The Difference in Ventilatory Threshold Among Adolescent Males Based on Maturity Status

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THE DIFFERENCES IN VENTILATORY THRESHOLD AMONG ADOLESCENT MALES BASED ON MATURITY STATUS

by

DYANE LONEY

A thesis submitted in partial fulfillment of requirements for the Honors in the Major Program in Sport and Exercise Science in the College of Education and Human Performance and in the Burnett Honors College at the University of Central Florida Orlando, Florida

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Thesis Chair: Jeffery R. Stout, Ph.D.
Abstract

Previous research has shown an inverse relationship between age and the relative intensity at which ventilatory threshold (VT) occurs in adolescent boys. However, no study has examined the effect of maturity status on VT in the differences in boys from the onset of puberty, adolescents. The purpose of this study was to compare VT among adolescent boys of different maturational groups. Methods: For this study, moderately active adolescent male participants (14 ± 3 y) completed this study. Maturational status of the participants was determined via years from peak height velocity (PHV), which is an estimation of somatic maturity status derived from age, standing height, seated height, body mass, and leg length. Participants were categorized into PRE- (lesser than 1 year till PHV), PERI- (within 1 year of PHV), and POST-PHV (greater than 1 year past PHV). All participants completed a ramp graded exercise test on a cycle ergometer. During the test, participants were given a three-minute warm-up with no resistance before starting at a workload of 30 watts which increased at a rate of 1 watt every 3 seconds until volitional fatigue. Throughout the test, oxygen consumption (VO$_2$) and ventilation were measured. VT was determined, as a percentage of VO$_{2\text{max}}$, from the ventilation versus VO$_2$ graph using the maximal deviation method. Differences in VT between maturational groups were examined using one-way ANOVA. Results: A significant (F=5.36; p=0.014) difference in VT among maturational groups was found (Appendix A, Figure 2). Post hoc analysis revealed that PRE (p=0.029) and PERI (p=0.009) had VT occur at a significantly greater relative percentage of VO$_{2\text{max}}$ than POST. However, no significant (p=0.970) differences were found between PRE and PERI (Appendix A, Figure 3). Conclusion: Adolescent males in PRE and PERI demonstrated higher VT as a percentage of their VO$_{2\text{max}}$ compared to POST. This finding
suggests the differences in the delayed switch from aerobic to anaerobic metabolism during incremental exercise in adolescent boys who are PRE and PERI.
Dedication

Thank you to my Mom, my Dad, Danielle, Deon, and Danice for your support throughout the process of my thesis and research.

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Chapter One: Introduction

The ventilatory threshold (VT) represents the intensity of exercise at which the majority of energy needed for muscle contraction transitions from primarily aerobic to anaerobic metabolism. Maturational status among adolescent boys contribute to differences in ventilatory threshold values as a percentage of maximal oxygen consumption rate (VO\(_2\)max). While previous research has examined differences between adult males and boys pre-, peri-, and post-puberty (de Prado et al., 2006), the maturity-related differences in ventilatory threshold among adolescent boys (14 ± 3 y) has yet to be investigated until now. The purpose of this study is to compare the ventilatory threshold values, as a percentage of VO\(_2\)max, in adolescent boys across a continuum of maturation statuses: pre-, peri-, and post-pubescent, as determined by years from peak height velocity (PHV). Therefore, the following sections will examine the relationship between ventilatory threshold and maturation statuses in adolescent boys in terms of progression towards biologically mature state and fatigue.

Mechanisms of Physical Activity

In correspondence to power output and oxygen consumption, oxygen facilitates metabolic demands and the production of ATP for energy (Lumb et al., 2005). The transportation of oxygen starts with the inspiration of external air which flows in the following order: the nasal cavity, pharynx, larynx, trachea, bronchioles, alveoli, blood stream, body cells, and then into the mitochondria (Marieb et al., 2013). Oxygen supplied to the mitochondria within skeletal muscle cells is where aerobic metabolism takes place and produces ATP while simultaneously, removing metabolic waste, like carbon dioxide, and generates water molecules through respiration (Connes et al., 2010). Energy derived from food in the form of macronutrients such as
carbohydrates, fats, and/or proteins (Chamberlin et al., 1995). Macronutrients are broken down molecularly with or without the presence of oxygen for energy (Chamberlin et al., 1995). From rest to moderate physical activity, all macronutrients in the presence of oxygen are processed for the creation of ATP in the presence of oxygen, known as aerobic metabolism (Housh et al., 2012). Physical activity succeeding moderate intensities of exercise (70 % to 100 % of effort), carbohydrates use primarily supplied from glycogen and phosphates stores for energy in the absence of oxygen, also known as anaerobic metabolism (Armstrong et al., 2015; McArdle et al., 2010). Carbohydrates are used to match the high and quick demands of muscle fiber recruitment for fast energy production; fat is a source of energy for aerobic metabolism during prolonged physical activity due to its unlimited capacity for storage (McArdle et al., 2010). Sources of carbohydrates will eventually run out leading to skeletal muscle fatigue or the insufficient supply of ATP to the muscle for muscular contraction (Marieb et al., 2013). The domains of energy and physical activity increase simultaneously starting with aerobic metabolism then into anaerobic metabolism. Most adults are efficient in energy production through anaerobic metabolic processes (Armstrong, et al., 2010). Unlike children who are most productive in aerobic metabolism via fat for energy and aerobic enzymes (Armstrong, et al., 2010; Lumb et al., 2005). Exercise metabolism efficiencies correlate to the capabilities of the skeletal muscle to produce enough energy depending on oxygenated or non-oxygenated metabolic pathways (Lumb et al., 2005).

**Physical Activity in Terms of VO2 levels**

Energy expenditure, which correlates with VO2 values, increases linearly with exercise intensity until a plateau occurs at maximal intensity (Jones el at., 2005). This plateau in VO2
values at maximal exercise intensity is known as VO\textsubscript{2}max (Howley et al., 1995). Starting from rest, peak values of VO\textsubscript{2} develop from the continuously increasing rate of energy expended and time until exhaustion until VO\textsubscript{2} levels plateau (Jones et al., 2005). Thus, steady-state is where muscular fatigue can be examined most effectively. In the approach of steady-state, increasing levels of VO\textsubscript{2} correspond to the ratio of minute ventilation to oxygen consumption known as ventilatory equivalent (McArdle et al., 2010). Observation of VO\textsubscript{2}max levels in relation to effective pulmonary ventilation is important in adolescences as levels correspond to health status for athletes (Jones et al. 2005). Theoretically, improvements in VO\textsubscript{2}max levels can be induced in adolescents similar to adults through training to exhaustion (Pitt et al., 2015).

