	10%
15:00	9.5	12%

***Adapted from Joakimsson (1989)**

VO_2max tests were only considered a true maximal test if the respiratory exchange ratio (RER) at the end is greater than or equal to 1.15, or lactate concentration is above 8.0 mmol (Edvardsen et al., 2014). Subjects were actively encouraged to reach above and beyond these cutoff points and to give a maximal effort. The tests were terminated at volitional fatigue, unless either of the following conditions occurred: 1) if the subject shows signs of abnormal stress such as impaired coordination, pallor, or dizziness, 2) if there was equipment failure, or 3) subject requested test termination.

Upon termination of the test, the subject straddled the belt, the treadmill was slowed to 3.0 mph, and if applicable, the grade was reduced to 0%. Subjects then cooled down by walking at 3.0 mph and 0% grade for 5 minutes. As soon as they began walking again, a post-exercise lactate concentration was measured and recorded. Their finger was pricked and post-exercise lactate levels recorded. All waste material and gloves were disposed of in the proper biohazard bin.

After testing, subjects were also asked to complete a short questionnaire (Appendix B) related to their history with running in track and field or cross country in high school in order to see if there was any relationship between a history of organized running and the ability to discern ventilatory changes.

Statistical Analyses

Separate paired sample t-tests were used to assess the differences in perceived and actual ventilatory threshold (VT) for VO2 (mg/kg/min) and time (minutes) at max. Mean differences were accompanied with their 95% confidence intervals (CI) and Cohen's d values. The assumption of normality was tested using the Shapiro-Wilk test. Descriptive statistics were used to describe all anthropometric and physiological measurements taken. Pearson product correlations were used to test for relationships between physiological variables at PVT and VT. Statistical significance was set a priori to $p \leq 0.01$.

Results

This section contains the results of VO2 testing and the associated data analysis including both inferential and descriptive statistics. Descriptive statistics are listed in *Table 2*. Subject 10 did not indicate their PVT and made it clear after their test that they did not understand the criteria. Subject 10's information was excluded from the data. The mean age of subjects was 20.38±1.69. The mean height of subjects was 68.63±2.52 inches or 173.92±6.48cm. The mean body mass of the subjects was 164.23±24.29lbs or 93.95±11.10kgs.

Table 2

Descriptive Characteristics of the Subjects

n = 19	Minimum	Maximum	Mean	Standard Deviation
Age	18	23	20.38	1.69
Height (in)	64	78	68.63	2.52
Height (cm)	162	198	173.92	6.48
Body Mass (lb.)	131.523	243.326	164.23	24.29
Body Mass (kg)	59.66	110.37	73.95	11.1

Table 3 lists the minimum, maximum, mean, and standard deviation of VO2max (in both ml/kg/min and L/min), VO2 at actual and perceived VT, % VO2 at actual VT, pre and post lactic acid, and VEmax. (Write a sentence or two that summarizes the data in this table.)

Table 3

Physiological Variables of Maximal Testing

n=20	Minimum	Maximum	Mean	Standard Deviation
VO2 Max (ml/kg/min)	31.2	54.2	43.63	5.73
VO2 Max (L/min)	1.97	4.38	3.25	0.65
VO2 at actual VT (L/min)	1.75	4.28	2.78	0.69
% VO2 Max at Actual VT	69.00%	100.00%	85.51%	10.33%
VO2 at Perceived VT (L/min)	1.69	4.15	2.67	0.68
Pre-Exercise Lactic Acid (mmol/L)	0.8	4.6	1.79	1.08
Post-Exercise Lactic Acid (mmol/L)	4.4	21.3	12.04	3.21
Vemax (L/min)	62.64	122.84	93.25	15.66

The goal of this study was to determine if recreational athletes could determine / detect the changes in breathing that are associated with their VT. *Table 4* analyzes and compares the mean values for VO@, VE, VF, TV, and %VO2max for all subjects at their actual vs. perceived VT. On average, subjects perceived their VT before hitting their actual VT. VO2, VE, VF, TV, and %VO2 were all lower for their average PVT vs the subjects actual VT.

