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Aerobic and Anaerobic Characteristics of Competitive Junior Cyclists

John William Harrell
University of Tennessee - Knoxville

To the Graduate Council:

I am submitting herewith a thesis written by John William Harrell entitled "Aerobic and Anaerobic Characteristics of Competitive Junior Cyclists." I have examined the final electronic copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Exercise Science.

David R. Bassett, Jr., Major Professor

We have read this thesis and recommend its acceptance:

Eugene C. Fitzhugh, Edward T. Howley

Accepted for the Council:
Carolyn R. Hodges

Vice Provost and Dean of the Graduate School

(Original signatures are on file with official student records.)

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Anne Mayhew
Vice Chancellor and
Dean of Graduate Studies

(Original signatures are on file with official student records.)

AEROBIC AND ANAEROBIC CHARACTERISTICS OF COMPETITIVE JUNIOR CYCLISTS

A Thesis
Presented for the
Master of Science
Degree
The University of Tennessee, Knoxville

John William Harrell
August 2006

DEDICATION

To Mom and Dad for making me understand the value of an education and their unwavering support on so many levels, no matter the circumstances. I can only hope to be for my children as you have been for me.

"I have never let my schooling interfere with my education."

– Mark Twain

"All truths are easy to understand once they are discovered; the point is to discover them."

– Galileo Galilei

"If I have ever made any valuable discoveries, it has been owing more to patient attention, than to any other talent."

– Isaac Newton

"It is a miracle that curiosity survives formal education."

– Albert Einstein

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To all the people that helped me in and out of the lab in the process of putting this together. They helped me find the way to the end. Without you, this wouldn't have been realistic; Carrie Albright, Erin Kuffel, Amber McMahan, Rachel Duckham, Pam Andrews, Jon Crowson, and all the participants…Thank you.

ABSTRACT

AEROBIC AND ANAEROBIC CHARACTERISTICS OF COMPETITIVE JUNIOR CYCLISTS

By John William Harrell

The purpose of this study was to investigate the aerobic and anaerobic characteristics of male, competitive junior cyclists. Ten, male competitive cyclists (15.1 ± 1.1 years old) from Central and East Tennessee volunteered to perform a maximal aerobic power (VO_{2max}), Wingate anaerobic power, and lactate threshold (LT) tests. The cyclists were 167.1 ± 6.6 centimeters (cm) tall, had 53.9 ± 7.7 kilograms (kg) of body mass, and had 14.0 ± 4.9 % body fat. They had 1.8 ± 1.1 years of cycling and racing experience. The VO_{2max} of these cyclists was 53.3 ± 6.6 $ml \cdot kg^{-1} \cdot min^{-1}$ (2.9 ± 0.6 $L \cdot min^{-1}$). During an anaerobic power test, the cyclists reached a peak power output (PO) of 640.7 ± 179.8 Watts (W) (11.8 ± 2.5 $W \cdot kg^{-1}$), had a mean PO of 475 ± 101.8 W (8.8 ± 1.2 $W \cdot kg^{-1}$). The junior cyclists fatigued at a rate of 10.6 ± 6.4 $W \cdot second^{-1}$ and had a fatigue index of 47.4 ± 16.5 %. The LT of this group occurred at 188 ± 56.7 W or 62.3 ± 8.1 % of VO_{2max}. Relative VO_{2max} was significantly correlated to absolute VO_{2max} ($r = 0.792$, $p < 0.01$), PO at LT ($r = 0.790$, $p < 0.01$), and mean anaerobic PO ($r = 0.646$, $p < 0.05$). Absolute VO_{2max} was significantly correlated to PO at LT ($r = 0.938$, $p < 0.01$). PO at LT is correlated to mean anaerobic PO ($r = 0.701$, $p < 0.05$). Peak anaerobic PO and mean anaerobic PO are correlated ($r = 0.698$, $p < 0.05$). Peak anaerobic PO is correlated to fatigue index ($r = 0.706$, $p < 0.05$). Junior cyclists generally rank lower than USCF adult cyclists, as a group. Tracking the physiological characteristics investigated

in this study may tell coaches and junior riders when they are ready to compete against adult riders.

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CHAPTER 1

INTRODUCTION

There have been several interventions set in motion in the past decade attempting to increase youth participation in physical activity and sport on the domestic and international level (22, 33). These interventions provide the youth population with both an opportunity to participate and a supportive environment in which to do so. Opportunity and support are two important factors to increase and maintain youth participation in sports (48). In the United States, there are many opportunities to participate in organized sports programs that allow for a large number of youths to become involved. Approximately 10 million high school students in the U.S. in 1997 were active in sports (47). Cycling is one sport in which kids are becoming involved. The Lance Armstrong Junior Olympic Road Series (LAJORS), a string of events for junior cycling development, has grown from 12 events in 1993 to 85 events in 2003. The increase in cycling and all sports participation has made competitive youth athletes an important population to study. There have been several studies done involving not only junior cyclists (34, 39, 57), but also other junior athletes (26, 34, 46, 54). These athletes range from endurance to sprint competitors. In all these studies, there are some common measurements that are important to athletic performance.

Maximal oxygen consumption (VO_{2max}) has long been considered a determinant of success and even a prerequisite in endurance competition. Competitive cycling is an endurance event and subsequently requires cyclists to have a high VO_{2max} (12, 13, 25). VO_{2max} values have been reported for both elite (12) and non-elite (16, 45, 52) adult competitive cyclists. VO_{2max} values for competitive youth cyclists have also been

reported (34, 39, 57). However, VO_{2max} values as a part of a full descriptive physiological profile, including anaerobic power and lactate threshold of a group of competitive junior cyclists have not been reported.

Although less attention has been given to anaerobic power (56), it is also an important part of competitive cycling (35). Anaerobic power measurements will tell how well a cyclist can perform during the times in a race that require high-intensity pedaling such as hill climbing, breaking away from the pack, and sprinting to the finish (14, 52). There are a few studies that profile the anaerobic power of junior cyclists (34) and some other athletes (26, 34), but these studies were not a full descriptive physiological profile including both aerobic power and lactate threshold.

Having a high VO_{2max} and anaerobic power production are not the only requirements to perform at a high velocity. It is also important for the athlete to compete and perform at a high percentage of VO_{2max} without fatiguing. Lactate threshold is defined as the critical work rate, or percentage of VO_{2max}, before lactic acid begins to accumulate in the blood. Lactate threshold is important predictor of performance because it determines performance velocity. Coyle et al. (1988) found that individuals with higher lactate thresholds are able to perform at equal relative intensities for longer durations than individuals who have lower lactate thresholds. To date, no studies have investigated lactate threshold in junior cyclists as a part of a full physiological profile.

Like many athletic events, cycling involves a combination of both aerobic and anaerobic energy production (56). Both energy systems play an important role in race performance. There is a need for normative values on competitive junior cyclists of all skill levels to provide information for coaches and youth competitors. Thus, the purpose

of this study is to describe the aerobic and anaerobic characteristics of junior competitive male cyclists.

Limitation

This study was limited to junior male, competitive cyclists who volunteered to participate in this research.

Delimitation

This study was delimited to 13 – 18 year old competitive cyclists from East and Central Tennessee.

Hypothesis

There will be no significant correlations between aerobic and anaerobic characteristics of competitive junior male cyclists from East and Central Tennessee.

CHAPTER 2

REVIEW OF LITERATURE

The purpose of this study is to characterize the aerobic and anaerobic fitness of male junior cyclists according to their United State Cycling Federation competition category. The increase in youth involvement in sports leads to an increased need to examine this population's performance characteristics. Coaches and athletes benefit from knowing the aerobic and anaerobic characteristics of their athletes for training and competitive purposes.

Youth Participation

Physical inactivity in youth is on the international health agenda (33). Television, computers, video games, and digital media have driven some, but not all youth inside. To combat this issue, countries all around the world are taking aim at inactivity (33). Sport and recreation, health promotion, and transport sectors are viewed as priority areas for increasing rates of physical activity across the world (22). Australian policies focus on the "delivery of successful sports participation to expand the reach and active membership of grass roots sporting clubs and associations" (3). Expectations include an increase in the number of people participating in sports, youth participation in organized sport, and boosted active memberships of sporting organizations (3). Canada has spread interventions across sport and recreation, the United Kingdom highlights the importance of sport, and the United States of America has adopted mixed strategies to increase sports participation amongst adolescents (22). These sports initiatives are being proven to be effective (33).

Many areas throughout the world have high rates of participation in sport and leisure activity. The rates of participation in sport are very high amongst adolescents in the Calgary area. In Calgary and Calgary area high schools, 94% of students participated in sport (23). A study of New Zealand children between 12 and 17 years of age found that between one-half and two-thirds of adolescents are interested in participating in a new sport or leisure activity (51). American high school students are exposed to a great number of organized sports programs. In 1997, approximately 62% of US high school students participated on at least one sports team in school and/or non-school settings. This is approximately 10 million youths in the United States, alone (47). Pate et al. (2000) also point out the benefit of sports participation, as it is associated with positive health behaviors. The benefits and positive health behaviors of sports participation should lead to more opportunities and supportive environments for all kids that wish to participate.

A study of New Zealand children 12 – 17 years old showed that with the opportunity and support to be more active, many adolescents would like to increase their participation in sports (48). Of those polled, 22% participated in cycling (both road and mountain) and 43% were interested in one or the other (48). The popularity of youth sports in the school and non-school level in the United States continues to explode and cycling is no exception. The LAJORS, a string of events for junior cycling development, encourages junior participation in cycling, and gives them a safe environment to compete. The LAJORS has grown from a modest 12 events in 10 states in 1993 to a hefty 85 events in 31 states in 2003. Another junior cycling series, the Northwest Juniors Racing Series, was averaging 40 junior cyclists per race in 2003. The director of the series, Dave

Schilling, said it was “quite an increase” from the average of 10 riders in years prior (53). More opportunities and more supportive environments have led to the increased participation in junior cycling. Greater participation eventually leads to an increase in the competitive level of cyclists involved and the drive to succeed.

The increase of both opportunity and support in the junior cycling community has made junior cyclists an important population to consider for research studies. In cycling, success can be predicted and quantified to describe a certain rider, or group of riders. This study aims to describe male junior cyclists in the Knox County area and Central Tennessee to give some insight into which physiological characteristics it takes to be a successful, competitive junior cyclist.

Maximal Aerobic Power

Maximal oxygen consumption (VO_{2max}) has long been considered the best measure of cardiovascular system function and one of the best determinants of success in endurance athletic performance (10), specifically cycling (12, 13, 25). It is generally considered to be a prerequisite to elite performance and competition in endurance events. A high VO_{2max} value means that an athlete can perform at high intensities before oxygen delivery limits aerobic energy synthesis (10). VO_{2max} represents the body’s ability to take in and utilize oxygen for energy production. Inhalation of air into the lungs, extraction of oxygen from the inhaled air, circulation of oxygen in the blood via the heart and blood vessels, delivery of oxygen through capillaries, oxygen removal from the blood, and utilization of oxygen by working muscle cells are important. VO_{2max} is important in endurance performance because it sets the absolute upper limit of aerobic energy production for each individual person (15, 42).

Aerobic adenosine triphosphate (ATP) production and resynthesis relies on the integration of the systems for oxygen supply, transport, delivery, and use. VO_{2max} is determined by the Fick equation which states the maximal volume of oxygen used is equal to maximal cardiac output (Q_{max}) of the heart multiplied by the maximal oxygen difference between arterial and venous blood $(A\text{-}VO_{2diff})_{max}$: $VO_{2max} = Q_{max} \cdot (A - V\,O_{2diff})_{max}$. Athletes with high exercise capacities also have well-developed oxygen transport and carbon dioxide removal systems. Training helps develop these systems (10).

However, VO_{2max} is not the only predictor of performance. If it was, then endurance contests could be settled in a laboratory. Only in heterogeneous groups of athletes does VO_{2max} correlate highly with endurance exercise performance. When homogeneous groups of athletes with similar VO_{2max} values are investigated, the correlation between VO_{2max} and performance is reduced. In a group of race walkers, the correlation between VO_{2max} and race pace was not significant because the VO_{2max} values for the subjects were within 3% of each other and their performances varied by 43% (29). Londeree et al. (1986) agree that individuals with similar VO_{2max} values can differ in performance.

Anaerobic Power

Aerobic systems and VO_{2max} have been shown to provide much of the total energy and therefore have substantial predictive power in distance racing events, but the difference that the anaerobic system can make in the finishing order of a race among well-matched, and relatively homogenous, groups of athletes should not be overlooked (11). Less attention has been given to this important source of energy (18) as an

influence on competitive road cycling performance (6, 55), but cyclists draw energy from both aerobic and anaerobic processes (7).

Competitive cycling demands both high aerobic and anaerobic capacities of the athletes (35). Cyclists must develop excellent aerobic power, and the anaerobic capacity necessary for breaking away from a pack of riders, climbing hills, and sprinting to the finish line at the end of the race (12, 14, 52).

The Wingate anaerobic test can be used as a sport-specific test of cyclists to assess anaerobic performance (5). It is a 30-second all-out test against a set resistance, which is proportional to body weight. The test yields three main values: peak power, mean power, and rate of fatigue. Peak power describes the highest mechanical power that is elicited during the test. Mean power is the average power that is sustained throughout the 30-second period. Lastly, rate of fatigue is the degree of power drop-off during the test. Athletes who specialize in sprinting, jumping, and power events typically score higher than endurance athletes (5). Jaskolski et al. (1988) found that maximal peak anaerobic power was higher in junior wrestlers than junior cyclists.

Although cycling requires both aerobic and anaerobic power, they do not appear to be significantly correlated (34, 52). Several attempts have been made to correlate anaerobic power and aerobic power, but a significant relationship has not been found (34, 35, 52). These findings suggest individuals with high parameters of aerobic capacity do not necessarily possess parameters with regards to their anaerobic power (34). Although they seem to be unrelated, both aerobic and anaerobic powers make important contributions during a competitive race (7).

It is known that aerobic processes supply most of the energy required in endurance exercise, but they do not provide adequate amounts of energy during strenuous exercise (breaking away, hill climbing, and sprinting). In high-intensity exercise, a large percentage of the energetic requirements is supplied by anaerobic pathways (18). Bulbulian et al. (1986) showed anaerobic work capacity significantly contributed to distance running performance in an aerobically homogenous group. In the homogenous group of junior cyclists in this study, anaerobic work capacity should contribute to performance on race day.