**Pulmonary Respiration and Gas Exchange**

Regulation of energy systems on a molecular level involves cellular respiration, ventilation, external and internal respiration (Williamson et al., 2011). During external respiration, inspired air enters the nasal cavity passing through the pharynx, then enters the larynx into the trachea and bronchial tree for the air to be cleaned, warmed, and moistened for diffusion (Marieb et al., 2013). In the last step of diffusion, air enters a part of the lungs called the alveoli, where gas exchange occurs across the blood air barrier (Marieb et al., 2013). Within one of the alveoli, or an alveolus, oxygen is repeatedly exchanged for carbon dioxide (CO\textsubscript{2}) during the respiration cycle (Marieb et al., 2013). Within an alveolus membrane, capillaries facilitate the exchange of oxygen for CO\textsubscript{2} (Marieb et al., 2013). Thus, during internal respiration, oxygen diffuses from the alveolus into the blood stream to bind with hemoglobin in red blood cells to be transported into active body cells for metabolism (Williamson et al., 2011). As an end result of ATP production, CO\textsubscript{2} diffuses from the body cells into the blood in exchange for
oxygen (Williamson et al., 2011). At a cellular level during cellular respiration, oxygen supplied from the inspiration of air is used by an organelle called the mitochondria to produce ATP in order to meet metabolic demands (Williamson et al., 2011). Diffusion capacity is influenced by changes in the surface area of the respiratory membrane, physical changes of the membrane, the resistance and activation of the respiratory system, or changes in relation to the uptake of gases by the red blood cells (Lumb et al., 2005). Solid evidence has shown that values of VO$_2$max are mostly associated with the supply of oxygen in mitochondria of the muscle (Lundby et al., 2015).

**Oxygen Delivery**

Oxygen consumption is essential in the metabolic processes in the human body. Under conditions of deficient oxygen supply or reduced gradient of pressure from high to low, the oxygenation of the blood and removal of CO$_2$ further describes limiting factors of oxygen uptake (Lumb et al., 2005). In order to continue the delivery of oxygen to the contracting muscle during exercise, blood flow is adjusted accordingly (Lundby et al., 2015). However, an understanding of oxygen consumption during rest and exercise in adolescents, through VO$_2$ and heart rate indicators of exercise intensity, is unknown (Sai-chuen et al., 2015). Maximal oxygen consumption rate (VO$_{2\max}$) further involves the efficiency of the transportation and usage of oxygen to exercising muscle for energy (Housh et al., 2012). Characteristics of oxygen transport relate to cardiac output and hemoglobin concentrations of the blood as oxygen, myoglobin levels, mitochondria size and quantity, and characteristics of enzymes for ATP production (Housh et al., 2012).
Response to CO₂

Respiration during exercise, stimulated by the hypothalamus of the central nervous system, influences gases (Champagnat et al., 2003). Increased stimulation of the center of the brain results in the flux of hydrogen ions from the lactate concentrations in the blood and increased levels of CO₂ thus increasing expired ventilation (Gregg et al., 2010). In the pulmonary circulatory system, receptors detect fluctuations in CO₂ through CO₂ partial pressure (PaCO₂) in the artery, CO₂ levels in the carotid body, and the stretch-sensitive afferent activity of CO₂ (Champagnat et al., 2003). The stretch-sensitive afferent activity describes the neural response to the lung expanding (Undem et al., ND).

Regulation of Ventilation

The control of the rate and depth of breathing is essential to maintain a state of homeostasis during various metabolic demands (from rest to high-intensity exercise) (Housh et al., 2012). A network of neurons in the brainstem receive neural input from the metabolic processes of the skeletal muscle to regulate breathing (Hess et al., 2013). Neural communication between the motor cortex and respiratory center is responsible for the variation in breathing patterns during multiple sports such as in swimming and the momentary holding of the breath during sprint running and weight lifting (Housh et al., 2012). Secondary controls of breathing evolve from: the hypothalamus, which senses the changes in the body’s temperature; the cerebellum, which sends signals from contracting muscles to the respiratory center; and the reticular formation which is sensitive to the stimulus of the central nervous system of the brain and facilitates ventilation during exercise (Housh et al., 2012). Throughout exercise
physiological and metabolic changes modify ventilation depth and rhythm regulated by the respiratory center of the brain, known as the pons and medulla (Marieb et al., 2013).

In response to the metabolic demands of exercise, the frequency and depth of breathing will adjust through factors of neural input from the brain, muscles, and joints, stimulating the release of hormones into the blood (Housh et al., 2012; Lumb et al., 2005). As the intensity of exercise increases the rate of breathing will increase to accommodate the increasing demands for energy (Jones et al., 2005). From rest to moderate intensity, the ratio of ventilation equivalent remains consistent regarding the ventilation rate, oxygen consumption, and release of carbon dioxide (Housh et al., 2012). During high-intensity training, the ratio of ventilation equivalent becomes disproportional in terms of gas levels due to the accumulation of lactic acid causing the respiratory center to lower pH levels in the blood resulting in the increase in ventilation (Housh et al., 2012). Thus, excessive ventilation, describes the increase in the release of CO₂ ‘s and anaerobic metabolism from buffering acids in the blood (McArdle et al., 2010). Identification of ventilatory threshold correspond to peak anaerobic metabolism and sometimes peak blood lactate levels from expired air (McArdle et al., 2010). The disproportion in the ratio of ventilatory equivalent ratio can further be determined by the measure of respiratory exchange ratio relative to ventilation (RER; VCO₂/VO₂) indicating the point of ventilatory threshold when oxygen is insufficiently being supplied to produce ATP in the mitochondria of working cells. Generally RER values are within the range of 1.00 – 1.21 in terms of age and physical fitness measured and increase in anaerobic processes in individuals (Howley et al., 1995).