Table 4

Comparing Means of Physiological Variables at VT vs. PVT

Variable	VT	PVT
VO2 (ml/kg/min)	37.25±7.07	35.77±6.89
VE (L/min)	68.15±19.89	62.56±21.04
VF (breaths/min)	40.18±11.74	37.70±11.12
TV (L)	2.15±.43	2.10±0.52
%VO2 max	85.51%±10.32%	82.04%±13.55%

VO2: Oxygen Consumption; VF: Ventilatory Frequency (breaths per minute)

VE: Minute Ventilation; TV: Tidal Volume; %VO2: Percent of Max VO2

Table 5 shows each subjects VT and perceived VT in minutes (30 second intervals), as well as the difference between those two values.

Table 5

Time at actual VT vs perceived VT (in 30s intervals)

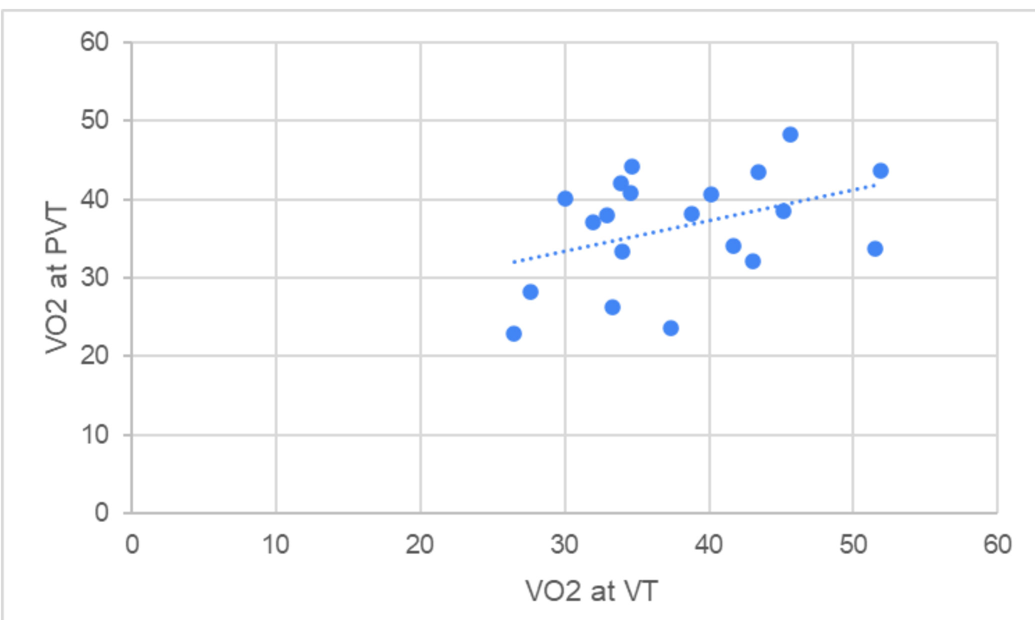
Subject	VT (time in min)	Perceived VT (time in min)	Difference
1	9	12	3
2	6	13.5	7.5
3	13	11.5	-1.5
4	4.5	6	1.5
5	3.5	7	3.5
6	4	10	6
7	3.5	9.5	6
8	7	11	4
9	3	9.5	6.5
10	5.5	7.5	2
11	5.5	5	-0.5
12	6.5	9.5	3
13	2.5	4.5	2
14	5	8.5	3.5
15	7	5.5	-1.5
16	7.5	4	-3.5
17	3.5	8	4.5
18	2	6	4
19	13.5	5	-8.5
20	8	7	-1

The following figures (figures 1-4) are graphical representations of the correlations between physiological variables of maximal exercise testing at actual VT compared with PVT.

Each graph has an associated r value below it. The closer the r value is to 1.000 means the more highly correlated these data points are. *Figure 1* shows the correlation between the values of VO2 during exercise at the time of perceived VT vs. actual VT. These values were determined through the maximal testing. The two values have moderate positive correlation with an r value of .403. *Figure 2* shows that there is also a moderate positive correlation for Ventilatory Frequency (VF) with an r value of .404. *Figure 3* shows a low positive correlation for Minute Ventilation (VE) between VT and PVT with an r value of .187. *Figure 4* shows a very high positive correlation between Minute Ventilation (VE) with an r value of .888.