Lactate Threshold

Lactate threshold is the critical level of work above which lactate begins to accumulate at a rapid rate in the blood (41). As an athlete or a coach, it would be valuable to know the lactate threshold, or onset of blood lactate accumulation (OBLA) for both training and racing purposes. Lactate threshold can be used as a training tool to determine the appropriate training pace. As an endurance performance predictor, it has been shown to be accurate and reliable (24, 41).

As mentioned earlier, VO_{2max} has long been recognized as an important determinant of endurance performance (2), specifically during competitive road cycling (12, 13, 25). VO_{2max} sets the upper limit for, not only steady-state oxygen consumption during performance, but also the lactate threshold (15). The performance velocity of an individual, or rate of oxygen consumption (VO_2) during competition, is related to the lactate threshold (15, 16, 24, 28). If two athletes have the same VO_{2max}, but one athlete's lactate threshold occurs at a higher percentage of the shared VO_{2max}, that athlete will be able to perform at a faster velocity and have a better performance time. Though VO_{2max}

is a good predictor of performance, individuals with similar VO_{2max} values may differ in the speed at which they perform (42). Coyle et al. (1988) found that differences in endurance performance between homogeneous groups of individuals can largely be explained in terms of lactate threshold. In a group of VO_{2max} matched cyclists, athletes with high lactate thresholds took almost twice as long to fatigue at 88% of their VO_{2max} and had blood lactate concentrations of almost one half at the end of the exercise session when compared to the athletes with a low lactate threshold (16). For this reason, Coyle et al. suggest that it is more accurate to express an individual's metabolic capability for endurance exercise by reporting VO_2 at lactate threshold than it is to report VO_{2max} (16).

Lactate threshold's usefulness is not limited to race day performance. Knowing lactate threshold helps in performance prediction and pacing, but it is also valuable to know for everyday training purposes. Figure 1 illustrates the generalized training effect of endurance exercise training to lower the blood lactate levels during exercise of progressively increasing intensity and also extend the level of exercise intensity before the OBLA (44).

Brooks et al. (1991) state the blood lactate concentration is determined by both lactate's rate of appearance and by how quickly it is cleared away for oxidation in the muscle (clearance) and its conversion to glycogen in the liver and muscle. To raise the lactate threshold, the body must adapt by producing less and/or removing more lactate. There is evidence indicating training-induced increases in respiratory capacity of muscle fibers results in less lactate production and these adaptations play an important role in improving performance (30). Donovan et al. (1983) found no significant effects of training on blood lactate appearance during exercise, but lower lactate levels were

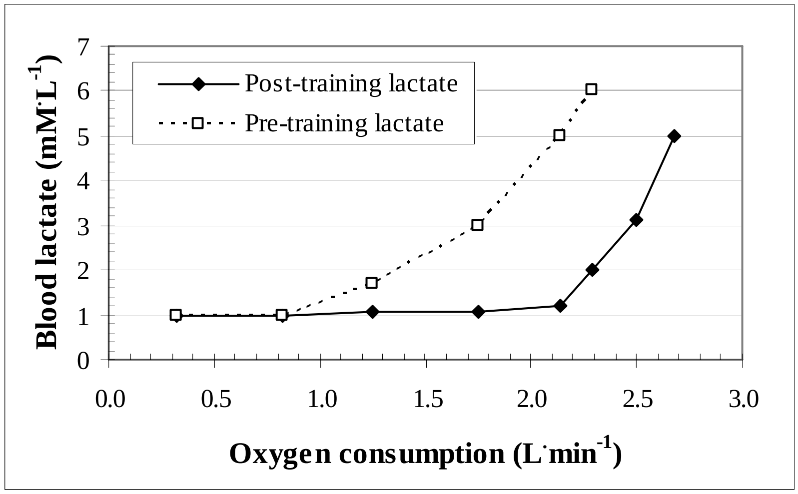

Figure 1. Generalized response of pre- and post-training blood lactate accumulation during graded exercise (44)

observed in trained subjects during exercise as a result of enhanced clearance. Whether or not it is both reduced production and increased clearance, or just increased clearance, is a topic of debate. The major point is there is less lactate accumulation in the blood during exercise after training. However, not all levels of training intensity will induce an adaptation to lower levels of blood lactate during exercise.

Both Katch et al. (1978) and Kindermann et al. (1979) emphasize training above or below the lactate threshold would theoretically result in different cardiorespiratory and metabolic training effects. Exercising at or slightly above the lactate threshold provides effective aerobic training, with the higher exercise intensities producing the greatest benefits, particularly for fit individuals (43). In the case of the junior cyclists in this study, they are fit and need to be training at levels above their lactate threshold. An athlete should occasionally experience high blood lactate levels in order to develop the

mechanisms of lactate removal because the ability to remove lactic acid is related to its concentration. The lactate threshold test identifies the exercise power output at which blood lactate begins to accumulate non-linearly, and it has been suggested that athletes should train at that level. This is the lowest power output where lactate clearance mechanisms fail to keep pace with lactate production (10). The above evidence makes it easy to understand why lactate threshold is important to competitive cyclists and competitive endurance athletes, alike.

CHAPTER 3

METHODS

All data collections were performed at the Applied Physiology Laboratory in the Health, Physical Education, and Recreation building on the campus of the University of Tennessee, Knoxville.

Participants

10 Male, competitive junior cyclists, ages 13 – 18 volunteered to participate in this study. All 10 participants were from East and Central Tennessee. The training history of all participants was noted, as well as their United States Cycling Federation racing category. Before testing, each participant and parent or guardian read and signed a child assent form and a parental permission form, respectively. Both participant and parent or guardian completed and signed a health history questionnaire approved by The University of Tennessee's Institutional Review Board.

Session 1

Height and Body Mass

Participants came to the lab for the first session having fasted for at least 3 to 4 hours and had refrained from any exercise for 24 hours. Height was measured using a stadiometer. Body mass was measured using an electronic platform balance, calibrated with known weights.

Body Composition

The Bod Pod was used to determine body composition by air displacement plethysmography (27, 31). Participants sat in the Bod Pod for two short trials while body

volume was determined. Participants wore lycra cycling shorts for the, as well as a lycra swim cap for the trials. Lung volume was estimated by the computer software.

Wingate Anaerobic Test

Participants performed a Wingate anaerobic test on a Lode cycle ergometer. The Lode cycle ergometer was fitted to match the participants' bike dimensions. Crank to saddle, saddle to handlebars, and handlebar height were the three measurements fitted for each participant. Each participant also brought in his own pair of cleated cycling shoes and pedals to attach to the cycle ergometer. Prior to the test, participants warmed up for 5 minutes at 100 Watts. Near the end of the warm up period, the subject was instructed to increase pedal cadence to a maximal effort. Immediately after the 5-minute warm up was complete, the 30-second Wingate test began. The Wingate test is an all-out cycling test for 30 seconds. Resistance, or braking force, is set at its full intensity from the start and is set based on age and gender by the Lode computer. These junior cyclists pedaled against a resistance of $0.071\ kg \cdot kg\ body\ weight^{-1}$. The test outcome measures include peak power, mean power, rate of fatigue, and fatigue index. Peak power is the highest power output at any point during the test. Mean power is the average power output over the full 30 seconds. Rate of fatigue and fatigue index calculated are as follows: Rate of fatigue = (highest power output – lowest power output) $\cdot$ (30 seconds)$^{-1}$, and Fatigue index = (highest power output – lowest power output) $\cdot$ (highest power output)$^{-1}$. Once the 30-second test was complete, participants actively cooled down for the duration of their choice.

Session 2

Maximal Aerobic Power

At least 1 hour after the Wingate anaerobic test, each participant completed a test of maximal aerobic power (VO_{2max}) on the Lode cycle ergometer fitted to each participant. Participants warmed up for 2 to 3 minutes at 80 Watts. The test protocol required the participants to pedal at 80 revolutions per minute (rpm) beginning at 120 Watts. The resistance increased 40 Watts every minute until the participant reached volitional fatigue (cannot maintain pedal cadence of at least 65 rpm). Respiratory gas exchange analysis was performed using a computerized metabolic system. Before each test, O_2 and CO_2 analyzers were calibrated using gases of know concentrations, and the flow meter was calibrated using a 3-liter syringe. Heart rate was monitored throughout the duration of the test using a Polar® heart rate monitor. The highest 30 second VO_2 value was used as the VO_{2max} as long as the participant had reached > 1.10 respiratory exchange ratio and within 10 beats of his age-predicted maximal heart rate.

Session 3

Lactate Threshold

At least 24 hours after the VO_{2max} test, participants performed a lactate threshold test. Like a VO_{2max} test, the lactate threshold test was an incremental graded exercise test on the Lode cycle ergometer fitted to each participant. However, participants only performed up to a near-maximal value. The participants initially pedaled at 80 rpm beginning at 80 Watts. The resistance increased by 40 Watts every three minutes. During the last minute of each 3-minute stage, including the initial resting period, 100 microliters of blood was obtained from a finger tip. A Long Point B-D micro-lance blood

lancet was used to extract blood from the finger tip. The blood was drawn into a 100-microliter, Aqua-Cap capillary tube. The blood sample was then ejected into a YSI blood sampling tube containing cetrimonium bromide and sodium fluoride and shaken. The participant completed several stages until he had reached near VO_{2max}. Once the test was complete, the blood lactate samples were analyzed using a YSI 2300 STAT Plus automated lactate analyzer. Lactate threshold was determined using the inflection point method. In this method, lactate threshold is the work rate at which blood lactate concentration began to rise nonlinearly and represents the point at which lactate entry into the blood exceeding its removal (10).

Statistics

Means and standard deviations were calculated for age, height, weight, lean body mass, and body fat percentages. Tables of the mean data and standard deviations collected from all the sessions for each subject are presented in the results section. A Pearson product-moment correlation coefficient matrix was produced in an attempt to find any significant relationships between VO_{2max}, Wingate power output, and power output at lactate threshold. All statistics were done using SPSS 14.0 and Microsoft Excel 2003 for Windows.

CHAPTER 4

RESULTS

Physical Characteristics

The physical characteristics of the each junior cyclist are listed in Table 1. The junior cyclists were 15.1 ± 1.1 years old and 167.1 ± 6.6 centimeters tall (mean ± standard deviation). They had 53.9 ± 7.7 kilograms of body mass, 14.0 ± 4.9 % body fat, and an average of 46.6 ± 8.2 kilograms of lean body mass.

Experience

Table 2 lists the riding experience of each of the participants. The junior cyclists had been training 3.8 ± 2.2 days per week for 1.7 ± 0.9 hours per training session. They had been training at this level for 1.8 ± 1.1 years. There were 2 category III racers, 3 category IV racers, and 5 category V racers. All of the cyclists were road cyclists except for the two category V racers who were mountain bikers.

Aerobic Characteristics

The data from the VO_{2max} testing is listed in Table 3. The junior cyclists had a relative VO_{2max} of 53.3 ± 6.6 $ml \cdot kg^{-1} \cdot min^{-1}$, an absolute VO_{2max} of 2.9 ± 0.6 $L \cdot min^{-1}$, and an average maximal power output of 308 ± 65.5 Watts during the graded exercise test (GXT).

Wingate Anaerobic Characteristics

The data collected from the Wingate anaerobic power test is presented in Table 4. During this 30-second all-out test, the junior cyclists achieved a peak power of 640.7 ± 179.8 Watts and 11.8 ± 2.5 $W \cdot kg^{-1}$, a mean power of 475 ± 101.8 W and 8.8 ± 1.2 $W \cdot kg^{-1}$, fatigued at a rate of 10.6 ± 6.4 $W \cdot sec^{-1}$, and had a fatigue index of 47.4 ± 16.5%.

Table 1. Physical characteristics of the junior cyclists

Subject	Age (years)	Height (cm)	Mass (kg)	Percent Body Fat (% BF)	Lean Body Mass (kg)
1	16	170.2	57.3	19.4	46.2
2	15	160.0	44.0	20.1	35.2
3	16	177.8	59.9	10.2	53.8
4	16	165.1	66.8	14.0	57.5
5	14	170.2	53.7	13.4	46.5
6	17	170.2	56.1	9.3	50.9
7	14	162.6	43.4	17.6	35.8
8	15	172.5	55.2	7.7	51.0
9	14	168.0	57.9	8.7	52.9
10	14	155.0	44.8	19.4	36.1
Mean	15.1	167.1	53.9	14.0	46.6
± SD	1.1	6.6	7.7	4.9	8.2

Table 2. Training and Experience of junior cyclists

Subject	Training Frequency (days/week)	Training Duration (hours/session)	Experience (years)	Racing Category	Road or Mountain
1	6	2	2	IV	Road
2	1	0.25	0.5	V	Road
3	6	2	3	III	Road
4	6	2.5	2	IV	Road
5	4	3	3	IV	Road
6	5.5	2	1	III	Road
7	2.5	2	0.5	V	Road
8	1	0.5	3	V	Road
9	1	2	2	V	Mountain
10	5	0.5	0.5	V	Mountain
Mean	3.8	1.7	1.8		
± SD	2.2	0.9	1.1		

Table 3. Aerobic power characteristics of the junior cyclists

Subject	Relative VO_{2max} ($ml \cdot kg^{-1} \cdot min^{-1}$)	Absolute VO_{2max} ($L \cdot min^{-1}$)	Maximal Power during GXT (Watts)
1	49.8	2.9	320
2	42.2	1.9	200
3	66.4	4.0	400
4	55.7	3.7	400
5	54.4	2.9	280
6	53.0	3.0	320
7	57.1	2.5	280
8	46.0	2.5	240
9	55.4	3.2	360
10	53.3	2.4	280
Mean	53.3	2.9	308
± SD	6.6	0.6	65.5

Table 4. Wingate test anaerobic power characteristics of the junior cyclists

Subject	Peak Power (Watts)	Peak Power ($W \cdot kg^{-1}$)	Mean Power (W)	Mean Power ($W \cdot kg^{-1}$)	Fatigue Rate ($W \cdot sec^{-1}$)	Fatigue Index (%)
1	702	12.2	523	9.1	11.3	48.3
2	321	7.3	251	5.7	4.8	44.9
3	628	10.5	560	9.3	4.9	23.8
4	913	13.7	583	8.7	19.7	64.7
5	926	17.2	541	10.1	23.6	76.5
6	597	10.6	546	9.7	4.5	22.6
7	509	11.8	421	9.7	7.2	42.4
8	602	10.9	459	8.3	10.1	50.3
9	659	11.4	487	8.4	9.9	45.1
10	550	12.3	379	8.5	10.2	55.6
Mean	640.7	11.8	475	8.8	10.6	47.4
± SD	179.8	2.5	101.8	1.2	6.4	16.5

Lactate Threshold

In Table 5, the results from the lactate threshold testing are shown for each junior cyclist. On average the lactate threshold occurred at a power output of 188 ± 56.7 Watts, or 62.3 ± 8.1 % of VO_{2max}.