Sensors throughout the body detect these changes through central and peripheral chemoreceptors (Marieb et al., 2013). Neural and chemical mechanisms influence the stimulation
of central and peripheral chemoreceptors in the brain (Marieb et al., 2013). As the brain recognizes changes in breathing rate and depth, levels of CO₂, O₂, and hydrogen ions (H+) are altered within the arterial blood (Lumb et al., 2005). Theoretically, in response to ventilation during exercise, peripheral and central chemoreceptors are activated by the brainstem respiratory system (Champagnat et al., 2003). From the stimulation of motor neurons within the muscles of the thoracic cavity during inspiration, the lungs become inflated; this is called the active phase of breathing (Lumb et al., 2005). However, during the passive phase of normal ventilation, or expiration, the inspiratory muscles become relaxed resulting in the elastic recoiling of the lungs (Lumb et al., 2005). Minute volume is the amount of air breathed in and out during normal respiration (Williamson et al., 2011). The energy cost of breathing during exercise describes the increase in minute ventilation and oxygen uptake during exercise in working muscles (McArdle et al., 2010). The study will examine the variability of adolescents exhibiting higher ventilation rates versus adults and their efficient respiration rates (Williamson et al., 2011).

**Ventilatory Threshold**

Ventilatory threshold (VT) is an estimate of an individual’s anaerobic threshold (AT) and represents the exercise intensity (i.e., cadence on ergometer) above which oxygen demand exceeds the oxygen supply (Gregg et al., 2010). The word “ventilatory” is derived from the word “ventilation,” meaning involuntary respiration response to metabolic demand (Connes et al., 2010). Ventilation is the movement of gases moving in and out of the lungs to supply oxygen and remove carbon dioxide from living cells (Williamson et al., 2011). During activities of high intensity, ventilation and levels of oxygen consumption increase linearly until the Owles point or break in linearity shown at high levels of oxygen consumption for trained individuals (Lumb et
al., 2005). With respect to time, before and at the start of exercise, an anticipatory response to exercise instantly increases ventilation (Lumb et al., 2005). During high intensity (above AT), compared to moderate intensity (below AT), ventilation will increase and reach a plateau or state of stagnation upon the continuation of severe work during exercise (Lumb et al., 2005). When breathlessness occurs during exercise, high portion of maximal breathing capacity (MBC) utilized will correlate to VO$_2$max (Lumb et al., 2005). Exercise induced ventilation during high intensity exercise, will eventually go back down to normal resting levels of ventilation. Dependent of preexisting lactate and oxygen consumption levels returning to normal or critical values in respect to prior exercise intensity (Lumb et al., 2005). Thus, ventilation intensity of exercise increases equivalently: lactic acid collects increasing respiration by signaling the respiratory system to lower pH levels in the blood (Housh et al., 2012).

Furthermore, limitations to tolerance of exercise may be limited the capacity for diffusion, control of ventilation, neurological factors, age, hormonal factors, body size, arterial blood gas tension, expiratory muscles (diaphragm, intercostal muscles, and abdominal muscles), and body chemoreceptors (Lumb et al., 2005). Relative to growth in children, aspects of ventilation, pulmonary volumes and capacities show signs of efficiency and functionality of the respiratory system (de Prado et al., 2006). For adolescents, changes in pulmonary volumes and capacities corresponding to changes in maximal ventilation still remains controversial (de Prado et al., 2006).

**Maturational Influence in Metabolism**

During maturation, muscle fibers will increase in size, and a transition from type I to type II muscle fibers will occur (Armstrong et al., 2015). This transition in muscle fiber type will
result in a greater reliance on anaerobic metabolism throughout maturation (Armstrong et al., 2015). Individuals with predominately large proportions of type II muscle fibers represent rapid kinetics versus high proportions of type I fibers which indicate high levels of endurance (Vanhatalo et al., 2016). Though muscle energy storage remains constant, in the period of adolescence, the body will experience a decrease in oxidative enzyme activity, transitioning from aerobic to anaerobic metabolism efficiency (Armstrong et al., 2015). As the demand of energy expenditure and VO₂max increases during endurance training, the need for oxygen is 20% to 30% more per unit of body mass (Williamson et al., 2011). This indicates that adolescents’ response to exercise differs compared to adults (Williamson et al., 2011).

Moreover, age is one of the multiple factors that affect the response to exercise (Stephens et al., 2006). Higher levels of fatigue in older adults are mainly influenced by the defective mitochondrial energy production and decreased aerobic capacity within (Santanasto et al., 2015). In adolescents, lower rates of fatigability may correspond to the rapid rate of energy usage from unlimited fat cell storage in adipose tissue (Williamson et al., 2011). This study gains significance as it relates to the variability of ventilatory threshold relative to percentage of VO₂max values in male adolescents’ response to exercise based on physiological mechanisms, metabolic factors, and growth (Armstrong et al., 2015).
Expectant Values for Testing

(Howley et al., 1995)

- **Respiratory Exchange Ratio (RER)** – increases with CO\textsubscript{2} and ventilation rate, acceptable values of 1.11 – 1.12 for male adolescents (14 ± 3 y) when plateau in VO\textsubscript{2max} is reached.

- **Metabolic Respiratory Quotient (RQ)** – maximum absolute value of \( \geq 0.75 \), determine anaerobic glycolysis with following equation: \( \Delta \text{RQ} = \text{RQ} - 0.75 \).

- VE/VO\textsubscript{2} – intake of oxygen during ventilation

- VE/VCO\textsubscript{2} - expulsion of carbon dioxide

- Maximal Heart Rate – adjusted to age

- VO\textsubscript{2} – oxygen consumption, possible range of values for adult males 2.0 – 4.0 L/min versus unknown data values for adolescent population

- VCO\textsubscript{2} – carbon dioxide exhalation

- VO\textsubscript{2max} – plateau in oxygen maximal uptake

Chapter Two: Review of Research Literature

Adolescent males versus adult males

The introduction of this developing line of research provides insight into the understanding of VT levels in adolescent male. From a biological perspective, humans age overtime go through continuous changes in structure and function (Capelli et al., 2016). The effects of exercise and successive maturation to meet metabolic demands specific to athletic performance in youth is unknown (Armstrong et al., 2015). Based on the developmental, physiological, and metabolic factors in biological maturation, children should not be considered
smaller replicas of adults (de Prado et al., 2006). Children and adolescents have been shown to have higher resistance to fatigue when compared to adults during intermittent bouts of maximal intensity (Armstrong et al., 2015). The purpose of this data analysis of ventilatory threshold relative to percentage of VO\textsubscript{2max}, was to provide an understanding of the relationships between anaerobic and aerobic performance concerning the age of adolescents established through physiological factors of growth and maturation in exercise (Armstrong et al., 2015).