Figure 1

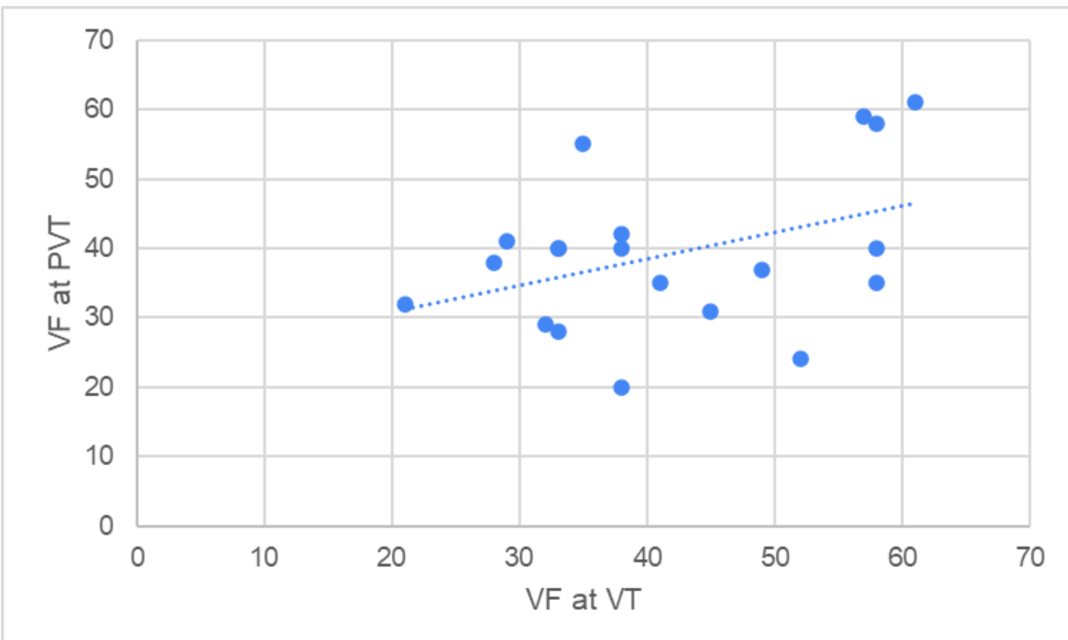
Correlation of Maximal Oxygen Consumption (VO2) at VT vs. PVT



*r = .403

Figure 2

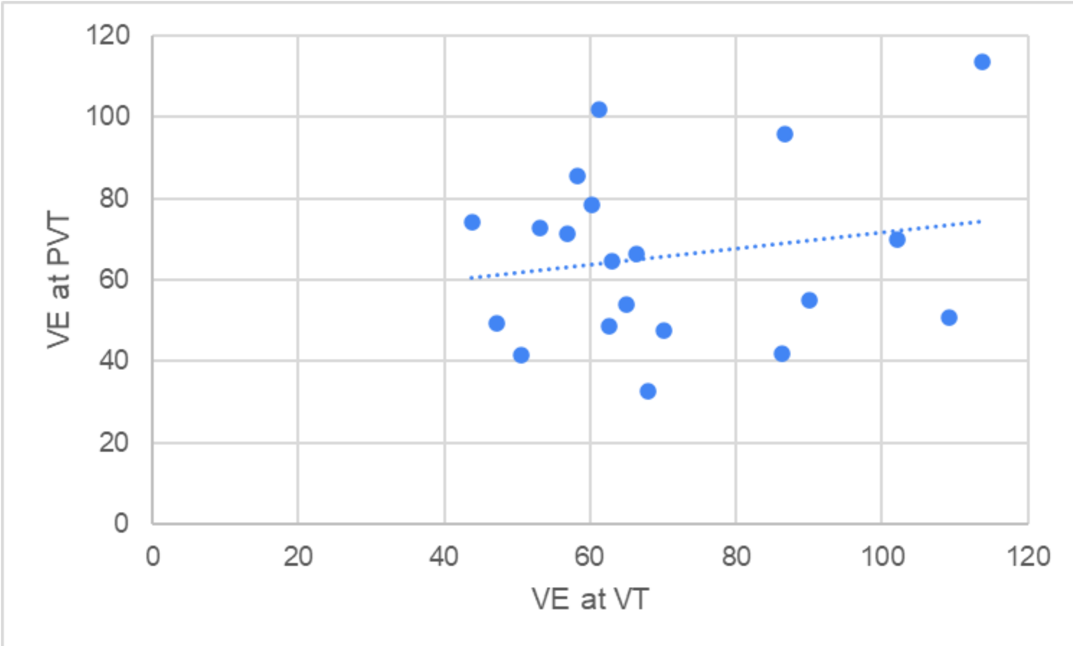
Correlation of Ventilatory Frequency (VF) in beats/min between VT and PVT