Correlations

A correlation matrix was produced and is presented as Table 6. In Table 6 correlations were calculated to assess the relationships between relative VO_{2max} ($ml \cdot kg^{-1} \cdot min^{-1}$), absolute VO_{2max} ($L \cdot min^{-1}$), power output (PO) at lactate threshold (LT), anaerobic mean PO, anaerobic peak PO, and anaerobic fatigue index. The following significant correlations are present as scatter plot charts in Figures 2 – 8.

Relative VO_{2max} and absolute VO_{2max} were significantly, positively correlated, $r = 0.792$ ($p < 0.01$) and is displayed in Figure 2. Positive correlations also existed between PO at LT and VO_{2max} $ml \cdot kg^{-1} \cdot min^{-1}$ ($r = 0.790$) shown in Figure 3 and between VO_{2max} $L \cdot min^{-1}$ and PO at LT ($r = 0.938$) ($p < 0.01$) illustrated in Figure 4.

There were four pairs of variables that yielded significant positive correlations at the 0.05 level of confidence. Anaerobic mean PO and relative VO_{2max} had a correlation of $r = 0.646$ and can be seen in Figure 5. Anaerobic mean PO and PO at LT had a correlation of $r = 0.701$ and is displayed in Figure 6. Anaerobic mean PO and anaerobic peak PO were significantly correlated ($r = 0.698$) and shown in Figure 7. Finally, Figure 8 illustrates that anaerobic peak PO and fatigue index were significantly correlated ($r = 0.706$).

Table 5. Lactate threshold characteristics of the junior cyclists

Subject	**Power Output at Lactate Threshold (Watts)**	**Lactate Threshold (% VO_{2max})**
1	160	50.0
2	80	60.0
3	280	70.0
4	240	60.0
5	200	71.4
6	240	75.0
7	160	57.1
8	160	66.7
9	200	55.6
10	160	57.1
Mean	188	62.3
± SD	56.7	8.1

Table 6. Correlation Matrix

	VO_{2max} ($ml \cdot kg^{-1} \cdot min^{-1}$)	VO_{2max} ($L \cdot min^{-1}$)	PO at LT (W)	Wingate Mean PO ($W \cdot kg^{-1}$)	Wingate Peak PO ($W \cdot kg^{-1}$)	Wingate Fatigue Index
VO_{2max} ($ml \cdot kg^{-1} \cdot min^{-1}$)	1	.792(**)	.790(**)	.646(*)	.323	-.261
VO_{2max} ($L \cdot min^{-1}$)		1	.938(**)	.513	.335	-.150
PO at LT (W)			1	.701(*)	.376	-.260
Wingate Mean PO ($W \cdot kg^{-1}$)				1	.698(*)	.013
Wingate Peak PO ($W \cdot kg^{-1}$)					1	.706(*)
Wingate Fatigue Index						1

** Correlation is significant at the 0.01 level (2-tailed).
* Correlation is significant at the 0.05 level (2-tailed).

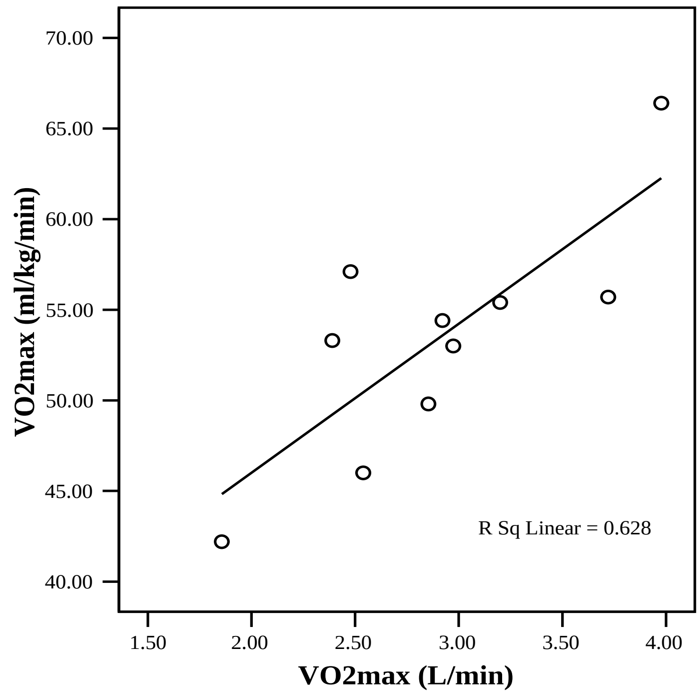

Figure 2. Scatter plot correlation of absolute and relative VO_{2max}
(r = .729, p < .01)

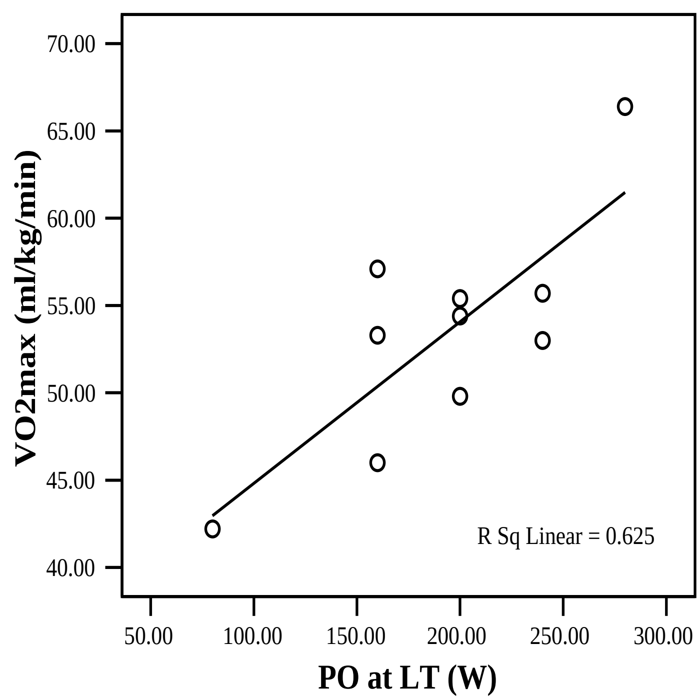

Figure 3. Scatter plot correlation of PO at LT and relative VO_{2max}
(r = .790, p < .01)

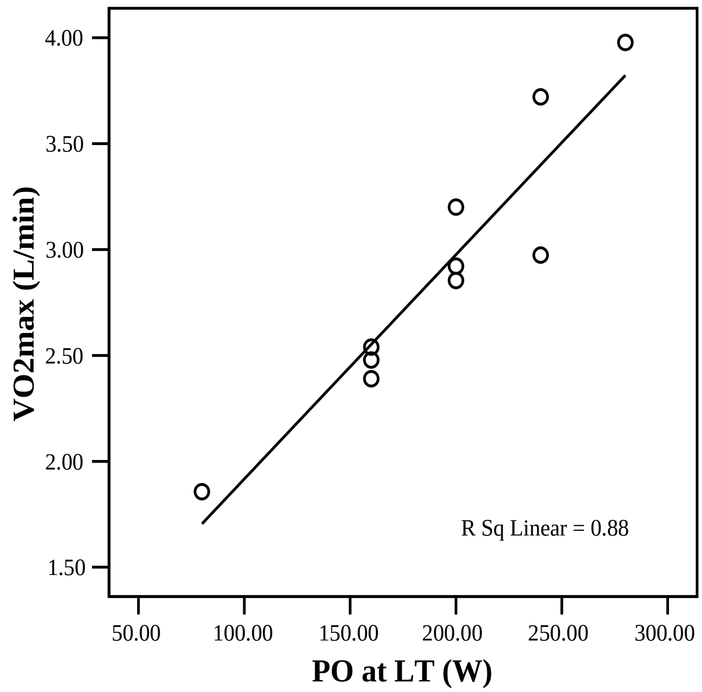

Figure 4. Scatter plot correlation of PO at LT and absolute VO_{2max}
(r = .938, p < .01)

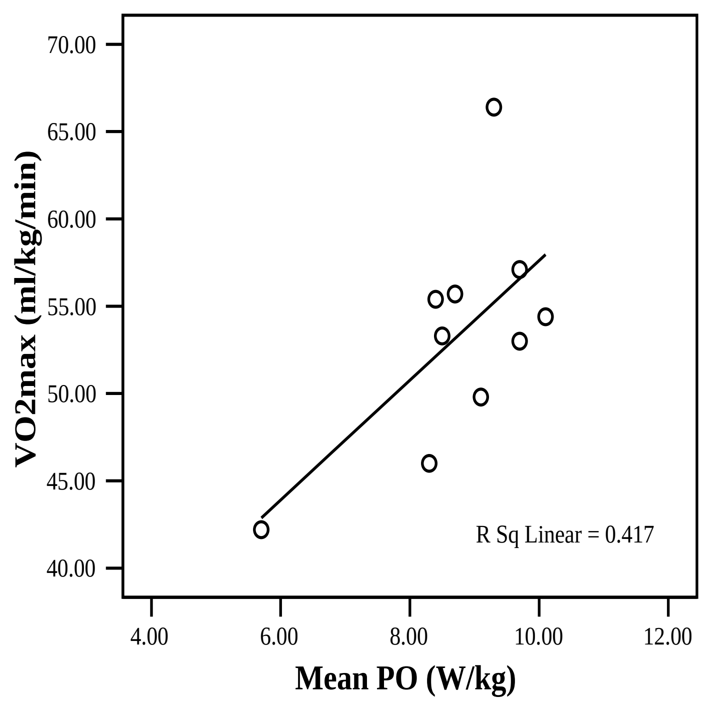

Figure 5. Scatter plot correlation of Wingate mean PO and relative VO_{2max}
(r = .646, p < .05)

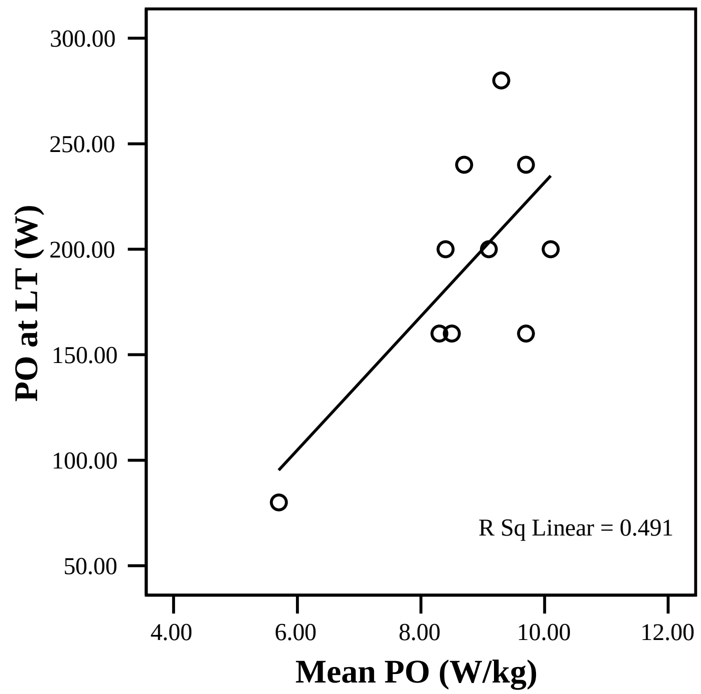

Figure 6. Scatter plot correlation of Wingate mean PO and PO at LT
($r = .701$, $p < .05$)

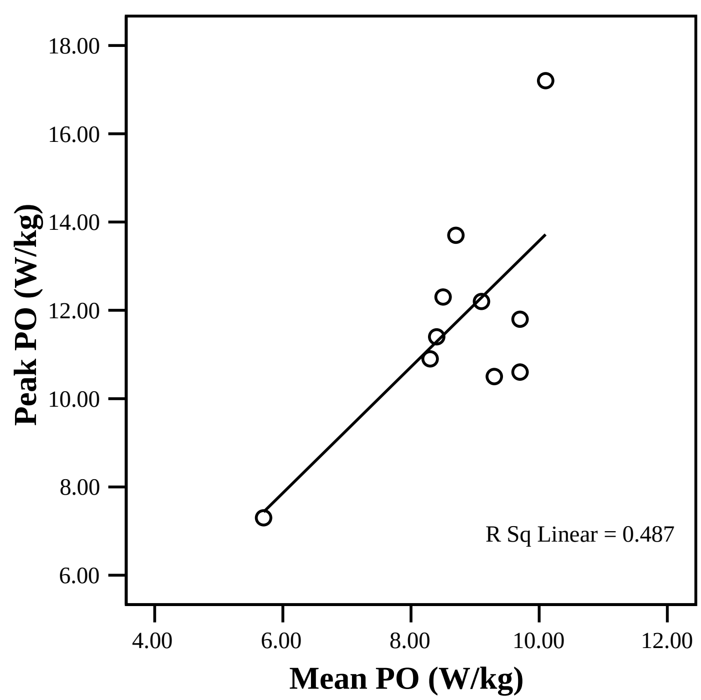

Figure 7. Scatter plot correlation of Wingate mean PO and peak PO
($r = .698$, $p < .05$)

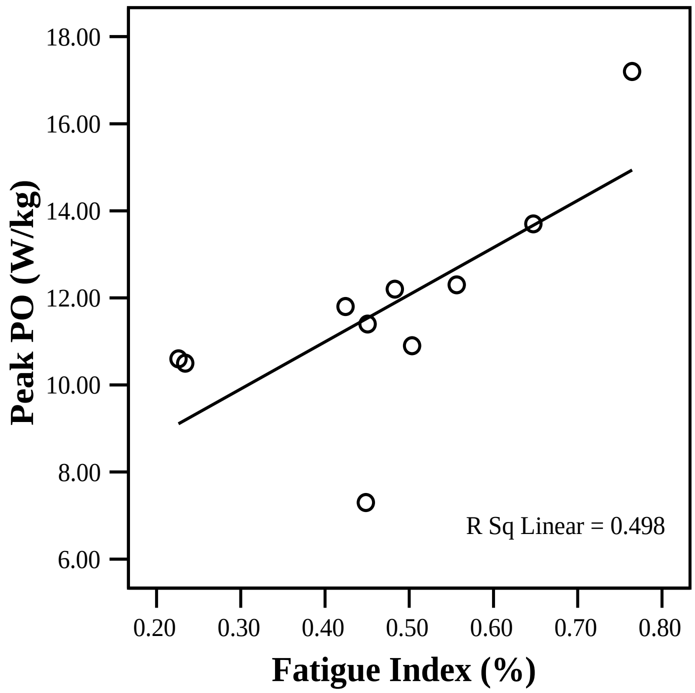

Figure 8. Scatter plot correlation of Wingate fatigue index and peak PO ($r = .706$, $p < .05$)

CHAPTER 5

DISCUSSION

The primary purpose of this study was to describe the aerobic and anaerobic characteristics of male, competitive junior cyclists. The increase in youth participation in sports has led to an increased need to examine this population for performance characteristics. The increase of opportunity and support to participate in cycling is leading the inflation of the junior cycling community and make them an important population to consider for research studies. The LAJORS has grown from 12 events in 10 states in 1993 to 85 events in 31 states in 2003 (53). The growth in junior cycling has made junior competitive cyclists prime candidates for new performance investigations.