**Variations in physiological and biological capabilities**

Youths’ responses to exercise compared to adults varies functionally and physiologically (Pitt et al., 2015). According to the Henneman size principle, children have lower voluntary recruitment of high intensity type II muscle fibers versus adults (Pitt et al., 2015). Theoretically, the higher resistance to fatigue during exercise in adolescents versus adults is related to the primary type I muscle fibers, oxidative efficiency, and other positive physiological changes (Tonson et al., 2010). Metabolic and physiological factors that are influenced by biological maturational include increases in strength, muscle mass, power, type II muscle fibers, muscle glycogen concentration, and glycolytic metabolism (Cunha et al., 2011). A noticeable shift in metabolic efficiency from the onset of puberty to adulthood are also dependent on neural, muscular, and biomechanical factors as trainability of muscular strength increases with age (Bergeron et al., 2015). During growth and development, communication between motor neurons and muscle fibers gradually increases (Williamson et al., 2011). Due to the maturation of the nervous system improvements in the responses to exercise based on concentration, memory, and learning, new skills promote the mastery of difficult physical activity (Williamson et al., 2011). Advancement in maturity and age relative to physical performance seems to provide most
athletes with significantly greater advantages when compared to counterparts of a lower maturity status of maturity and age (Deprez et al., 2013).

**Non-invasive measure**

In the assessment of the adolescent population, special considerations of ethics have always been a major concern. For ethical reasons, the descriptive variable of metabolism, VO₂ max tests, is used in studies with children and adolescents versus invasive measures of research, such as muscle biopsy and blood sampling (Howley et al., 1995). VO₂ levels may provide insightful analysis of intramuscular activity, pulmonary functionality, circulatory functionality, and muscular metabolism systems in adolescent test subjects (Armstrong et al., 2015). Conducive to many other studies, non-invasive measures, such as gas analysis of ventilatory threshold during exercise, have proven to be most reliable in the analysis of metabolic activity on a cellular level for children, adolescents, and adults (Gregg et al., 2010).

**Peak Height Velocity**

The basis of maturity status derives from the indication of skeletal age and secondary sex characteristics (Bergeron et al., 2015). However, assessment of secondary sex traits can be invasive, inaccurate due to the basis of observation, and provides indications only for a moment versus long term (Bergeron et al., 2015). Analysis of skeletal age as an estimate of maturity status for adolescents has proven to be most effective (Bergeron et al., 2015). When assessing specific maturational events, maturity timing is used to describe the individual’s age at peak height velocity (PHV) (Bergeron et al., 2015). Biological markers of adulthood vary in timing and tempo, further emphasizing categorization in maturation and metabolism (Cunha et al., 2011). According to Granados and colleagues (2015), the average age at peak height velocity in
males is 13.7 years old versus females at 12.1 years old. Classification of age group and maturation is relatable due to the variables of performance and metabolism in VO$_{2}$max (Cunha et al., 2011). Peak height velocity measures the onset of puberty which varies in adolescents particularly in this study (Mahon et al., 1998). Variations in puberty correlate to changes in physiological responses to efficiency in various exercise domains.

**Ventilation Threshold**

The breath-by-breath analysis and values of ventilation in the adolescent population during exercise breeds a complex investigation (Armstrong et al., 2015). In the transition from aerobic to anaerobic metabolism during exercise, increased and irregular breathing patterns may correlate to the approach or reach of anaerobic threshold (Cunha et al., 2011). Anaerobic threshold varies in individual ability to support working cells with oxygen to sustain exercise intensity (Housh et al., 2012). Understanding VO$_{2}$max ventilatory threshold relative to percentage of VO$_{2}$max, stems from variations in body composition, maturity, and body sizing within the populations of adults, children, and adolescents (Cunha et al., 2011). We also know that ventilation increases proportionally to exercise intensity and has a negative relationship to energy expenditure during ramp exercise testing (Cunha et al., 2011). Observation and analysis of ventilatory threshold in exercise domains or sports will further provide information on the trainability of each adolescent athlete optimized by functional capabilities due to maturational status.
Chapter Three: Methodology

Purpose

Following preparations for experimentation provides basis of analysis in the differences in ventilation thresholds in adolescent males compared to adult males through fatigue threshold testing. This exercise protocol will uniquely provide non-invasive measures during ramp exercise testing for male adolescents. Information from testing provides indications of the effects of growth and development stages in adolescent males during physical performance, such as in domains in exercise of sports. Since children are most efficient in aerobic metabolism compared to adults, an increase in anaerobic efficiency along with maturity was predicted to be observed through ventilatory threshold relative to percentage of VO$_2$max for this study (Armstrong et al., 2015).

Subjects

The criteria for adolescent male participants include being between the ages of 11 to 17 years old, generally healthy, and currently engaged in moderate physical activity. The categorization of groups was based on the number of years until they reach peak height velocity or growth spurt to measure the onset of puberty. Participants were specifically placed into groups based on the onset of puberty in less than a year (PRE, – 1); puberty greater than one year (POST, +1); and during puberty (PERI, between -1 and +1).

Before participation in this study, test subjects provided evidence of a cleared physical from a medical doctor within the last year (See Appendix B). Furthermore, participants were required to complete a Confidential Medical and Activity Questionnaire with the assistance of a parent or adult guardian specifying any physical limitations that would hinder the participants
from completing the study’s parameters (See Appendix C). Test subjects were also required to refrain from any ergogenic nutritional supplementation, such as creatine, caffeine, steroids, etc. Test subjects were asked to provide an informed consent from a parent or guardian prior to the study to participate (See Appendix D).

Participants were recruited from local high schools, sports clubs, and sports teams. The initial goal of this study was to have a total of 40 test subjects. However, limitations in recruitment, travel times, and motivation hindered this study from reaching the previously stated number of participants. Overall, 22 adolescent males between the ages of 11 to 17 years old participated in this study.

**Instruments**

- A Health-o-meter (Patient Weighing Scale, Model 500 KL, Pelstar, Alsip, IL, USA) was used to measure the seating and standing height of participants.
- The ramp exercise protocol was completed on an electromagnetically braked cycle ergometer (Excalibur Sport, Lode, Groningen, the Netherlands).
- A metabolic cart (TrueOne 2400, Parvo Medics, Sandy, UT, USA) collected and analyzed oxygen consumption and ventilation values.
- Bioelectrical impedance analyzer (InBody 770, Cerritos, CA, USA) and air displacement plethysmograph (BOD POD GS, COSMED, Rome, Italy) measured body composition.
- Heart rate was measured using a heart rate monitor (Polar WearLink, Polar Electro, Lake Success, NY, USA).
Procedures

Participants engaged in a total of 12 visits to UCF’s Institute of Exercise Physiology and Wellness. Each test subject participated in multiple screenings to prove validity. The experiment consisted of peak height velocity estimations, body composition testing, and a ramp exercise protocol. Testing sessions were completed within one day and within similar time periods of the day. All procedures were overseen by the direction of Dr. Jeffery Stout, a team of certified strength and conditioning specialists (CSCS), and students of the Institute of Exercise and Physiology and Wellness. Furthermore, this study was approved by the University of Central Florida Institutional Review Board (See Appendix E).