*r = .404

Figure 3

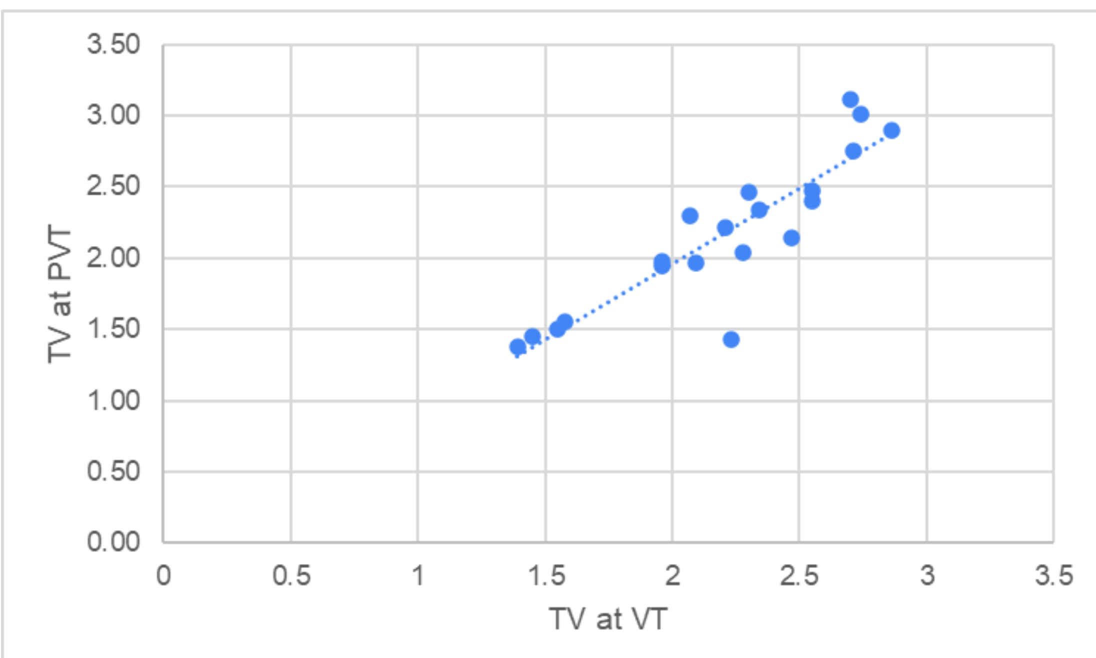
Correlation of Minute Ventilation (VE) in L/Min between VT and PVT



*r = .187

Figure 4

Correlation of Tidal Volume (TV) in L between VT and PVT



*r = .888

Analysis

Separate paired sample *t*-tests were used to assess the differences in perceived and actual ventilatory threshold (VT) for VO_2 (mg/kg/min) and time (minutes) at max. Mean differences were accompanied with their 95% confidence intervals (CI) and Cohen's d values. The assumption of normality was tested using the Shapiro-Wilk test. This data is shown below.

Measure 1	Measure 2	*t*	*df*	*p*
VO2 at Actual VT (ml/kg/min)	VO2 at Perceived VT (ml/kg/min)	0.807	19	0.429
Time at Actual VT (mins)	Time at Perceived VT (mins)	-2.332	19	0.031

Results Summary

There were no violations of normality for either paired comparison. There was no statistical difference in VO_2 between actual and perceived VT, $t(19) = 0.807$, $p = 0.429$; Actual = 37.90±7.26 and Perceived = 35.77±6.89. There was a statistical difference of 2.00(0.21, 3.80) minutes between actual and perceived VT, $t(19) = 0.2.332$, $p = 0.431$, $d = .521$ with actual VT at 6.03±3.11 and perceived VT at 8.03±2.73.

Discussion

The relationships and interactions between the physiological variables tested at the actual VT that was obtained and the perceived VT that was indicated by the test subjects. The mean differences for several other variables and comparisons to other related studies are discussed in the following paragraphs. Practical implications for recreational athletes will be discussed along with the limitations and aims for future research.