Physical Characteristics

The junior cyclists in this study were slightly younger (15.1 ± 1.1 years) than junior cyclists in previous studies (16.7 ± 1.3, 17.0 ± 1.0, and 16.6 ± 1.0) (33, 38, 55), but similar in age to those in another study of junior cyclists (15.8 ± 1.1) (35). Also, these participants were slightly shorter (167.1 ± 6.6 cm) and had less body mass (53.9 ± 7.7 kg) than those in previous studies of junior cyclists (176.7 ± 4.0, 176.0 ± 7.3, 180.0 ± 5.0, and 172.0 ± 5.2 cm) (67.5 ± 5.1, 66.1 ± 10.4, 70.6 ± 7.8, and 59.4 ± 5.2 kg) (34, 35, 39, 57). This group of junior cyclists had a higher percentage of body fat (14.0 ± 4.9 %) than juniors in a previous study (5.8 ± 2.1, 6.0 ±1.6, and 5.7 ± 1.8 %), as well (57). McArdle et al. (2001) point out that as males age from 12 to 17 years, they will experience a drop in body fat from approximately 14% to below 10%, in general.

Aerobic Power

VO_{2max} has long been considered the best measure of cardiovascular fitness and one of the best determinants of success in endurance athletic performance (10), specifically cycling (12, 13, 25). The maximal aerobic power of the cyclists in this study was 53.3 ± 6.6 $ml \cdot kg^{-1} \cdot min^{-1}$ (mean ± standard deviation). Compared to normative values of 15 year olds, this value is considered to be "good" according to Shvartz et al. (1990) who did a literature review of aerobic fitness to create norms of VO_{2max} values from age 6 to 75. This value is less than values recorded in other studies of youth cyclists but very similar to values for youth wrestlers (34, 35, 39, 57). It is likely the junior cyclists in this study (15.1 ± 1.1 years old) will experience an increase in VO_{2max} as they train and mature and be comparable to the older youth cyclists and adult cyclists (46).

Jaskolski et. al. (1989) tested youth cyclists that had a VO_{2max} of 59.2 ± 5.66 $ml \cdot kg^{-1} \cdot min^{-1}$. Kime et al. (2003) tested junior cyclists with relative VO_{2max} values of 57.3 ± 4.5 $ml \cdot kg^{-1} \cdot min^{-1}$. Yuan et al. (2004) reported the VO_{2max} values of a group of youth cyclists at 60.6 ± 5.9. Jaskolski et al. (1988) also tested wrestlers with VO_{2max} values of 53.3 ± 4.7 $ml \cdot kg^{-1} \cdot min^{-1}$ on a cycle ergometer.

VO_{2max} values for adult cyclists have been reported to be even higher; 66.0 ± 1.2 $ml \cdot kg^{-1} \cdot min^{-1}$, 68.6 ± 1.5 $ml \cdot kg^{-1} \cdot min^{-1}$ (16), 69.39 ± 1.28 $ml \cdot kg^{-1} \cdot min^{-1}$ (USCF category II), 64.98 ± 1.71 $ml \cdot kg^{-1} \cdot min^{-1}$ (USCF category III), 63.63 ± 1.94 $ml \cdot kg^{-1} \cdot min^{-1}$ (USCF category IV) (52), 56.5 $ml \cdot kg^{-1} \cdot min^{-1}$ (Amateur Bicycle League of America (ABLA) category 4), 61.1 $ml \cdot kg^{-1} \cdot min^{-1}$ (ABLA category 3), 65.2 $ml \cdot kg^{-1} \cdot min^{-1}$ (ABLA category 2), and 74.4 $ml \cdot kg^{-1} \cdot min^{-1}$ (ABLA category 1) (25). The relative VO_{2max} values of the junior cyclists in East and Central Tennessee are similar to those of

the average 18.9 ± 0.9 year old student who had a reported VO_{2max} of 54.6 ± 5.3 ml · kg^{-1} · min^{-1} on a cycle ergometer (18).

In this study, the cyclists' absolute VO_{2max} values were 2.9 ± 0.6 L · min^{-1} and are lower than previously reported numbers for adult cyclists (16, 17, 25, 52), youth cyclists (30), and endurance and non-endurance athletes of all ages (34, 46). According to the norms created by Shvartz et al. (1990), 2.9 ± 0.6 L · min^{-1} is considered "good." Jaskolski et al. (1988) reported youth cyclists (16.7 ± 1.3 years old) to have absolute VO_{2max} values of 4.40 ± 0.63 L · min^{-1} and youth wrestlers (16.9 ± 1.1 years old) to have absolute VO_{2max} values of 3.99 ± 0.60 L · min^{-1}.

It is expected that as these athletes grow and train, they will have an increase in their absolute VO_{2max} values, but there have been mixed reports of changes in relative VO_{2max} values as junior athletes age. Murase et al. (1981) reported middle- and long-distance junior runners in Group I of a study to have an absolute VO_{2max} of 3.54 L · min^{-1} (65.4 ml · kg^{-1} · min^{-1}) at age 14.8 and an increase to 4.49 L · min^{-1} (75.5 ml · kg^{-1} · min^{-1}) by age 18.0. Group II in the study increased from 3.19 L · min^{-1} (64.8 ml · kg^{-1} · min^{-1}) at 15.1 years old to 3.84 L · min^{-1} (70.8 ml · kg^{-1} · min^{-1}) at 17.2 years old (46). Daniels et al. (1978) reported a difference in absolute VO_{2max} values between one-year age differences in a longitudinal study of juniors in a middle- and long-distance running program. However, there were no differences in relative VO_{2max} values between each one-year interval (19).

Wingate Anaerobic Power

Although it is widely accepted that maximal aerobic power is important in determining endurance performance, it is not the only factor. Anaerobic power is

important at selected portions of an endurance cycling event (12, 14, 52). The peak and mean anaerobic power relative to body mass of the junior cyclists who participated in this study was comparable to values from previous studies (34, 35, 57). In this study, the junior cyclists had a peak power output of 11.8 ± 2.5 W · kg^{-1} and a mean power output of 8.8 ± 1.2 W · kg^{-1}. In previous anaerobic power studies involving junior cyclists and junior wrestlers, Jaskolski et al. (1988) reported a peak anaerobic power output of 11.71 $\pm$ 1.23 W · kg^{-1} for cyclists and 11.47 ± 0.84 W · kg^{-1} for wrestlers. In 1989, Jaskolski et al. reported junior cyclists to increase peak anaerobic power output from 10.7 ± 1.06 W · kg^{-1} in December to 11.0 ± 0.9 W · kg^{-1} in March. Inbar et al (1986) suggested research is needed on the specific developmental stage at which an individual acquires the adult characteristics in anaerobic exercise.

Tanaka et al. (1993) reported adult USCF cyclists in categories II, III, and IV to have peak anaerobic power outputs of 13.86 ± 0.23, 13.55 ± 0.25, and 12.80 ± 0.41 W · kg^{-1}, respectively. Tanaka et al. (1993) also reported those cyclists to have mean anaerobic power outputs of 11.22 ± 0.18, 11.06 ± 0.15, and 10.40 ± 0.30 W · kg^{-1}, respectively. Taken together, the results of these studies suggest that although the junior cyclists in the present study had comparable anaerobic power to other junior cyclists, adult cyclists have a higher peak anaerobic power output and a higher mean anaerobic power output. Astrand (1952) showed that during a maximal graded exercise test, the children participating could not achieve lactic acid levels similar to adults suggesting the inferiority of children’s anaerobic energy production pathway. Inbar et al. (1986) also concluded that anaerobic performance in children was inferior to that of adults.

The participants' mean rate of fatigue in this study, 10.6 ± 6.4 $W \cdot sec^{-1}$, was less than that of other junior competitive cyclists (34, 35) and non-endurance athletes (34). Jaskolski et al. (1988) reported junior cyclists had a fatigue rate of 12.1 ± 4.3 $W \cdot sec^{-1}$ and junior wrestlers had a fatigue rate of 12.6 ± 3.9 $W \cdot sec^{-1}$. In 1989, Jaskolski et al. reported junior cyclists fatigued at a rate of 11.2 ± 3.27 $W \cdot sec^{-1}$ and 11.8 ± 3.23 $W \cdot sec^{-1}$. The fatigue index of junior cyclists in East and Central Tennessee is 47.4 ± 16.5 %. Tanaka et al. (1993) reported the fatigue index of adult cyclists to be 34.25 ± 0.76, 33.46 ± 1.53, and 36.65 ± 1.73 %. The resistance used in this study for the Wingate anaerobic test (0.071 $kg \cdot kg$ body $weight^{-1}$) was also less than the resistance used by Tanaka et al. to test adult USCF cyclists (0.095 $kg \cdot kg$ body $weight^{-1}$) (52). These results suggest that junior cyclists fatigue more rapidly during a 30-second all out effort: this is consistent with studies indicating that the anaerobic power in youth is less well developed than in adults (32).

Lactate Threshold

As an endurance performance predictor, lactate threshold has been shown to be both reliable and valuable as a training tool (24, 41). The lactate threshold of this group of youth cyclists (62.3 ± 8.1 % VO_{2max}) was comparable to one previous study of junior cyclists whose lactate threshold was 62.2 ± 5.6 % VO_{2max} (57), but lower than that of another study of junior cyclists whose lactate thresholds were 74 and 70 % of VO_{2max} (39). The percentage of VO_{2max} at which lactate threshold occurs in youth cyclists seems to be consistently lower than values reported for adult competitive, sub-elite cyclists who have lactate thresholds reported at 79.2 ± 1.1 (5.7 ± 1.0 years of cycling training

experience), 75.3 ± 1.5 (4.2 ± 0.9 years of training) (15), 81.5 ± 1.8 (5.1 ± 0.9 years of training), and 65.8 ± 1.7 % VO_{2max} (2.7 ± 0.7 years of training) (16).

Correlations

An attempt was made to correlate the aerobic and anaerobic characteristics of these junior cyclists as well as power output at lactate threshold. Earlier studies have also done this in both junior (34, 35) and adult (52) cyclists, and junior wrestlers (34).

VO_{2max} $ml \cdot kg^{-1} \cdot min^{-1}$ and VO_{2max} $L \cdot min^{-1}$ were significantly correlated, $r = 0.792$ ($p < 0.01$). This is consistent with previous studies (38, 52). Tanaka et al. (1993) found a correlation of $r = 0.644$ ($p < 0.05$) between VO_{2max} $ml \cdot kg^{-1} \cdot min^{-1}$ and VO_{2max} $L \cdot min^{-1}$ in adult male cyclists. Katch et al. (1979) also found a significant correlation of $r = 0.53$ ($p < 0.05$) between VO_{2max} $ml \cdot kg^{-1} \cdot min^{-1}$ and VO_{2max} $L \cdot min^{-1}$ in healthy adult males during a GXT on a treadmill.

Power output at LT was positively correlated to VO_{2max} $ml \cdot kg^{-1} \cdot min^{-1}$ and VO_{2max} $L \cdot min^{-1}$, $r = 0.790$ and $r = 0.938$, respectively ($p < 0.01$). Power output at LT can be expressed as follows, where ME equals gross mechanical efficiency (44):
$PO \text{ at } LT = VO_{2max} \times \% VO_{2max} \text{ at } LT \times ME$. This equation illustrates PO at LT is highly dependent upon VO_{2max} and results in a significant correlation between VO_{2max} and PO at LT. This means an athlete who can consume and utilize more oxygen will achieve a higher power output at lactate threshold than an athlete that has a lower VO_{2max} and has been matched for % VO_{2max} at LT and ME.

The relationship between Wingate peak PO and fatigue index can be explained by fast twitch muscle fibers. Previous studies have shown that individuals with a high percentage of fast twitch fibers have a higher peak PO, and a more rapid rate of fatigue

(4, 32). For instance, Bar-Or et al. (1980) reported a significant relationship of $r = 0.54$ ($p < 0.05$) between the percentage of fast twitch fibers in the vastus lateralis muscle and Wingate peak power. Kaczkowski et al. (1982) also found a significant correlation between peak Wingate PO and percentage of fast twitch fibers in vastus lateralis muscle, $r = 0.59$ ($p < 0.05$). These two studies support the notion that a high Wingate peak PO is indicative of a high percentage of fast twitch muscle fibers in the vastus laterlis. Fast twitch fibers fatigue rapidly because of their low energy production capacity. In this study, the Wingate fatigue index was significantly correlated to Wingate peak PO at an r-value of $r = 0.706$ ($p < 0.05$). The results of this current research study agree with Jaskolski et al. (1989) who also found Wingate peak PO to be significantly correlated to power decrease, $r = 0.742$ ($p < 0.05$), in junior cyclists.

In this study, Wingate peak PO was significantly correlated with Wingate mean PO, $r = 0.698$ ($p < 0.05$). Tanaka et al. (1993) also found a significant correlation between Wingate mean and peak PO, $r = 0.909$ ($p < 0.05$), in adult male USCF cyclists. It appears that the higher PO a cyclists can create, the greater the mean PO will be for the 30-second interval during a Wingate anaerobic test.

In this study, Wingate mean PO was significantly correlated with VO_{2max} $ml \cdot kg^{-1} \cdot min^{-1}$, $r = 0.646$ ($p < 0.05$). This was somewhat surprising since Tanaka et al. (1993) did not find a significant correlation between these two variables in adult male USCF cyclists. There was also a significant correlation, $r = 0.701$ ($p < 0.05$), between Wingate mean PO and PO at LT. To this researcher's knowledge, there are not any published studies that correlate these two variables. These finding come as a surprise because aerobic and anaerobic energy production have previously been shown to be unrelated

(52). The positive correlation between measures of aerobic and anaerobic power observed in the present study could be due to two factors:

1. As junior cyclists mature and physically develop, they will increase both their aerobic and anaerobic performance simultaneously, leading to a positive correlation between these variables
2. Cyclists train both energy systems so that they will work in concert with one another during a race; hence, the more highly trained cyclists would be expected to achieve higher values for both aerobic and anaerobic variables.