Peak Height Velocity Estimation Methods

Before testing, participants were measured for standing height, seated height, body mass and lean body mass. Years from peak height velocity were calculated using standing height, seated height, body mass, and age. Standing and seated height (±0.1 cm) was measured using the Health-o-meter Professional (Patient Weighing Scale, Model 500 KL, Pelstar, Alsip, IL, USA). Body mass measurements was collected from the calibrated scale, attached to the BOD POD. The equation used to calculate years from peak height velocity (PHV) originated from Mirwald and colleagues (2002). In order to utilize Mirwald’s equation, PHV years were used to determine maturational groups. The cutoff in years for each group is included in the following manner: less than -1, greater than +1, and between -1 and +1.
**Body Composition Methods**

For each testing session, measurements in body composition were determined using bioelectrical impedance (BIA) and air displacement plethysmography. For BIA, test subjects were asked to remove all footwear including socks, and asked to stand on the platform of the equipment while holding both hands out to the side. Holding their position for one minute, an electrical current was sent throughout their body to evaluate body composition. Values of total body water, lean body mass, skeletal muscle mass, fat mass, percent body fat, leg lean mass and the visceral fat area were further evaluated by BIA testing. For air displacement plethysmography (BOD POD), participants dressed in spandex-style undergarments, remove footwear including socks, wear provided swim cap, and stood in the seated position in the BOD POD (BOD POD GS, COSMED, Rome, Italy) to determine body composition. Thoracic gas volume was predicted using the BOD POD and Lohman’s density model for all participants. During BOD POD testing, values of body fat percentage, fat-free mass percentage, fat mass, fat-free mass, body volume and body density were recorded.

**Ramp Exercise Protocol Methods**

During the ramp exercise protocol, each subject was equipped with a heart rate monitor, while breathing through a metabolic cart. After setting up their equipment, they were asked to sit on a cycle ergometer (Lode, Excalibur Sport, Groningen, the Netherlands), which were adjusted to a position approximately where the hips aligned with the ergometer seat and the feet appropriately met the pedals. Participants were then asked to remain at rest for three minutes before allowed ‘warm-up,’ or moment of free pedaling at a comfortable cadence with no
resistance. This rest period provided a controlled group in data and allowed for the equipment to stabilize in readings. Following, testing began with continuous pedaling with a starting workload of 30 watts and one watt increase every three seconds while remaining seated (20 watts/minute). Throughout the warm-up and ramp portions of testing, participants must maintain a cadence of 65-85 revolutions per minute (rpm). The test thus ceased when participants could no longer stay within the rpm range despite verbal encouragement. Ratings of perceived exertion were recorded from the start of testing for every minute afterward while using a visual chart of the Borg scale 6 to 20; number 6 being very, very light effort to 20 being extreme fatigue.

**Metabolic Cart Methods**

The oxygen consumption was analyzed during the ramp exercise protocol; a flexible mask was placed on each participant’s face and fitted around their mouth and nose to ensure accurate collection of expired air. The samples of expired air were taken and analyzed by the metabolic cart (TrueOne 2400, Parvo Medics, Sandy, UT, USA) to calculate the gases expired with each breath. In the collection of data using the metabolic cart, heart rate, VO₂, VCO₂, ventilation, respiratory exchange ratio was measured and collected for calculations of averages every 10 seconds. Furthermore, test subjects were asked to remain silent and keep hand placement constant on the ergometer handlebars during testing to promote valid measures of ventilation threshold.

**Threshold Determination Methods**

Ventilatory threshold testing was determined using the maximal deviation (Dmax) methodology by Cheng and colleagues (1992). The Dmax method, sets a physiological variable
versus time, power output, or VO$_2$. From the graph, the data points were set with a third-order polynomial regression line:

\[ y = ax^3 + bx^2 + cx + d \]

Following the input of variables, a linear line was computed from the first and last data points. The indicated point from the third-order polynomial line were the best fit so that the furthest perpendicular distance from the linear line is considered the ventilatory threshold. All data values for this study were downloaded into 10-second averages. Then, a procedure conducting a 30-second moving average showed the increase in the fit of the third-order polynomial. Data values were then plotted to their respective graphs and equations for the third-order polynomial and linear lines to be calculated. Finally, the Dmax point on the third-order polynomial line was calculated using an equation by Machado and colleagues (2012):

\[ D_{\text{max}} = \left\{ -b + \sqrt{\left[ b^2 - 3 \times a(c - \Delta) \right]} \right\} / 3 \times a \]

Where a, b and c are the parameters of the third-order polynomial equation and delta (\(\Delta\)) is the slope of the linear line connecting the first and last data points.

**Statistical Analysis**

All participants’ ventilatory thresholds (VT relative to % of VO$_{2\text{max}}$) were entered into SPSS for one-way ANOVA testing to examine significances in mean values for each test group (Green et al., 2008). One way ANOVA indicated significance in mean VT values for each group (Appendix A, Figure 1 & 2). To prove significant differences in groups LSD (Least Significant Difference) post hoc analysis was run as a follow-up test to evaluate the comparison in paired
groups (Appendix A, Figure 3). Based on the 95% confidence interval, indications of significance differences were evaluated between each test group (Appendix A, Figure 3).

**Chapter Four: Results**

**Differences in Ventilatory Threshold**

In total, 22 subjects were divided into groups of PRE, PERI, and POST PHV. Anthropometric measures of PHV groups, standing height (PRE: 148.0 ± 5.5; PERI: 169.3 ± 8.8; POST: 177.2 ±10.2 cm), PHV in relation to years (PRE: 2.22 ± 0.44; PERI: 0.595 ± 0.405; POST: 2.35 ± 1.09 y), weight (PRE: 42.65 ± 6.65; PERI: 54.657± 10.416; POST:71.2655 ± 14.4325 kg), and age (PRE: 11.69 ± 0.68; PERI: 14.13 ± 1.1; POST: 16.355 ± 1.365 y). One-way ANOVA revealed significant differences (F=5.36; p=0.014) in VT among maturational groups (Appendix A, Figure 2). Post hoc analysis showed significantly greater VT values, as a percent of their VO$_{2\text{max}}$, in PRE (p = 0.029; p < 0.05) and PERI (p = 0.009; p < 0.05) when compared to POST (Table 1) (Appendix A, Figure 3). Furthermore, no significant (p=0.970) differences were found between PRE - and PERI – PHV (Appendix A, Figure 3).