Summary of the Study

Subjects were recruited (*n*=20, age= 20.5 ± 1.7 yrs.) to participate in the study. Subjects performed a modified maximal treadmill protocol with gas analysis. Subjects indicated when they noticed a considerable change in breathing and were recorded as perceived ventilatory threshold (PVT). Actual VT was calculated from maximal exercise test results. Pearson product correlation and independent samples t-tests were used to test relationships and mean differences between ventilatory frequency (VF), minute ventilation (VE), and tidal volume (Vt) at PVT and VT. Separate paired sample t-tests were used to assess the differences in perceived and actual ventilatory threshold (VT) for oxygen consumption (VO2)(mg/kg/min) and time (min). Mean differences were accompanied with their 95% confidence intervals (CI) and Cohen's d values. The assumption of normality was tested using the Shapiro-Wilk test. Significance was set at $p < 0.05$. The results showed that there were no violations of normality for either paired comparison. There was no statistical difference in VO2 between actual and perceived VT, $t(19) = 0.807$, $p = 0.429$; Actual =37.90±7.26 and Perceived =36.49±7.07. There was a statistical difference of 2.00(0.21, 3.80) min between actual and perceived VT, $t(19) = 0.2.332$, $p = 0.431$, $d = .521$ with actual VT at 6.03±3.11 and perceived VT at 8.03±2.73. A strong positive correlation was found between actual VT and PVT with TV ($r=.888$). No statistically significant differences for mean difference between %/VO2max, VF, VE, and Vt at PVT versus VT were found.

The purpose of this study was to see if recreational athletes could reliably and accurately pinpoint their ventilatory threshold by noting changes in their breathing. The results tend to support our hypothesis being that recreational athletes could not reliably pinpoint their VT based on respiratory changes.

In this study, we had a few physiological variables with a positive correlation. The strongest variable with a positive correlation was TV, at $r= 0.888$ (figure 4). However, we also found that VF had a moderate positive correlation at r= 0.404. This finding was in contrast to Lieberman (1994) who found the relationship for TV between VT and PVT to be less strong (r=.73) compared to VF (r=.81). VE also had a much greater correlation in Lieberman's (1994) study (r=.76) in contrast to a very low correlation in this study (r=.187). In our study, we used a testing protocol that involved 1-minute long stages. This was very different than Lieberman's (1994), in that they used a 4-minute-long stage. This three-minute difference in stage could account for the differences found between the studies. Wasserman et al. (1987) studied the reliability of ventilatory data in incremental exercise testing and found that it is best studied when there are short intervals between intensity increases. This agrees with Quinn and Coons (2011) who found that it was much clearer to identify the breakpoint of VE/VO2 to ascertain VT with shorter 1-minute stages in comparison to longer stages. At the start of exercise, subject's tidal volume increased quickly, and then began to level off as they neared their ventilatory threshold. This process aligns with the respiratory compensation mechanisms in the body (West & Luks, 2016).

Lieberman (1994) and Ng (2004) reported slightly stronger correlations in their studies for VO2 at VT and PVT (r=.85) and VO2 at VT and Auditory Breathing Threshold (ABT) (r=.86), respectively, compared with this study (r=.714). One difference between these studies was their explanation to the participants of when to indicate their perceived threshold. Lieberman (1994) asked participants to raise their hand when they noticed an increase in the depth or rate of breathing, Ng (2004) asked participants to raise their hand when their breathing became audible, and in this study, subjects were asked to raise their hand when they could sense a change in pace, intensity, or volume of breathing. Though each of the phrases are similar, there might have been slightly different interpretations in meaning that could have affected the results.

When comparing the results of this study which used changes in breathing to find VT, studies that looked at the Talk Test as a means to find VT were slightly more accurate (Dehart-Beverley et al., 2000). These studies had very strong correlations between the VT and the time at which it became uncomfortable to talk. Only one study contradicted this, as it had participants with VO_2 and heart rate values at VT that were significantly less than all three levels (+, EQ, and -) of the talk test (Quinn and Coons, 2011). They found that these values were much more closely related when comparing the negative stages of the talk test and the LT instead of the VT.

Practical Implications

The goal of this study was to investigate if recreational athletes (both male and female) could detect their VT by noting the significant signs of change within their breathing. While there have been several studies that have looked into the reliability of using something like the "talk test" for detecting VT for recreational adults (Dehart-Beverley et al., 2000), there were no true studies looking into recreational athletes and VT in both male and female subjects.

The results of this study demonstrate that recreational athletes cannot distinguish the changes within their breathing that are associated with their VT. Practically, this means that recreational athletes cannot be instructed to use their breathing signs to train at or above their anaerobic threshold. This means that a coach, further education or training and/ or some type of monitor will be needed for these athletes to determine intensity levels.