In brief, the heterogeneity in age and training status could explain why this study found a positive correlation between Wingate mean PO and PO at LT, whereas other studies did not, or the relationship between aerobic and anaerobic power could be a statistical artifact of one outlying value.

The aerobic and anaerobic characteristics of the junior cyclists in this study cannot be accurately compared to the youth participants in other studies because they have not been matched for years of cycling experience or age. The differences that exist between the juniors in this study and the juniors that participated in other studies are most likely related to training and age.

Conclusions

It has been previously noted that laboratory measurements do not determine who is going to win a race (10), and it is not always possible to predict who would be more successful in a competition. Cycling requires teamwork, aerodynamics, biomechanical skills, strategy, and years of experience acquired through racing to be successful (17, 28,

52). Both aerobic and anaerobic powers are essential for the success of a cyclist, but they are not the only factors.

In summary, aerobic and anaerobic power production of competitive youth cyclists in East and Central Tennessee have been characterized in this study since both appear to be of crucial importance in cycling races (52). Junior cyclists, in general, rank lower than adult USCF competitive racers, as a group. Tracking the physiological variables measured in this study as the junior cyclists mature might tell coaches and the racers when they are ready to compete against senior cyclists.

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APPENDICES

Appendix A

Appendix A

INFORMED CONSENT FORM

Aerobic and Anaerobic Characteristics of Competitive Junior Cyclists

Principal Investigator: John Harrell
Address: The University of Tennessee
Department of Exercise, Sport & Leisure Studies
1914 Andy Holt Ave.
Knoxville, TN 37966
Telephone: (865) 974 – 8768

Purpose

The purpose of this study is to describe the physiological characteristics of competitive Junior Cyclists, specifically aerobic and anaerobic power and lactate threshold. If you give your consent, you will be asked to perform the tests described below. Each of the three days of testing will take approximately 1 hour to complete. You will complete a health history questionnaire prior to participation. All testing will be performed in the Applied Exercise Physiology Laboratory in the Health, Physical Education, and Recreation (HPER) building on the University of Tennessee, Knoxville campus.

Testing

1. The first day of testing you should arrive at the laboratory fasted for 4 hours and abstained from any physical activity for 24 hours.
2. Your height and weight will be measured. Your body fat will be determined using the Bod Pod. During these tests you will wear either a swimsuit or spandex cycling shorts. You will be asked to sit in the Bod Pod chamber for 2 one-minute trials while your body fat is determined. While in the Bod Pod chamber, your will be required to be motionless, but you may breathe normally and see your surroundings.
3. You will perform a Wingate anaerobic test on a cycle ergometer. You will warm up for 10 minutes at an effort equal to approximately 50% of your maximal capacity. You will rest for 2 to 3 minutes. The Wingate test is an all-out cycling test for 30 seconds. Resistance, or braking force, is set at its full intensity right from the start and based on your age and gender. Once the 30 seconds is complete, you may cool down for the duration of their choice.
4. Your maximal aerobic capacity will be measured by the VO_{2max} test. Aerobic capacity is the maximal volume of oxygen (VO_{2max}) your body can take in and utilize for energy production. It will be at least 24 hours after the Wingate anaerobic test and any structured exercise. You will perform this maximal oxygen consumption test on a cycle ergometer and breathe through a two-way breathing apparatus for respiratory gas measurement. The apparatus does not disrupt your normal breathing pattern or intake. The test will begin at 160 Watts (W) and increase 40 W every minute until you can no longer maintain the pedal cadence (at least 65 rpm). Your heart rate will be monitored using a heart rate monitor that is a strap worn around your chest and your heart rate is transmitted to a watch.
5. Another 24 hours must elapse before the next test. On the day of the lactate threshold test, you must abstain from strenuous exercise. The lactate threshold test is similar to the VO_{2max} test. It is performed on a cycle ergometer and it is an incremental graded exercise test. However, you will not be asked to perform a maximal effort, only near maximal. A small amount of blood will be drawn into a 50 microliter capillary from a finger tip at rest and during the last 30 seconds of each 3 minutes stage using a sterile finger stick lancet. These samples will be analyzed by an automated blood analyzer.

Potential Risks
The risks associated with exercising include abnormal blood pressure responses, muscular soreness, musculo-skeletal injuries, difficulty breathing, dizziness, and in very few cases heart attack or death. If you experience any abnormal feelings while cycling such as chest pain or sever breathlessness, stop cycling immediately. There are no known risks to the body fat test you will complete. There is a slight risk of bruising and infection. Standard sterile procedures will be used to minimize the risk with the fingertip blood sampling procedure.

Benefits of Participation
The results of your tests will provide you with physiological data which includes your body composition, VO_{2max}, lactate threshold, and anaerobic capability.

Confidentiality
The information obtained from the tests will be treated as privileged and confidential and will not be released to any person without your consent. The information gathered will be used in research reports and presentations. Your name and other identity information will not be disclosed. All data will be stored in a locked filing cabinet in 343 Health Physical Education and Recreation building (HPER). Informed consent forms will be stored for no less than 3 years after the completion of the study in 317 HPER.

Emergency Medical Treatment
The University of Tennessee does not automatically reimburse subjects for medical claims or other compensation. If physical injury is suffered in the course of research, or for more information, please notify the investigator in charge (John Harrell, (865) 974 – 8768).

Contact Information
If you have questions at any time concerning the study or the procedures, or if you experience abnormal responses as a result of participation, you should contact your physician and John Harrell at (865) 974 – 8768. If you have questions regarding your rights as a participant, contact the Research Compliance Services of the Office of Research at (865) 974 – 3466.

Right to Ask Questions and to Withdraw
You are free to decide whether or not to participate in this study and are free to withdraw from the study at any time.

Before you sign this form, please ask any questions about any aspect of this study that may be unclear to you.

Consent
By signing this paper, I am indicating that I understand and agree to take part in this research study.

________________________________ ____________________
Your signature Date

________________________________ ____________________
Researcher's signature Date

Appendix B

Appendix B
PARENTAL PERMISSION FORM
Aerobic and Anaerobic Characteristics of Competitive Junior Cyclists

Principal Investigator: John Harrell
Address: The University of Tennessee
Department of Exercise, Sport & Leisure Studies
1914 Andy Holt Ave.
Knoxville, TN 37966
Telephone: (865) 974 – 8768

Purpose

The purpose of this study is to describe the physiological characteristics of competitive Junior Cyclists, specifically aerobic and anaerobic power and lactate threshold. If you give your consent, your child will be asked to perform the tests described below. Each of the three days of testing will take approximately 1 hour to complete. You complete a health history questionnaire with your child of his or her history prior to participation. All testing will be performed in the Applied Exercise Physiology Laboratory in the Health, Physical Education, and Recreation (HPER) building on the University of Tennessee, Knoxville campus.

Testing

1. The first day of testing your child should arrive at the laboratory fasted for 4 hours and abstained from any physical activity for 24 hours.
2. Your child's height and weight will be measured. Your child's body fat will be determined using the Bod Pod. During these tests your child will wear either a swimsuit or spandex cycling shorts. He or she will sit in the Bod Pod chamber for 2 one-minute trials while his or her body fat is determined. While in the Bod Pod chamber, your child is required to be motionless, but he or she may breathe normally and see his or her surroundings.
3. After steps one and two on the same day, your child will perform a Wingate anaerobic test on a cycle ergometer. Your child will warm up for 10 minutes at an effort equal to approximately 50% of his or her maximal capacity. Your child will rest for 2 to 3 minutes until they are ready. The Wingate test is an all-out cycling test for 30 seconds. Resistance, or braking force, is set at its full intensity right from the start and based on your child's age and gender. Once the 30 seconds is complete, your child may cool down for the duration of their choice.
4. Your child's maximal aerobic capacity will be measured by the VO_{2max} test. Aerobic capacity is the maximal volume of oxygen (VO_{2max}) your child's body can take in and utilize for energy production. It will be at least 24 hours after the Wingate anaerobic test and any structured exercise. Your child will perform this maximal oxygen consumption test on a cycle ergometer and breathe through a two-way breathing apparatus for respiratory gas measurement. The apparatus does not disrupt your child's normal breathing pattern or intake. The test will begin at 160 Watts (W) and increase 40 W every minute until your child can no longer maintain the pedal cadence (at least 65 rpm). Your child's heart rate will be monitored using a heart rate monitor that is a strap worn around his or her chest and heart rate is transmitted to a watch.
5. Another 24 hours must elapse before the next test. On the day of the lactate threshold test, your child must abstain from strenuous exercise. The lactate threshold test is similar to the VO_{2max} test. It is performed on a cycle ergometer and it is an incremental graded exercise test. However, your child will not be asked to perform a maximal effort, only near maximal. Also, a small amount of blood will be drawn into 2, 50 microliter capillaries from a finger tip at rest and during the last 30 seconds of each 3 minutes stage using a sterile finger stick lancet. These samples will be analyzed by an automated blood analyzer.

Potential Risks
The risks associated with exercising include abnormal blood pressure responses, muscular soreness, musculo-skeletal injuries, difficulty breathing, dizziness, and in very few cases heart attack or death. If your child experiences any abnormal feelings while cycling such as chest pain or sever breathlessness, he or she should stop cycling immediately. There are no known risks to the body fat test your child will complete. There is a slight risk of bruising and infection when blood is drawn from a finger tip. Standard sterile procedures will be used to minimize the risk with the fingertip blood sampling procedure.

Benefits of Participation
The results of your child's tests will provide him or her with physiological data which includes his or her body composition, VO_{2max}, lactate threshold, and anaerobic capability.

Confidentiality
The information obtained from the tests will be treated as privileged and confidential and will not be released to any person without your and your child's consent. The information gathered will be used in research reports and presentations. Your child's name and other identity information will not be disclosed. All data will be stored in a locked filing cabinet in 343 Health Physical Education and Recreation building (HPER). Informed consent forms will be stored for no less than 3 years after the completion of the study in 317 HPER.

Emergency Medical Treatment
The University of Tennessee does not automatically reimburse participants for medical claims or other compensation. If physical injury is suffered in the course of research, or for more information, please notify the principal investigator (John Harrell, (865) 974 – 8768).

Contact Information
If you have or your child has questions at any time concerning the study or the procedures, or your child experiences abnormal responses as a result of participation, you should contact your child's physician and John Harrell at (865) 974 – 8768. If you have questions regarding your child's rights as a participant, contact the Research Compliance Services of the Office of Research at (865) 974 – 3466.

Right to Ask Questions and to Withdraw
Your child is free to decide whether or not to participate in this study and is free to withdraw from the study at any time.

Before you and your child sign this form, please ask any questions about any aspect of this study that may be unclear to you or your child.

Consent
By signing this paper, I am indicating that I understand and agree to take part in this research study.

______________________________ ____________________
Your child's signature Date

______________________________ ____________________
Parent/Guardian Signature Date

______________________________ ____________________
Researcher's signature Date

Appendix C

Appendix C

CHILD ASSENT FORM

Aerobic and Anaerobic Characteristics of Competitive Junior Cyclists

My name is John Harrell. Your parent's and your coach say that you are willing to help me. All you have to do is ride a bike like you already do, and let me collect some data. I'm also going to measure you height and weight. You will have to come in on three separate occasions and do a slightly different test, but they all involve riding a bike. It is really easy, and I am sure that you will do a good job. I will also ask you to sit in an egg-shaped chamber and sit still. You won't have to do anything but sit as motionless as possible, but you can breathe. Are you willing to help with this project?

Yes No (circle one)

Great! I think you will find that these things are easy and fun to do. If you decide that you don't want to do this anymore at any point during any of the tests, all you have to do is tell me. You can just say, "I don't want to do this anymore." Okay?

I understand I don't understand (circle one)

I really appreciate your help! This is the room where we're going to do these things I just told you about. You either sit in the chamber or ride the bike. If you're ready, we'll begin.

Here is a description of the tests, if you have any questions or don't understand what some of the words mean, just ask and I'll explain what they mean.

<u>Testing</u>

6. The first day of testing you should arrive at the laboratory fasted for 4 hours and abstained from any structured physical activity (for example, practice) for 24 hours. Physical education classes are allowed. All sessions can be done on a weekend or during a weekday after school. If you do this session after school, be sure you do not eat after lunch or do any structured exercise throughout the day other than physical education class.

7. Your height and weight will be measured. Your body fat will be determined using the Bod Pod. During these tests you will wear either a swimsuit or spandex cycling shorts. You will sit in the Bod Pod chamber for 2 one-minute trials while his or her body fat is determined. While in the Bod Pod chamber, you are required to be motionless, but you may breathe normally and see your surroundings.

8. You will perform a Wingate anaerobic test on a cycle ergometer. You will warm up for 10 minutes at an effort equal to approximately 50% of your maximal capacity. You will rest for 2 to 3 minutes. The Wingate test is an all-out cycling

test for 30 seconds, so you don't want to be too tired from something you did earlier in the day. Resistance, or braking force, is set at its full intensity right from the start and based on your age and gender. Once the 30 seconds is complete, you may cool down for the duration of their choice.

9. Your maximal aerobic capacity will be measured by the VO_{2max} test. Aerobic capacity is the maximal volume of oxygen (VO_{2max}) your body can take in and utilize for energy production. It will be at least 1 day after the Wingate anaerobic test and any structured, strenuous exercise, such as a practice or workout. Participation in school physical education is allowed. You can eat before this test, but I suggest you don't eat too much or too soon before the test because it is a hard test and I don't want the food to hinder your performance. You will perform this maximal oxygen consumption test on a cycle ergometer and breathe through a breathing apparatus for respiratory gas measurement. The apparatus does not disrupt your normal breathing pattern or intake. The test will begin at 160 Watts (W) and increase 40 W every minute until you can no longer maintain the pedal cadence (at least 65 rpm). Your heart rate will be monitored using a heart rate monitor that is a strap worn around your chest and your heart rate is transmitted to a watch.

10. Another day must pass before the next test. On the day of the lactate threshold test, you must abstain from strenuous structured exercise, such as a practice or a workout. Participation in physical activity classes on the day of the test in school is allowed. Also, you may eat prior to the test, but again, do not eat too much and hinder your performance. The lactate threshold test is similar to the VO_{2max} test. It is performed on a cycle ergometer and it is an exercise test that gets harder as time goes on. However, you will not be asked to perform a maximal effort, only near maximal. I will draw a small amount of blood (2 drops) into 2 very thin, short tubes at the end of each level of the exercise from the fingertip of your choice with a small needle. These samples will be analyzed by an automated blood analyzer, and then properly disposed of.