**Chapter Five: Discussion**

The main finding in this study was that adolescent males in PRE and PERI maturational groups demonstrated significantly higher VT as a percentage of their VO$_{2\text{max}}$ compared to POST maturational groups. This finding suggests that boys who are PRE and PERI have a delayed switch from aerobic to anaerobic metabolism during incremental exercise. Previous studies have performed VT data analyses in adolescents, children, and adults (Krahenbuhl et al., 1985; Pitetti et al., 2002; Reybrouck et al., 1985;). These findings suggested the differences in children and
adolescent were relative to anthropometric and physiological measures used to describe growth (Krahenbuhl et al., 1985). Thus, the onset of puberty results in changes in metabolic and hormonal responses to exercise in adolescents (Boisseau et al., 2000; Cunha et al., 2011; Gaisl et al., 1988; Krahenbuhl et al., 1985).

The purpose of this study was to examine the variability of metabolic processes during incremental exercise based on the onset of puberty. Differences in substrate utilization in children and adults supported our assumption of variability within adolescence based on maturity (Boisseau et al., 2000). Similarly, previous studies indicated assumptions of differences in VT among adolescent males based on the observation of variability in fat oxidation, glycolytic metabolism, and muscle glycogen concentration in comparison to male children and adult males (Armstrong et al., 2015; Reybrouck et al., 1985; Riddell et al., 2008; Stephens et al., 2006). Collectively, adolescents experience growth at varying magnitudes and timing from the onset of puberty to the full adult-like metabolic profiles (Cunha et al., 2011). As predicted beforehand, POST maturational groups most closely resembled the adult-like metabolic profile of anaerobic efficiency versus PRE and PERI (Armstrong et al., 2015; Riddell et al., 2008;). Therefore, the completion of puberty signifies the complete development of adult metabolic profile (Stephens et al., 2006). Growth hormones, insulin-factor like growth hormones, and steroid sex hormones influence the onset of pubertal growth spurts (Boisseau & Delmarche, et al., 2000). Participants’ values of PHV was in relation to age to express the importance of maturity status versus age alone. Thus, individuals with a higher status of maturity based on PHV showed a lower VT values relative to percentage of VO\textsubscript{2max}. In resemblance to our PRE group and male children from previous studies, peak values of fat oxidation relative to lean body mass was shown to be
significantly higher than the rate of relative metabolism in adult males (Riddell et al., 2008; Armstrong et al., 2015). In relation to the profiles of PRE and PERI groups, utilization of fat for energy decreases with age (Stephens et al., 2006). With the profile of fat oxidation as their dominate use of metabolism, PER and PERI had higher perceived aerobic capacities and higher point of VT relative to percentage of VO$_{2max}$ versus POST.

Using Dmax method we effectively plotted VT (figure 5) in terms of ventilation (L/min) versus oxygen consumption (L/min) to determine to participant’s metabolic efficiencies within PRE, PERI, and POST. In the breath by breath analysis of each test subject, Dmax method help to avoid error in data analysis originating from the possible large fluctuations in breathing pattern observed in children (Cheng et al., 1992). Prior to this study, indications of respiratory patterns showed variability in VO$_2$ in adults and VO$_2$ and VCO$_2$ for children and the relatively large noise breath-by-breath ventilatory and gas exchange responses in children compared to adults (Potter et al., 1999). These findings previously stated expresses variability in ventilation based on status of maturity (Potter et al., 1999). Corresponding to maturity status, peak values of PHV coincide with peak values of lung growth relative to chronological age (Eydne et al., 1988). Additionally, breathing rate and ventilatory efficiency decreases with age (Klentrou et al., 2006). From PRE - to POST- PHV, breathing functionality depends age, height, weight, fat distribution, dimensions of thoracic cavity, ratio of ventilation and carbon dioxide, lung size and body surface area (Cotes et al., 1993; Krahenbuhl et al., 1985). The data from this study emphasizes the need for precaution in the adolescent population for variability in ventilatory measures in response to exercise (Cunha et al., 2011). All underlining factors involved in the growth and metabolic
processes of adolescent males expressed differences in physical performance within this population.

**Chapter Six: Conclusion**

To summarize, results from this study suggest the transition in substrate utilization as a factor of maturity in male adolescents. Variability in VT relative to percentage of VO$_{2\text{max}}$, expressed the variability in energy specific trainability of adolescent males based on years until the onset of puberty. Research findings suggest the implications of exercise prescription for adolescent males to be based on status of maturity relative to PHV due to variations in metabolic efficiency and physiological mechanisms of exercise. However, as significant statistical differences were observed in this study, a larger pool of participants and a longitudinal study of data values may be needed for conclusive results.

**Future Research**

Based on the observations of predicted VO$_{2\text{max}}$ variability in male and female children from South Asia, European whites, and African-Caribbean’s differences in VT relative to percentage of VO$_{2\text{max}}$, may vary further in participants of different ethical backgrounds (Nightingale et al., 2016). Also, for further future implications, performing additional research with participants with ventilatory chemoreceptors insensitivity (e.g. obstructive lung disease and obesity etc.) may be needed to be analyzed for possible exposure of unforeseen differences in VT relative to percentage of VO$_{2\text{max}}$ among adolescent males (Beaver et al., 1986).
References


APPENDIX A: TABLES
Table 1: Mean Values of Ventilatory Threshold (Percentage of VO$_{2\text{max}}$) for Maturity Groups