Limitations and Future Research

The first limitation of this study was the sample size. We only were able to test 20 subjects due to a variety of reasons. Our testing time was during the week, so some subjects had classes during all of our available times. We also had 3 subjects not pass their PARQ and were then not eligible to be tested. Another subject's results could not be counted due to an incidental touching of the emergency stop button by the subject. This means that the subject did not reach the end criteria set forth by Edvardsen et al. (2014). Having a greater sample size would have given this study more validity and stronger conclusions. The low number of subjects also meant that we could not use appendix C as we intended to. We intended to test if subjects with a background in endurance exercises like cross country or track had better results than those that had no background in endurance exercise, but due to low numbers that value would have been weak and inconclusive. Future studies should look into the differences between those subjects who have a background in endurance-based exercise and no background in endurance-based exercise.

The second limitation of this study was the treadmill speed. The goal was to match the treadmill protocol proposed by Joakimsson (1989), but the treadmill in the laboratory at the university has a maximum speed of 9.5mph. This had an effect on the result of one VT and affected several of the VO2max values obtained because instead of increasing speed to 11.0mph as the protocol read, there had to be an adjustment with increasing grade every minute by 2%. This was only a slight change, but because one of the goals of the study was to be specific to most recreational sports (played on a field or court) as possible by keeping the treadmill test at 0% incline for as long as possible, it can be considered a limitation.

Our third limitation was our timing. We had to test all subjects in a 33-day window to meet a deadline to present information at a national professional conference. This meant the exclusion of some subjects that we otherwise would have utilized. Due to conflicting schedules, this led to our subject number being lower than desired. . Specifically, it led to a lack of female participants.

A fourth limitation was the subject's unfamiliarity with the mask and testing set up. None of the subjects have ever been tested in this way before, which leads them to be very uneasy when stepping up on the treadmill with a mask on and tubes hanging off in front of them. It was also stated by a few subjects that this new mask setup led them to be distracted from listening or paying attention to their breathing signs. Future studies should look to have all subjects get a baseline test with the mask to avoid any unfamiliarity with testing processes.

Fifth was the size of our treadmill. The treadmill used for testing was dated and narrow. This led to multiple subjects needing to be told to move right or left during the test to avoid them causing possible injury. This led to distraction and confusion in some parts of the test and certainly could have been a factor in subjects not paying full attention to their breathing signs. Future studies should ensure that the treadmill has a wide deck so subjects are not at risk for any falls.

Lastly, our sixth and largest limitation is that when we read our script to the subjects (Appendix C) before starting their test, it was usually the first time that these recreational athletes have ever heard of an “Anaerobic Threshold”. This confusion over what an anaerobic threshold is led to questions before the test on the specifics that we could not answer to keep each subject even in testing quality. Future studies should have educational review and pre-testing to ensure that each subject understands the concept of the anaerobic threshold and can better identify it in the midst of exercise without second-guessing themselves.

Overall, future research should focus on familiarizing subjects with the testing equipment, treadmill, and the concepts that they are being asked to identify before participation in testing. These new pre-test familiarizations could lead to stronger results that could revolutionize recreational training.

Conclusion

The goal of this study was to investigate how accurately recreational athletes could detect their VT. It was discovered that recreational athletes cannot reliably pinpoint their VT by using notable changes in their breathing. Due to their lack of ability to detect this, coaches and professionals will not be able to instruct these recreational athletes to use their breathing as a tool to train at or above their anaerobic threshold. Future studies are needed to test what education strategies/interventions could be used to improve these results and allow coaches to give better instruction on training at optimal performance levels.

Previous research demonstrated that several other populations were capable of perceiving VT. The results of the present study support previous research and provide valuable information that can help coaching professionals in prescribing exercise. Currently, there is little research on the ability of recreational athletes to understand training intensity. This research has shown a need to better understand how to educate players to train at or above their VT to produce the desired training effects, especially in this population due to isolated training without the assistance of a coach or exercise professional.

The goal of exercise within the population of recreational athletes is to achieve sufficient fitness for their desired sport or sports at a recreational level. This recreational level means that no coach is truly necessary if they can find simple tools to train at their basic but optimal intensities like at or above their anaerobic threshold. Recreational athletes are not trying to break world records, but more simply trying to stay in shape for the sports they enjoy playing for fun. It is important to help these athletes, as they make up the majority of exercisers, in training so that they have the same opportunity as other populations to compete at their desired level.