If at any point after these tests, you don't feel like you usually do and you feel like something is wrong please tell your parent or guardian.

______________________________	_____________________
Your Signature	Date
______________________________	_____________________
Parent / Guardian's Signature	Date
______________________________	_____________________
Researcher's Signature	Date

Appendix D

Appendix D

HEALTH HISTORY QUESTIONNAIRE

NAME________________________________ DATE__________________________

DATE OF BIRTH_______________________ AGE___________________________

PHONE NUMBERS (HOME)____________________(WORK)____________________

e-mail address:____

When is the best time to contact you?____

Please answer the following questions. This information will only be used for research purposes and will not be made public. Please answer the following questions based on physical exercise in which you regularly engage. **This should not include daily work activities such as walking from one office to another.**

1. Do you engage in any regular exercise other than cycling? Yes/No (If yes, please describe.)

____

____

2. On average, how many times per week do you train for cycling?

0_____1_____2_____3_____4_____5_____6_____7_____

3. On average how long is each of these training sessions: _________________

4. What is your United States Cycling Federation category?

I II III IV V

5. How long have you been training at this level?

Less than 6 months _________
6 – 12 months _________
1 – 2 years _________
3 or more years _________

6. Do you know of any reasons why you should not participate in physical activity:
____
____

MEDICAL HISTORY

Past History:
Have you ever been diagnosed with the following conditions? Please check the appropriate column.

	Yes	No	Don’t Know
Rheumatic Fever	( )	( )	( )
Heart Murmur	( )	( )	( )
High Blood Pressure	( )	( )	( )
Any heart problem	( )	( )	( )
Lung Disease	( )	( )	( )
Seizures	( )	( )	( )
Irregular heart beat	( )	( )	( )
Bronchitis	( )	( )	( )
Emphysema	( )	( )	( )
Diabetes	( )	( )	( )
Asthma	( )	( )	( )
Kidney Disease	( )	( )	( )
Liver Disease	( )	( )	( )
Severe Allergies	( )	( )	( )
Orthopedic problems	( )	( )	( )
Hyper- or Hypothyroidism	( )	( )	( )
AIDS, hepatitis, or other blood-borne infectious disease	( )	( )	( )

Present Symptom Review:
Have you recently had any of the following symptoms? Please check if so.

Chest Pain	( )	Frequent Urination	( )
Shortness of Breath	( )	Blood in Urine	( )
Heart palpitations	( )	Burning sensations	( )
Leg or ankle swelling	( )	Severe headache	( )
Coughing up blood	( )	Blurred vision	( )
Low blood sugar	( )	Difficulty walking	( )
Feeling faint or dizzy	( )	Weakness in arm	( )
Leg numbness	( )	Significant emotional problem	( )

Are you taking any medications? Yes/No
If yes, please describe: ____

Do you smoke? Yes / No   If yes, how many per day?______________

OTHER INFORMATION
Whom should we notify in case of emergency?

Name ______________________________

Address ______________________________

Phone # ______________________________

I have been given the opportunity to ask questions about any of the above items that were unclear, and I have answered all questions completely and truthfully to the best of my knowledge.

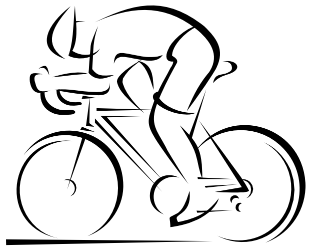
SIGNATURE____ DATE__________________

PARENT/GUARDIAN SIGNATURE____________________________DATE__________

Appendix E

Appendix E

JUNIOR CYCLISTS



PERFORMANCE STUDY

If you're 13 – 18 years old, this is your chance!

A Performance study is being conducted through
The Department of Exercise, Sport & Leisure Studies at the University of Tennessee

Walk away with the information you need for more efficient training

- VO_{2max}
- Body Composition
- Power
- Heart Rate Responses
- Optimal Training Zones

REFINE YOUR TRAINING PLAN FOR MORE EFFICIENCY

SHARE THE INFORMATION WITH YOUR COACHES TO DEVELOP MORE EFFECTIVE TRAINING ZONES

Work out a Time and a Date that fits into YOUR Schedule
Weekends or After School
Testing Starts March 13th and Runs to July 1st

Contact John Harrell for more information or to set up your testing days at:
Email address: jharrel7@utk.edu
Office phone: (865) 974 – 8768
Cell phone: (317) 201 – 3431

Appendix F

Appendix F

FORM B

THE UNIVERSITY OF TENNESSEE, KNOXVILLE

Application for Review of Research Involving Human Participants

IRB#__________________________

Date Received in OR ____________

I. IDENTIFICATION OF PROJECT

1. **Principle Investigator**

John Harrell
Department of Exercise, Sport & Leisure Studies
University of Tennessee, Knoxville
322 HPER
1914 Andy Holt Ave.
Knoxville, TN 37966
(865) 974 - 8768
jharrel7@utk.edu

2. **Faculty Advisor**

David Bassett, Ph.D.
Department of Exercise, Sport & Leisure Studies
University of Tennessee, Knoxville
343 HPER
1914 Andy Holt Ave.
Knoxville, TN 37966
(865) 974 – 8766
dbassett@utk.edu

3. **Department/Unit:** Department of Exercise, Sport & Leisure Studies, College of Education, Health & Human Sciences

4. **Project Classification:** Master of Science Thesis Research Project

5. **Title of Project:** Aerobic and Anaerobic Characteristics of Competitive Junior Cyclists

6. **Starting Date:** Upon IRB Approval

7. **Estimated Completion Date:** May 2006

8. **External Funding:** None

II. PROJECT OBJECTIVES

Over recent decades, youth participation in sport has grown tremendously and has become increasingly more competitive, both on the club and school levels. Cycling is no different. The increase of youth participation in sport has led to several research studies involving not only youth cyclists,[3, 4, 5] but also other athletes,[2, 5, 7, 9] ranging from endurance events to high intensity activities.

Maximal oxygen consumption (VO_{2max}) is a determinant of success in competitive cycling.[8, 13, 14] VO_{2max} values have been reported for both elite[8] and non-elite[1, 6, 11] adult competitive cyclists. VO_{2max} values for competitive youth cyclists have also been reported.[3, 4, 5] However, a full physiological profile of a group of competitive youth cyclists has not been found.

Along with VO_{2max}, anaerobic power is an important part of competitive cycling. It is involved in break-away attempts, hill-climbing, and final sprints during races.[1] There are a few studies that profile the anaerobic power of youth cyclists[5] and some other athletes,[2, 5] but these studies did not measure aerobic power and lactate threshold.

Lactate threshold is another important predictor of performance. Coyle, et al. found that individuals with higher lactate thresholds are able to perform for longer durations than individuals who have lower lactate thresholds at equal relative intensities.[6] Lactate threshold has not been a part of a comprehensive study of VO_{2max} and anaerobic power in youth cyclists.

Like many athletic events, cycling involves a combination of both aerobic and anaerobic energy production.[12] Since both energy systems play an important role in race performance, there is a need for normative values on competitive youth cyclists on all levels. The purpose of this study is to describe the aerobic and anaerobic characteristics of junior competitive cyclists.

III. DESCRIPTION AND SOURCE OF RESEARCH PARTICIPANT

Twenty healthy, competitive, junior cyclists, ages 13 – 18 years, will volunteer for this study. Participants will be from the KnoxVelo cycling club, and the Knox County area. They will be contacted through their coaches, by announcements on the club website, and paper flyers handed out at various Knox County cycle shops. Parents will be provided with all the same information as the junior cyclists.

IV. METHODS AND PROCEDURES

All testing will be conducted by John Harrell, a Masters student in the exercise physiology program. Testing will take place in the Applied Exercise Physiology Laboratory in the Health, Physical Education, and Recreation building. Testing will require three visits to the laboratory on three different days. On day one each participant will be measured for height, weight, body composition, and they will do the Wingate Anaerobic test. On their second visit, the participants will perform a maximal oxygen consumption test. On their third and final visit, a lactate threshold test will be conducted. Each of the three separate visits will last approximately 1 hour. These sessions can be on any day of the week that is convenient for both the participant and their parent.

Written informed consent (attachment A), or Parental Permission (attachment B) and Child Assent (attachment C) approved by the University of Tennessee Institutional

Review Board, and a Health History Questionnaire (attachment D) will be obtained prior to any testing. Participants will come to the lab for the first session having fasted for 4 hours and refrained from any exercise for 24 hours. Height will be measured using a stadiometer and weight will be measured by an electronic platform balance. Body composition will be assessed by air displacement plethysmography using the Bod Pod system (LMI, Inc., Concord, CA). Participants will wear either a swimsuit or spandex cycling shorts for the Bod Pod test, as well as a spandex swim cap. They will first be weighed, placed in the Bod Pod chamber, and asked to sit still for 2 trials while body volume is being determined.

Wingate anaerobic test

As a part of the first session, participants will perform a Wingate anaerobic test on a Lode cycle ergometer (Lode BV, Groningen, The Netherlands). Prior to the test, participants will warm up for 10 minutes at approximately 50% VO_{2max}. After 2 to 3 minutes rest, the participant should be ready to begin. The Wingate test is an all-out cycling test for 30 seconds. Resistance, or braking force, is set at its full intensity right from the start which is 0.8 * body weight in Nm for males over 14 and 0.77 * body weight in Nm for females of the same age. Once the 30-second test is complete, participants then cool down for the duration of their choice.

Maximal oxygen consumption

At least 24 hours after the Wingate anaerobic test, an incremental graded exercise test on a braked cycle ergometer will be used to determine VO_{2max}. Participants will warm up for 2 to 3 minutes, or until they are ready to perform. They will pedal at 80 revolutions per minute (rpm) beginning at 80 Watts. The resistance will increase 40 Watts every minute until the participant reaches volitional fatigue (cannot maintain pedal cadence of at least 65 rpm). Respiratory gas exchange analysis will be performed using a computerized metabolic system. Before each test, O_2 and CO_2 analyzers will be calibrated using gases of know concentrations, and the flow meter will be calibrated using a 3-liter syringe. Heart rate will be monitored throughout the duration of the test using a heart rate monitor.

Lactate threshold

At least 24 hours after the Wingate anaerobic test and VO2max test, participants will perform a lactate threshold test. Like a VO_{2max} test, the lactate threshold test is an incremental graded exercise test on a cycle ergometer. However, participants only perform up to a near maximal value. The participants will initially pedal at 40 W. The resistance will increase by 40 W every three minutes. During the last thirty seconds of each stage, including the initial resting period, 100 micro liters of blood will be obtained from a finger tip using an Autolet II and Unilet lancet (Owen Mumford, Ltd., Woodstock, Oxford, England). The blood will be drawn into 2, 50-microliter, Aqua-Cap capillaries (Drummond Scientific Company, Broomall, PA). The participant will complete several stages until they have reached near VO_{2max}, and blood will be drawn at the end of each stage by the principal investigator. Once the test is complete, blood lactate analysis will be done using a YSI 2300 STAT Plus automated lactate analyzer (SunBelt Scientific,

Inc., Atlanta, GA). Once the blood has been analyzed, it will be properly disposed of in a biohazard waste container.

V. SPECIFIC RISKS AND PROTECTION MEASURES

Physical activity carries with it the risks of abnormal blood pressure responses, muscular soreness, musculo-skeletal injuries, difficulty breathing, dizziness, and, in very few cases, hearth attack or death. The Health History Questionnaire will reduce these risks by screening out potentially high risk participants. Only trained cyclists who are accustomed to vigorous physical activity will be involved in this study. There is a risk of bruising and infection with the fingertip blood sampling procedure. Standard sterile procedures will be used to minimize the risk. Should the participants experience any abnormal physical responses after they have left the lab, they will be instructed to contact their physician and the principal investigator.

Participants' confidentiality will be protected by keeping the data and consent forms in a locked file cabinet in 317 HPER. All participants' names will be replaced with a participant number to protect identity. All results will be presented in a collective format, not by individual participant. The data, informed consent forms, parental permission forms, and child assent forms will be kept for 3 years after the study is completed.

VI. BENEFITS

As stated above, the testing involves minimal risk to the highly conditioned participants included in this study. Benefits to the participants include having a body composition test, maximal aerobic fitness test, anaerobic fitness test, and lactate threshold test.

VII. METHODS FOR OBTAINING "INFORMED CONSENT" FROM PARTICIPANTS

The purpose of this study and the details of the testing will be verbally explained by the principal investigator. They will be described through the Participant Informed Consent Form, Parental Permission Form, and Child Assent Form to the participants and the parent or guardian of the participant. Participants, as well as guardians and parents, will have the opportunity to discuss any questions or concerns with the principal investigator prior to deciding to participate in any portion of the study. Participation is entirely voluntary and the participant's and parent's or guardian's decision whether or not to participate will involve no penalty or loss of benefits to which the participant is otherwise entitled. The participant and parent or guardian will be verbally reminded of his option to withdraw from the study before initiation of testing and at points throughout the research project. No special conditions are attached to the consent to participate in this study. A copy of the informed consent form and the information sheet is included at the end of this document.

VIII. QUALIFICATIONS OF THE INVESTIGATOR(S) TO CONDUCT REASEARCH

The principal investigator, John W. Harrell, is a graduate student and has received formal training in laboratory exercise physiology from the exercise physiology program at The University of Tennessee. He has participated in several laboratory sessions collecting data. He is familiar with the operations of the above mentioned equipment. John Harrell is also certified in Cardiopulmonary Resuscitation (American Red Cross) and Standard First Aid (American Red Cross).

The faculty advisor, David Bassett, Ph. D., has formal training in exercise physiology and has conducted many exercise physiology projects. He is certified in CPR (American Red Cross) and as an Exercise Specialist (American College of Sports Medicine).

IX. FACILITIES AND EQUIPMENT TO BE USED IN THE RESEARCH

The University of Tennessee, Knoxville Department of Exercise, Sport, and Leisure Studies houses an Applied Physiology Laboratory with a Bod Pod, cycle ergometer, and all necessary equipment needed for this study. All tests will be conducted in the Applied Exercise Physiology lab in the Health, Physical Education, and Recreation building.