<table>
<thead>
<tr>
<th>VT</th>
<th>N</th>
<th>Mean</th>
<th>Std. Deviation</th>
<th>Std. Error</th>
<th>95% Confidence Interval for Mean</th>
<th>Minimum</th>
<th>Maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Lower Bound</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Upper Bound</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Minimum</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Maximum</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PRE</td>
<td>4</td>
<td>70.0208</td>
<td>2.25127</td>
<td>1.12563</td>
<td>66.4386</td>
<td>73.6031</td>
<td>66.96</td>
</tr>
<tr>
<td>PERI</td>
<td>7</td>
<td>70.1418</td>
<td>2.44370</td>
<td>.92363</td>
<td>67.8818</td>
<td>72.4019</td>
<td>65.00</td>
</tr>
<tr>
<td>POST</td>
<td>11</td>
<td>62.9478</td>
<td>6.68567</td>
<td>2.01580</td>
<td>58.4563</td>
<td>67.4393</td>
<td>49.37</td>
</tr>
<tr>
<td>Total</td>
<td>22</td>
<td>66.5228</td>
<td>6.09147</td>
<td>1.29871</td>
<td>63.8220</td>
<td>69.2236</td>
<td>49.37</td>
</tr>
</tbody>
</table>

Table 2: Significant Differences in Maturity Groups Using One-way ANOVA

<table>
<thead>
<tr>
<th>VT</th>
<th>Sum of Squares</th>
<th>df</th>
<th>Mean Square</th>
<th>F</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Between Groups</td>
<td>281.210</td>
<td>2</td>
<td>140.605</td>
<td>5.364</td>
<td>.014</td>
</tr>
<tr>
<td>Within Groups</td>
<td>498.016</td>
<td>19</td>
<td>26.211</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>779.227</td>
<td>21</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Table 3: Multiple Comparisons of Significant Mean VT Values between Maturity Groups

Dependent Variable: VT

<table>
<thead>
<tr>
<th>(I) Group</th>
<th>(J) Group</th>
<th>Mean Difference (I-J)</th>
<th>Std. Error</th>
<th>Sig.</th>
<th>95% Confidence Interval</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Lower Bound</td>
</tr>
<tr>
<td>PRE</td>
<td>PERI</td>
<td>-.12100</td>
<td>3.20895</td>
<td>.970</td>
<td>-6.8374</td>
</tr>
<tr>
<td>POST</td>
<td>PRE</td>
<td>7.07299*</td>
<td>2.98926</td>
<td>.029</td>
<td>.8164</td>
</tr>
<tr>
<td></td>
<td>POST</td>
<td>7.19399*</td>
<td>2.47535</td>
<td>.009</td>
<td>2.0130</td>
</tr>
<tr>
<td>POST</td>
<td>PERI</td>
<td>-7.07299*</td>
<td>2.98926</td>
<td>.029</td>
<td>-13.3296</td>
</tr>
<tr>
<td></td>
<td>PERI</td>
<td>-7.19399*</td>
<td>2.47535</td>
<td>.009</td>
<td>-12.3749</td>
</tr>
</tbody>
</table>

* The mean difference is significant at the 0.05 level.
APPENDIX B: PHYSICAL FORM
Florida High School Athletic Association
Preparticipation Physical Evaluation (Page 1 of 3)

This completed form must be kept on file by the school. This form is valid for 265 calendar days from the date of the evaluation as written on page 2. This form is non-transferable; a change of schools during the validity period of this form will require page 1 of this form to be re-submitted.

Part 1. Student Information (to be completed by student or parent)

Student's Name: ____________________________ Sex: ______ Age: _____ Date of Birth: _____ / _____ / _____

School: ____________________________ Grade in School: _____ Sport(s): ____________________________

Home Address: ____________________________________________ Home Phone: (____) ______ ______ ______

Name of Parent/Guardian: ________________________________________ Email: ____________________________

Person to Contact in Case of Emergency: ____________________________

Relationship to Student: ________________________________________

Home Phone: (____) ______ ______ ______ Work Phone: (____) ______ ______ ______ Cell Phone: (____) ______ ______ ______

Personal/Family Physician: ________________________________________ City/State: ____________________________

Office Phone: (____) ______ ______ ______

Part 2. Medical History (to be completed by student or parent). Explain “yes” answers below. Circle questions you don’t know answers to.

1. Have you had a medical illness or injury since your last check-up or sports physical? Yes ______ No ______

2. Do you have an ongoing chronic illness? ______

3. Have you ever been hospitalized overnight? ______

4. Have you ever had surgery? ______

5. Are you currently taking any prescription or non-prescription (over-the-counter) medications or pills or using an inhaler? ______

6. Have you ever taken any supplements or vitamins to help you gain or lose weight or improve your performance? ______

7. Do you have any allergies (for example, pollen, latex, medicine, food or sting insects)? ______

8. Have you ever had a rash or blisters develop during or after exercise? ______

9. Have you ever passed out during or after exercise? ______

10. Have you ever been dizzy during or after exercise? ______

11. Have you ever had chest pain during or after exercise? ______

12. Do you feel tired more quickly than your friends do during exercise? ______

13. Have you ever had racing of your heart or skipped heartbeats? ______

14. Have you had high blood pressure or high cholesterol? ______

15. Have you ever been told you have a heart murmur? ______

16. Has any family member or relative died of heart problems or sudden death before age 50? ______

17. Have you had a severe viral infection (for example, myositis or mononucleosis) within the last month? ______

18. Has a physician ever denied or restricted your participation in sports for any heart problems? ______

19. Do you have any current skin problems (for example, itching, rashes, acne, warts, fungus, blisters or pressure areas)? ______

20. Have you ever had a head injury or concussion? ______

21. Have you ever been knocked out, become unconscious or lost your memory? ______

22. Have you ever had a seizure? ______

23. Do you have frequent or severe headaches? ______

24. Have you ever had numbness or tingling in your arms, hands, legs or feet? ______

25. Have you ever had a finger, bun or pinched nerve? ______

26. Have you ever become ill from exercising in the heat? ______

27. Do you cough, wheeze or have trouble breathing during or after activity? ______

28. Do you have asthma? ______

29. Do you have seasonal allergies that require medical treatment? ______

30. Have you ever used any special protective or corrective equipment or medical devices that aren’t usually used for your sport or position (for example, lower brace, special tooth shell, foot orthotics, splint, retainer on your teeth or hearing aid)? ______

31. Have you had any problems with your eyes or vision? ______

32. Do you wear glasses, contacts or protective eyewear? ______

33. Have you ever had a sprain, strain or swelling after injury? ______

34. Have you broken or fractured any bones or dislocated any joints? ______

35. Have you had any other problems with pain or swelling in muscles, tendons, bones or joints? ______

36. Do you want to weigh more or less than you do now? ______

37. Do you lose weight regularly to meet weight requirements for your sport? ______

38. Do you feel stressed out? ______

39. Have you ever been diagnosed with sickle cell anemia? ______

40. Have you ever been diagnosed with having the sickle cell trait? ______

41. Include the dates of your most recent immunizations (shots) for: Tetanus: ______ Measles: ______

FEMALES ONLY (optional)