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Appendices

APPENDIX A

INFORMED CONSENT

The University of Akron
Institutional Review Board

Title of Study: The Accuracy of Recreational Athletes in Self-Detecting Anaerobic Threshold

Introduction: You are invited to participate in a research study being conducted by Andrew Biegner and Elizabeth Booth, Undergraduate students at the University of Akron School of Exercise and Nutrition Science

Purpose: Being successful in any recreational sport is not possible without moderate to high cardiorespiratory fitness. In order to keep up with the demands of recreational sporting (even if those demands are lower than higher level NCAA or professional sports), athletes must participate in some training outside of competition. Recreational athletes rarely have coaches or professionals with them to assist them through each training session, so these athletes rely on the information they find on their own and implement that information as they see fit. This presents the difficulty of trying to feel out exactly how intense these athletes should be training at. Unlike high level endurance athletes, recreational athletes are not taught how to properly train their aerobic and anaerobic systems. Therefore, a study like this may help them learn the knowledge they lack that may be vital in training for their respective sports.

While these athletes are competing in recreational sports and not high level sports, in order to see improvement in these sports they must train above a certain intensity. This intensity is referred to as your anaerobic threshold, and it indicates the level of intensity of exercise where the human body begins to rely more heavily on the anaerobic system than the aerobic system that it had been relying on prior to the threshold. This is marked by a significant increase in O2 consumption and also a rise in lactate that occurs faster than the human body can clear it causing lactic acid. Various studies have shown that when you train above this threshold there can be significant improvements to the athletes aerobic and anaerobic energy systems. In final, the purpose of this study is to determine if recreational athletes between the age of 18-35 that do not participate in NCAA level sports and participate in exercise at least 3 times a week for 30 minutes could self detect changes in the ventilation associated with their ventilatory and anaerobic thresholds.

Procedures: Once you have been cleared by The University of Akron athletic training staff for running, and you have reviewed and signed this informed consent form, you will be approved to participate in this study. You have been asked to refrain from strenuous activity or alcohol for 12 hours, and caffeine or food for 2 hours prior to this testing. All testing will be conducted in this exercise physiology lab at the university.

After approval, all resting measurements will be made. Height, weight, and waist circumference will be measured. You will then be read a script explaining what your ventilatory threshold is, and when to raise your hand during testing. You also will have your Bod Pod measurement taken. The Bod Pod is a body composition tracking system which uses air displacement to measure total weight, body fat percentage, and fat free mass.

After this, I will begin taking the resting measures for the maximal exercise testing. Resting heart rate and blood pressure will be taken, and lactate levels will be measured by finger prick. You will then be fitted with a Polar heart rate monitor and a mask connected to a gas analyzer. You will warm up on the treadmill for 3 minutes at 3.5mph and 0% grade. After the warm up, you will start the maximal testing consisting of modified treadmill protocol. The treadmill will start at 5.0 mph and 0% grade. The speed will then increase each minute by 0.5 mph. Speed will continue to be increased in this manner until 9.5 mph. If you are still running at this point, the speed will stay at 9.5 mph, and the grade will then be increased by 2% each minute. This protocol with minimal change in grade was chosen in order to mimic the running involved in recreational sports (usually played on a flat field or court) as much as possible.

You will be actively encouraged to give a maximal effort. The test will be terminated at volitional fatigue, unless either of the following conditions occur: 1) if the subject shows signs of abnormal stress such as impaired coordination, pallor, or dizziness, 2) if there is equipment failure.

Upon termination of the test, you will straddle the belt, the treadmill will be slowed to 3.0 mph, and if applicable, the grade will be reduced to 0%. At this time, your finger will be pricked once more to measure lactate levels. You will then cool-down by walking at 3.0 mph and 0% grade for 5 minutes.

Risks and Discomforts: Because this research study is based on maximal effort testing, you will be asked to give your best effort. You may experience muscle aches and breathing discomfort as you fatigue. You may also experience discomfort during the collection of lactate levels via finger prick. All testing will be conducted by trained exercise professionals. You may experience discomfort during the Bod Pod test solely due to the task of sitting in a tight enclosed area.