X. RESPONSIBILITY OF PROJECT DIRECTOR

By compliance with the policies established by the Institutional Review Board of The University of Tennessee, the principal investigator(s) subscribe to the principles stated in "The Belmont Report" and standards of professional ethics in all research, development, and related activities involving human participants under the auspices of The University of Tennessee. The principle investigator(s) further agree that:

1. Approval will be obtained from the Institutional Review Board prior to instituting any change in this research project.
2. Development of any unexpected risks will be immediately reported to Research Compliance Services.
3. An annual review and progress report (Form R) will be completed and submitted when requested by the Institutional Review Board.
4. Singed informed consent documents will be kept for the duration of the project and for no less than three years thereafter at a location approved by the Institutional Review Board.

XI. SIGNATURES

Principal Investigator _____John W. Harrell ________

Signature _______________________ Date _________________

Student Advisor _____ David R. Bassett, Jr., Ph.D.____

Signature _______________________ Date _________________

XII. DEPARTMENT REVIEW AND APPROVAL
The application described above has been reviewed has been reviewed by the IRB department review committee and has been approved. The DRC further recommends that this application be reviewed as:

[ ] Expedited Review – Category(s):______________

OR

[ ] Full IRB Review

Chair, DRC __________________________________

Signature ________________________ Date ________________

Department Head _____Joy T. DeSensi, Ph.D.______

Signature ________________________ Date _________________

Protocol sent to Research Compliance Services for final approval on

(Date) ________________

Approved:
Research Compliance Services
Office of Research
404 Andy Holt Tower

Signature ________________________ Date __________________

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Appendix G

Appendix G

Subject 1	
Height	170 cm
Percent Fat	19.4%
Percent Lean	80.6%
Fat Weight	24.5 lb
Lean Weight	101.8 lb
Total Weight	126.4 lb

Wingate Anaerobic Test	
Mean Power (W)	523
Peak Power (W)	702
Minimum Power (W)	431
Time to Peak Power (Sec)	6
Rate to Fatigue ($W \cdot Sec^{-1}$)	11.3
Peak Power / Body Mass ($W \cdot kg^{-1}$)	12.2
Mean Power / Body Mass ($W \cdot kg^{-1}$)	9.1

VO_{2max}

Power Output (W)	*VO2* ($ml \cdot kg^{-1} \cdot min^{-1}$)	*VO2* ($L \cdot min^{-1}$)
120	26.7	1.44
160	30.1	1.72
200	34.9	2
240	40	2.29
280	45.4	2.6
320	49.8	2.85

Lactate Threshold

Power Output (W)	*[LA]* ($mMol \cdot L^{-1}$)	
0	2.09	
80	1.38	
120	1.48	
160	1.83	**LT**
200	3.98	
240	4.07	

Subject 2

Height	160 cm
Percent Fat	20.1%
Percent Lean	79.9%
Fat Weight	19.6 lb
Lean Weight	77.5 lb
Total Weight	97.1 lb

Wingate Anaerobic Test	
Mean Power (W)	251
Peak Power (W)	321
Minimum Power (W)	178
Time to Peak Power (Sec)	0.4
Rate to Fatigue ($W \cdot Sec^{-1}$)	4.8
Peak Power / Body Mass ($W \cdot kg^{-1}$)	7.3
Mean Power / Body Mass ($W \cdot kg^{-1}$)	5.7

VO_{2max}

Power Output (W)	*VO2 ($ml \cdot kg^{-1} \cdot min^{-1}$)*	*VO2 ($L \cdot min^{-1}$)*
120	30.1	1.33
160	36.5	1.61
200	42.2	1.86

Lactate Threshold

Power Output (W)	*[LA] ($mMol \cdot L^{-1}$)*	
0	1.21	
80	1.93	**LT**
120	3.79	

Subject 3

Height	178 cm
Percent Fat	10.2%
Percent Lean	89.8%
Fat Weight	13.5 lb
Lean Weight	118.6 lb
Total Weight	132.1 lb

Wingate Anaerobic Test	
Mean Power (W)	560
Peak Power (W)	628
Minimum Power (W)	484
Time to Peak Power (Sec)	0.4
Rate to Fatigue ($W \cdot Sec^{-1}$)	4.9
Peak Power / Body Mass ($W \cdot kg^{-1}$)	11
Mean Power / Body Mass ($W \cdot kg^{-1}$)	9.3

VO_{2max}

Power Output (W)	*VO2 ($ml \cdot kg^{-1} \cdot min^{-1}$)*	*VO2 ($L \cdot min^{-1}$)*
120	16.9	1.01
160	32.6	1.95
200	37.3	2.23
240	44.2	2.65
280	49.4	2.96
320	54.1	3.24
360	59.3	3.55
400	66.4	3.98

Lactate Threshold

Power Output (W)	*[LA] ($mMol \cdot L^{-1}$)*	
0	1.8	
80	3.65	
120	1.49	
160	5.87	
200	1.76	
240	2.68	
280	4.47	**LT**
320	8.1	

Subject 4

Height	166 cm
Percent Fat	14.0%
Percent Lean	86.0%
Fat Weight	20.7
Lean Weight	126.7
Total Weight	147.3

Wingate Anaerobic Test

Mean Power (W)	583
Peak Power (W)	913
Minimum Power (W)	349
Time to Peak Power (Sec)	1.4
Rate to Fatigue ($W \cdot Sec^{-1}$)	19.7
Peak Power / Body Mass ($W \cdot kg^{-1}$)	13.7
Mean Power / Body Mass ($W \cdot kg^{-1}$)	8.7

VO_{2max}

Power Output (W)	*VO2* ($ml \cdot kg^{-1} \cdot min^{-1}$)	*VO2* ($L \cdot min^{-1}$)
120	22.8	1.52
160	27.3	1.83
200	33.8	2.26
240	39.6	2.65
280	45.2	3.02
320	52.1	3.48
360	55.7	3.72
400	55.4	3.7

Lactate Threshold

Power Output (W)	*[LA]* ($mMol \cdot L^{-1}$)	
0	3.02	
80	3.37	
120	2.76	
160	2.63	
200	2.91	
240	2.40	**LT**
280	6.00	

Subject 5

Height	169 cm
Percent Fat	13.4%
Percent Lean	86.6%
Fat Weight	15.9 lb
Lean Weight	102.6 lb
Total Weight	118.5 lb

Wingate Anaerobic Test

Mean Power (W)	541
Peak Power (W)	926
Minimum Power (W)	308
Time to Peak Power (Sec)	3.8
Rate to Fatigue ($W \cdot Sec^{-1}$)	23.6
Peak Power / Body Mass ($W \cdot kg^{-1}$)	17.2
Mean Power / Body Mass ($W \cdot kg^{-1}$)	10.1

VO_{2max}

Power Output (W)	*VO2 ($ml \cdot kg^{-1} \cdot min^{-1}$)*	*VO2 ($L \cdot min^{-1}$)*
120	25.4	1.36
160	32.9	1.77
200	40.1	2.16
240	44.5	2.39
280	50.4	2.71
320	54.4	2.92

Lactate Threshold

Power Output (W)	*[LA] ($mMol \cdot L^{-1}$)*	
0	2.71	
80	3.15	
120	1.04	
160	3.59	
200	4.43	**LT**
240	7.17	

Subject 6

Height	170 cm
Percent Fat	9.3%
Percent Lean	90.7%
Fat Weight	11.5
Lean Weight	112.1
Total Weight	123.6

Wingate Anaerobic Test	
Mean Power (W)	546
Peak Power (W)	597
Minimum Power (W)	507
Time to Peak Power (Sec)	10.2
Rate to Fatigue ($W \cdot Sec^{-1}$)	4.5
Peak Power / Body Mass ($W \cdot kg^{-1}$)	10.6
Mean Power / Body Mass ($W \cdot kg^{-1}$)	9.7

VO_{2max}

Power Output (W)	*VO2 ($ml \cdot kg^{-1} \cdot min^{-1}$)*	*VO2 ($L \cdot min^{-1}$)*
120	29.1	1.63
160	30.8	1.73
200	39.5	2.22
240	42.7	2.4
280	49.5	2.78
320	53	2.98

Lactate Threshold

Power Output (W)	*[LA] ($mMol \cdot L^{-1}$)*	
0	2.05	
80	0.90	
120	1.44	
160	1.89	
200	2.28	
240	1.52	**LT**
280	5.30	

Subject 7

Height	163 cm
Percent Fat	17.6%
Percent Lean	82.4%
Fat Weight	16.8 lb
Lean Weight	78.7 lb
Total Weight	95.5 lb

Wingate Anaerobic Test

Mean Power (W)	421
Peak Power (W)	509
Minimum Power (W)	320
Time to Peak Power (Sec)	3.6
Rate to Fatigue ($W \cdot Sec^{-1}$)	7.2
Peak Power / Body Mass ($W \cdot kg^{-1}$)	11.8
Mean Power / Body Mass ($W \cdot kg^{-1}$)	9.7

VO_{2max}

Power Output (W)	*VO2 ($ml \cdot kg^{-1} \cdot min^{-1}$)*	*VO2 ($L \cdot min^{-1}$)*
120	27.8	1.21
160	38.8	1.68
200	43.1	1.87
240	50.6	2.2
280	57.1	2.48

Lactate Threshold

Power Output (W)	*[LA] ($mMol \cdot L^{-1}$)*	
0	2.08	
80	0.40	
120	2.46	
160	4.21	**LT**
200	7.80	
240	11.80	

Subject 8

Height	173 cm
Percent Fat	7.7%
Percent Lean	92.3%
Fat Weight	9.4 lb
Lean Weight	112.3 lb
Total Weight	121.7 lb

Wingate Anaerobic Test

Mean Power (W)	459
Peak Power (W)	602
Minimum Power (W)	302
Time to Peak Power (Sec)	0.4
Rate to Fatigue ($W \cdot Sec^{-1}$)	10.1
Peak Power / Body Mass ($W \cdot kg^{-1}$)	10.9
Mean Power / Body Mass ($W \cdot kg^{-1}$)	8.3

VO_{2max}

Power Output (W)	*VO2 ($ml \cdot kg^{-1} \cdot min^{-1}$)*	*VO2 ($L \cdot min^{-1}$)*
120	22.730.8	1.26
160	30.8	1.7
200	36.3	2
240	46	2.54

Lactate Threshold

Power Output (W)	*[LA] ($mMol \cdot L^{-1}$)*	
0	0.96	
80	0.73	
120	2.91	
160	3.64	**LT**
200	5.21	
240	8.00	

Subject 9

Height	168 cm
Percent Fat	8.7%
Percent Lean	91.3%
Fat Weight	11.1 lb
Lean Weight	116.2 lb
Total Weight	127.3 lb

Wingate Anaerobic Test

Mean Power (W)	487
Peak Power (W)	659
Minimum Power (W)	367
Time to Peak Power (Sec)	0.4
Rate to Fatigue ($W \cdot Sec^{-1}$)	9.9
Peak Power / Body Mass ($W \cdot kg^{-1}$)	11.4
Mean Power / Body Mass ($W \cdot kg^{-1}$)	8.4

VO_{2max}

Power Output (W)	*VO2 ($ml \cdot kg^{-1} \cdot min^{-1}$)*	*VO2 ($L \cdot min^{-1}$)*
120	25.4	1.47
160	30.8	1.78
200	37.3	2.16
240	43.8	2.53
280	50.8	2.94
320	55.4	3.2

Lactate Threshold

Power Output (W)	*[LA] ($mMol \cdot L^{-1}$)*	
0	0.76	
80	1.93	
120	0.85	
160	2.69	
200	3.16	**LT**
240	5.04	

Subject 10

Height	155 cm
Percent Fat	19.4%
Percent Lean	80.6%
Fat Weight	19.1 lb
Lean Weight	79.4 lb
Total Weight	98.5 lb

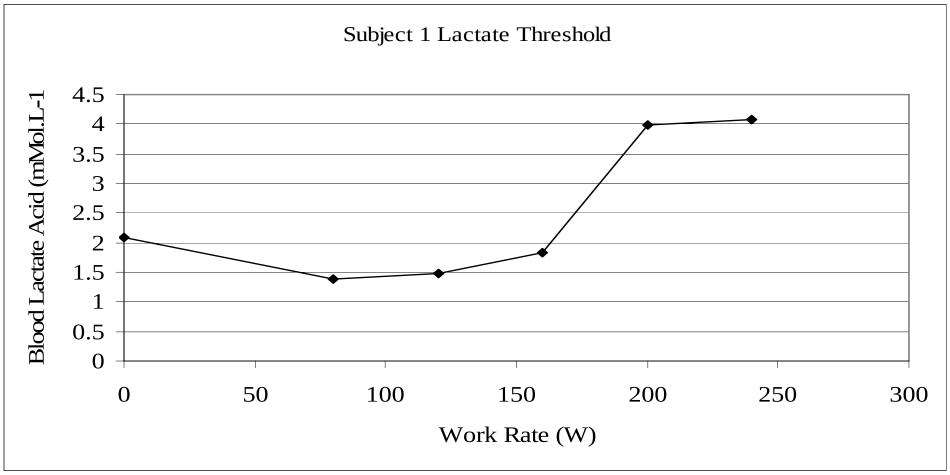
Wingate Anaerobic Test	
Mean Power (W)	379
Peak Power (W)	550
Minimum Power (W)	254
Time to Peak Power (Sec)	1
Rate to Fatigue (W·Sec^{-1})	10.2
Peak Power / Body Mass (W·kg^{-1})	12.3
Mean Power / Body Mass (W·kg^{-1})	8.5

VO_{2max} Test

Power Output (W)	*VO2 (ml·kg^{-1}·min^{-1})*	*VO2 (L·min^{-1})*
120	24.3	1.09
160	34.2	1.53
200	42.5	1.9
240	48.1	2.15
280	53.3	2.39

Lactate Threshold

Power Output (W)	*[LA] (mMol·L^{-1})*	
0	1.77	
80	2.23	
120	1.19	
160	2.44	**LT**
200	5.73	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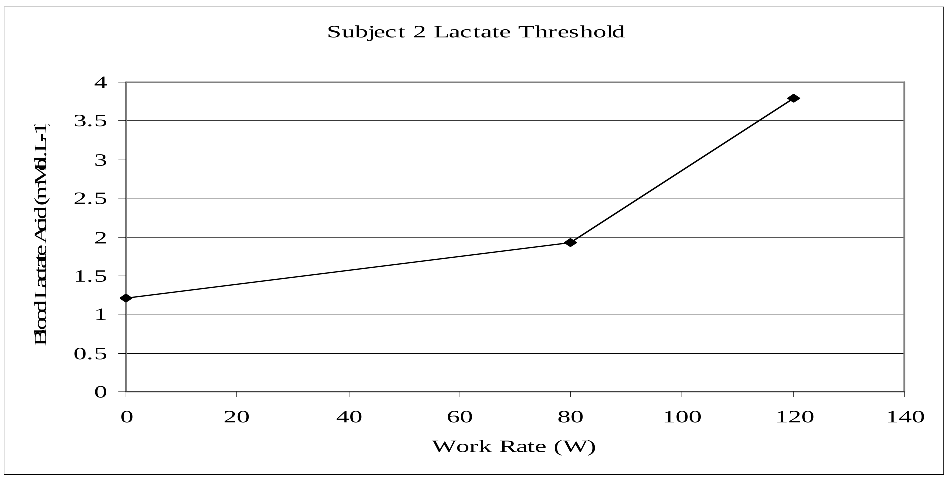
Blood Lactate Acid (mMol.L-1
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
0
50
100
150
200
250
300
Work Rate (W)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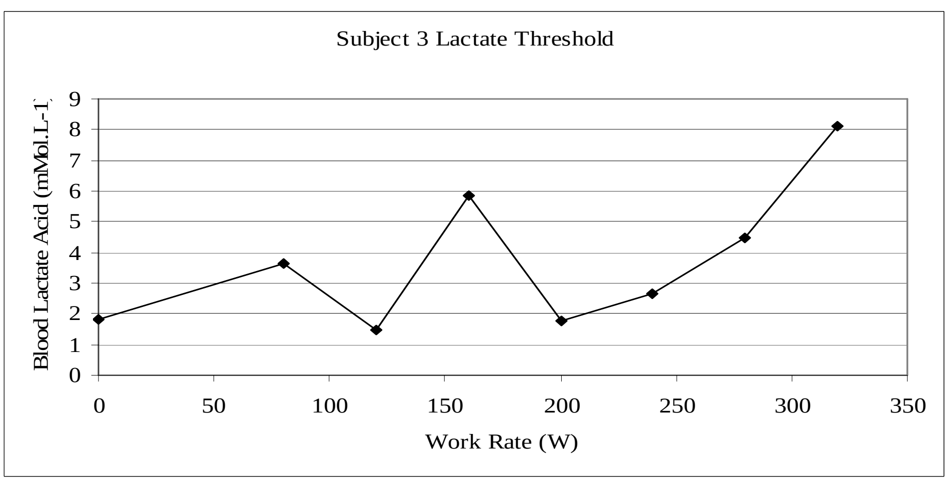
Blood Lactate Acid (mMol.L-1
4
3.5
3
2.5
2
1.5
1
0.5
0
0
20
40
60
80
100
120
140
Work Rate (W)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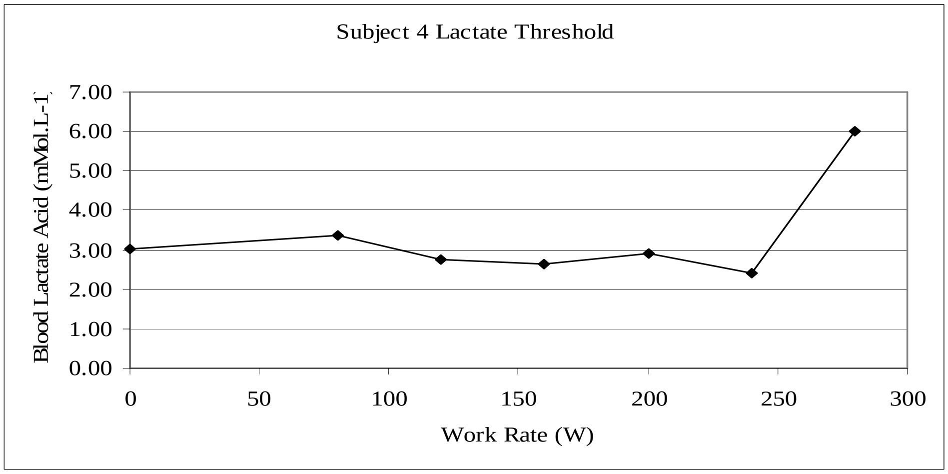
Blood Lactate Acid (mMol.L-1
9
8
7
6
5
4
3
2
1
0
0
50
100
150
200
250
300
350
Work Rate (W)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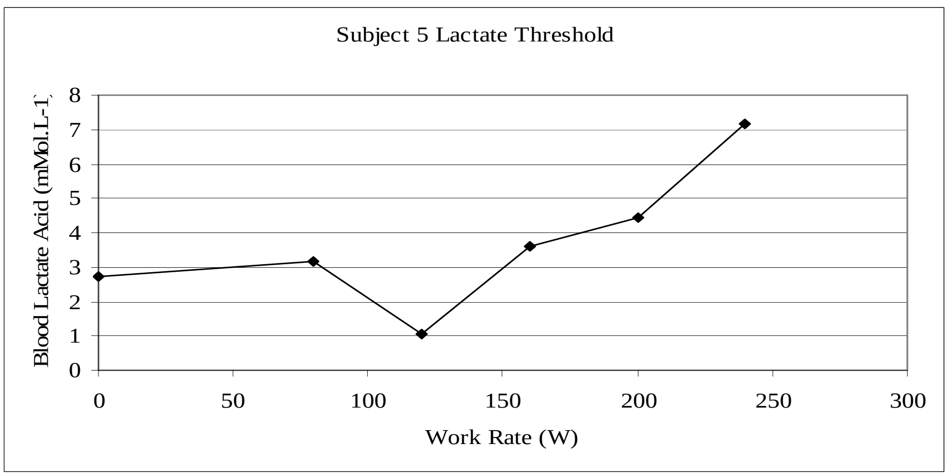
6.00
5.00
4.00
3.00
2.00
1.00
0.00
0
50
100
150
200
250
300
Work Rate (W)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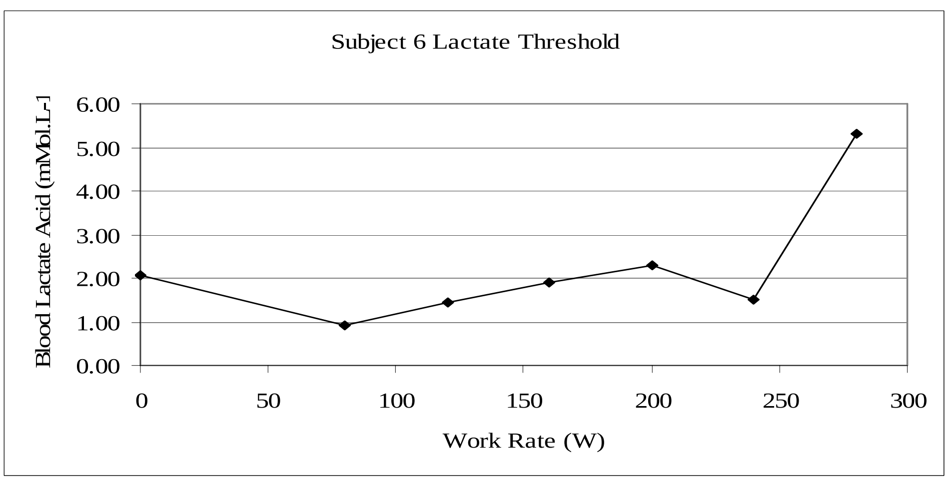
Blood Lactate Acid (mMol.L-1)
8
7
6
5
4
3
2
1
0
0
50
100
150
200
250
300
Work Rate (W)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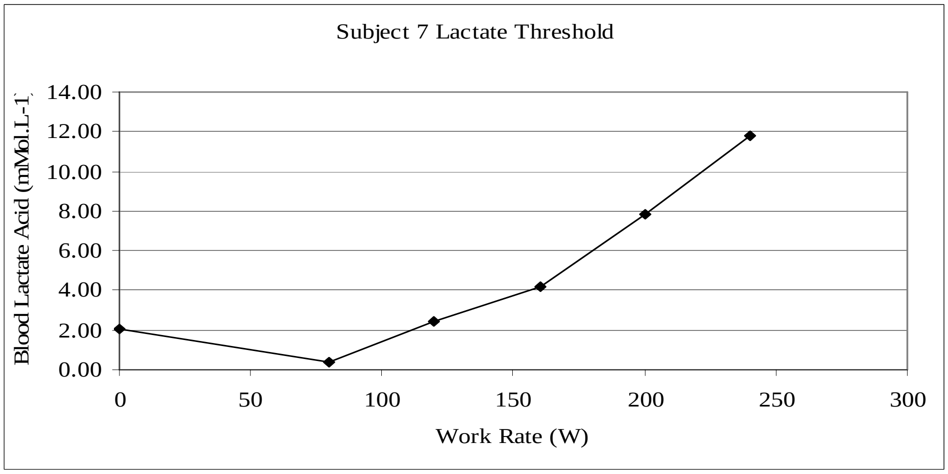
Blood Lactate Acid (mMol.L-1)
6.00
5.00
4.00
3.00
2.00
1.00
0.00
0
50
100
150
200
250
300
Work Rate (W)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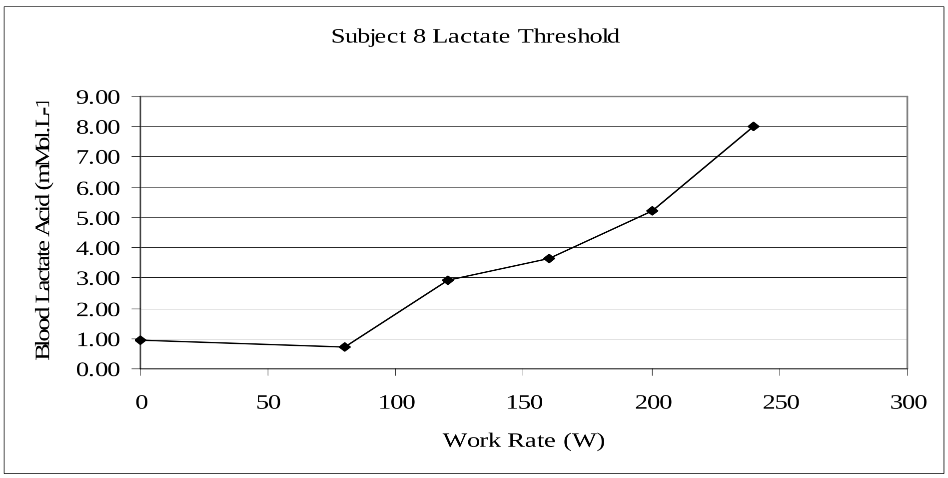
Blood Lactate Acid (mMol.L-1)
14.00
12.00
10.00
8.00
6.00
4.00
2.00
0.00
0
50
100
150
200
250
300
Work Rate (W)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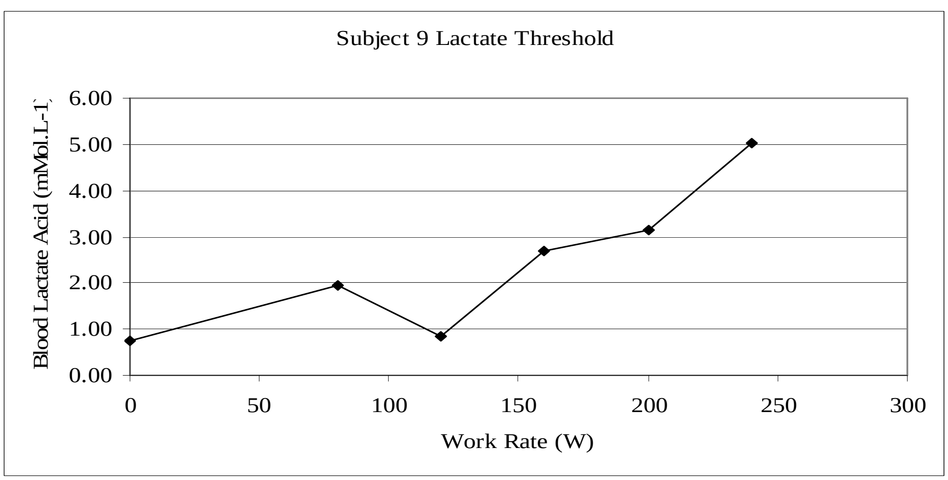
Blood Lactate Acid (mMol.L-1
9.00
8.00
7.00
6.00
5.00
4.00
3.00
2.00
1.00
0.00
0
50
100
150
200
250
300
Work Rate (W)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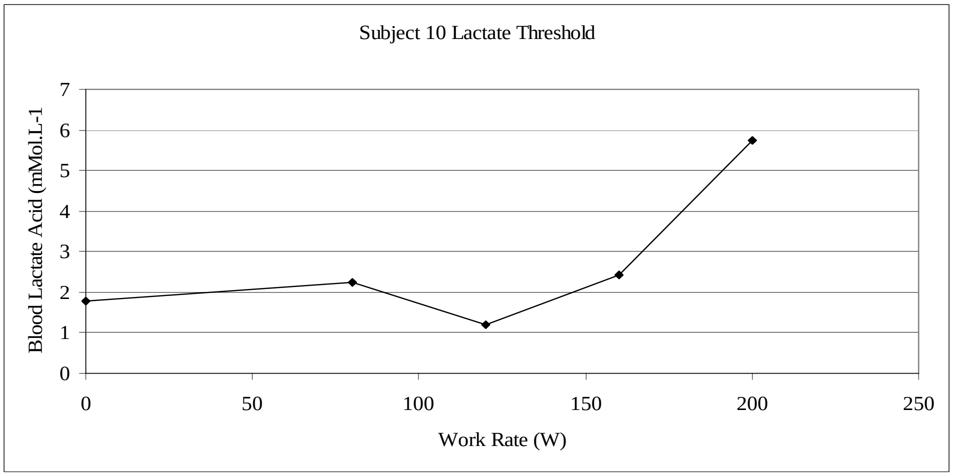
Blood Lactate Acid (mMol.L-1)
6.00
5.00
4.00
3.00
2.00
1.00
0.00
0
50
100
150
200
250
300
Work Rate (W)


Subject 10 Lactate Threshold
Blood Lactate Acid (mMol.L-1
0
1
2
3
4
5
6
7
0
50
100
150
200
250
Work Rate (W)

VITA

John William Harrell was born in Indianapolis, Indiana on February 22, 1982. He attended Roncalli High School and graduated in June of 2000.

In August of 2000, John entered the University of Dayton. He graduated in August 2004, with a Bachelor of Science and Education in Exercise Science / Fitness Management.

The same August he graduated from the University of Dayton, he enrolled at the University of Tennessee and held a position as a graduate teaching associate for the Physical Education and Activities Program. He completed his Masters of Science degree in Exercise Science with a concentration in exercise physiology in August of 2006.