Benefits: The benefits of you participating in this study include experiencing a breathing-analyzed maximal exercise test, and learning your maximal oxygen consumption and body composition. Another benefit of participating in this study would be acquiring the knowledge regarding body composition due to the Bod Pod

Exclusions: You are not eligible to participate in this research project if you are under 18 or pregnant. If you have received any other X-Ray or radiation type scan within this past week, you will not be able to participate until at least 7 days have passed since last exposure. If your resting systolic blood pressure is above 200hg or your diastolic blood pressure is above 110mmHg while at rest, you will not be eligible to complete our testing. Any individual with a resting HR above 90 bpm will also not be eligible to participate. Also, if you are marked as a high risk individual on the PAR-Q you will not be eligible to participate

Payments to Participants: None.

Right to refuse or withdraw: Taking part in this project is entirely up to you, and no one will hold it against you if you decide not to do it. If you do take part, you may stop at any time.

Anonymous and Confidential Data Collection: Any identifying information collected will be kept in a secure location and only the researchers will have access to the data. Participants will not be individually identified in any publication or presentation of the research results. Only aggregate data will be used. Your signed consent form will be kept separate from your data, and nobody will be able to link your results or responses to you.

Confidentiality of records: Will be maintained.

Who to contact with questions: Advisor, Ronald Otterstetter: 330-972-7738, Co-Principal Investigator, Andrew Biegner: (716) 864-9136, Co-Principal Investigator, Elizabeth Booth: (813) 499-6722

This project has been reviewed and approved by The University of Akron Institutional Review Board. If you have any questions about your rights as a research participant, you may call the IRB at (330) 972-7666.

Acceptance & signature: I have read the information provided above and all of my questions have been answered. I voluntarily agree to participate in this study. I will receive a copy of this consent form for my information.

______________________________________ ______________________

Participant Signature Date

APPENDIX B

QUESTIONNAIRE

Subject: ____

Please answer all questions as accurately as possible.

1. Age ____

2. Year in college (i.e Freshman, Sophomore, etc.) ____________________

3. Did you run track or cross country in high school? ___________

a. If so, how many years of experience did you have running track/cross country? ________

b. If so, what events did you compete in regularly?
____
____
____ ______

4. Do you currently participate in endurance-based training? (This would include any cardio work such as running, cycling, or swimming, at least 3 times a week): (Yes or No) __________

a. If yes, please describe the training below:
____
____
____
____

5. In order to participate in this study, you must be a recreational athlete that participates in exercise at least 3 days a week for at least 30 minutes. Please describe this activity/exercise you participate in here:
____
____
____

APPENDIX C

SCRIPT

To be read to all participants before VO2max testing:

“Today you will be running a maximal exercise test. Your goal should be to perform this test at your maximum effort. The entirety of the test will take place on the treadmill. After a warmup, you will start at 5.0mph and 0% grade. Each minute, the speed will increase 0.5mph until you reach 9.5mph. If you are still running at that point, the grade will begin to increase by 2% each minute. We want you to give this test your best effort, so you will be actively encouraged to run until you hit your limit.

With the increasing speed, your body will transition from using its aerobic system to more of its anaerobic system to keep up with the energy demand. This is called your anaerobic threshold. When this happens, your breathing changes. This will happen at some point during this test but that point differs from person to person. This study is being conducted to see if you can perceive these changes. Therefore, we would like you to raise your hand when you can sense a change in pace, intensity, or volume of your breathing.

If you at any time during this test feel symptoms such as pain near the area of your heart, excessive shortness of breath, wheezing, leg cramps, lightheadedness or confusion, the feeling of being cold while exercising, or you are not sweating at a high intensity of work, please perform the sign we went over (the classic cut sign by taking the hand and making a swiping motion across the neck area) and we will halt the test immediately. If you have any other reason for wanting to stop this test, please make the same motion and we will stop the test with zero repercussions or questions asked. Once on the treadmill, I will show you the large red button in the middle of the handlebar that can be pressed at any time to halt the test as well.”

APPENDIX D

MODIFIED TREADMILL PROTOCOL

Time	Speed (mph)	Grade
0:00	5.0	0%
1:00	5.5	0%
2:00	6.0	0%
3:00	6.5	0%
4:00	7.0	0%
5:00	7.5	0%
6:00	8.0	0%
7:00	8.5	0%
8:00	9.0	0%
9:00	9.5	0%
10:00	9.5	2%
11:00	9.5	4%
12:00	9.5	6%
13:00	9.5	8%
14:00	9.5	10%
15:00	9.5	12%