42. When was your last menstrual period? ______

43. When was your most recent menstrual period? ______

44. How many times do you usually have from the start of one period to the start of another? ______

45. How many periods have you had in the last year? ______

46. What was the longest time between periods in the last year? ______

Explain “yes” answers here: ____________________________________________

We hereby state, to the best of our knowledge, that our answers to the above questions are complete and correct. In addition to the routine medical evaluation required by Florida Statute and FHSAA Rule 11B-5.5, we understand and acknowledge that we are hereby advised that the student should undergo a cardiac screen assessment, which may include each diagnostic test as EKG or ECG, cardioanogram (CGA) and/or echocardiogram (ECHO) at our own expense.
Part 3. Physical Examination (to be completed by licensed physician, licensed osteopathic physician, licensed chiropractic physician, licensed physician assistant or certified advanced registered nurse practitioner).

<table>
<thead>
<tr>
<th>Height:</th>
<th>Weight:</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>% Body Fat (optional):</th>
<th>Pulse:</th>
<th>Blood Pressure:</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Temperature:</th>
<th>Right:</th>
<th>Left:</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Hearing: right:</th>
<th>F</th>
<th>F</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>left:</th>
<th>F</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Findings:</th>
<th>Normal:</th>
<th>Abnormal Findings:</th>
<th>Initials:</th>
</tr>
</thead>
</table>

**MEDICAL**

1. Appearance
2. Eyes/Ears/Nose/Throat
3. Lymph Nodes
4. Heart
5. Pulses
6. Lungs
7. Abdomen
8. Gynecia (males only)
9. Skin

**MUSCULOSKELETAL**

10. Neck
11. Back
12. Shoulder/Arm
13. Elbow/Forearm
14. Wrist/Hand
15. Hip/Thigh
16. Knee
17. Leg/Ankle
18. Foot

* — station-based examination only

**ASSESSMENT OF EXAMINING PHYSICIAN/PHYSICIAN ASSISTANT/NURSE PRACTITIONER**

I hereby certify that each examination listed above was performed by myself or an individual under my direct supervision with the following conclusion(s):

Cleared without limitation

Disability: 
Diagnosis: 

Precautions: 

Not cleared for: 
Reason: 

Cleared after completing evaluation/rehabilitation for: 

Referred to: 
For: 

Recommendations:

Name of Physician/Physician Assistant/Nurse Practitioner (print): 
Date: / / 
Address: 

Signature of Physician/Physician Assistant/Nurse Practitioner: 

Florida High School Athletic Association
Preparticipation Physical Evaluation (Page 2 of 3)

This completed form must be kept on file by the school. This form is valid for 365 calendar days from the date of the evaluation as written on page 1. This form is non-transferable; a change of schools during the validity period of this form will require page 1 of this form to be re-submitted.
Florida High School Athletic Association
Preparticipation Physical Evaluation (Page 3 of 3)

This completed form must be kept on file by the school. This form is valid for 365 calendar days from the date of the evaluation as written on page 2.
This form is non-transferable; a change of schools during the validity period of this form will require page 1 of this form to be resubmitted.

ASSESSMENT OF PHYSICIAN TO WHOM REFERRED (if applicable)
I hereby certify that the examination(s) for which referred was/were performed by myself or an individual under my direct supervision with the following condition(s):

- Cleared without limitation
  - Disability: 
  - Diagnosis: 

- Precautions: 

- Not cleared for: 
  - Reason: 

- Cleared after completing evaluation/rehabilitation for:

Recommenations:

Name of Physician (print): 
Date: / / 
Address: 

Signature of Physician: 

Confidential Medical and Activity History Questionnaire

Participant #

When was your last physical examination?

1. List any medications, herbals or supplements you currently take or have taken the last month:

<table>
<thead>
<tr>
<th>Medication</th>
<th>Reason for medication</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
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<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

2. Are you allergic to any medications? If yes, please list medications and reaction.

3. Please list any allergies, including food allergies that you may have?

4. Have you ever been hospitalized? If yes, please explain.

<table>
<thead>
<tr>
<th>Year of hospitalization</th>
<th>Reason</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

5. Illnesses and other Health Issues

List any chronic (long-term) illnesses that have caused you to seek medical care.
Human Performance Laboratory
University of Central Florida

Any others (specify):

<table>
<thead>
<tr>
<th>Question</th>
<th>Yes</th>
<th>No</th>
</tr>
</thead>
<tbody>
<tr>
<td>Do you smoke cigarettes or use any other tobacco products?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Do you have a history of drug or alcohol dependency?</td>
<td>yes</td>
<td>no</td>
</tr>
<tr>
<td>Do you ever have any pain in your chest?</td>
<td>yes</td>
<td>no</td>
</tr>
<tr>
<td>Are you ever bothered by racing of your heart?</td>
<td>yes</td>
<td>no</td>
</tr>
<tr>
<td>Do you ever notice abnormal or skipped heartbeats?</td>
<td>yes</td>
<td>no</td>
</tr>
<tr>
<td>Do you ever have any arm or jaw discomfort, nausea, or vomiting</td>
<td></td>
<td></td>
</tr>
<tr>
<td>associated with cardiac symptoms?</td>
<td>yes</td>
<td>no</td>
</tr>
<tr>
<td>Do you ever have difficulty breathing?</td>
<td>yes</td>
<td>no</td>
</tr>
<tr>
<td>Do you ever experience shortness of breath?</td>
<td>yes</td>
<td>no</td>
</tr>
<tr>
<td>Do you ever become dizzy during exercise?</td>
<td>yes</td>
<td>no</td>
</tr>
<tr>
<td>Are you pregnant?</td>
<td>yes</td>
<td>no</td>
</tr>
<tr>
<td>Is there a chance that you may be pregnant?</td>
<td>yes</td>
<td>no</td>
</tr>
<tr>
<td>Have you ever had any tingling or numbness in your arms or legs?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Has a member of your family or close relative died of heart problems or</td>
<td>yes</td>
<td>no</td>
</tr>
<tr>
<td>sudden death before the age of 50?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Has a health care practitioner ever denied or restricted your</td>
<td>yes</td>
<td>no</td>
</tr>
<tr>
<td>participation in sports for any problem</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Are you presently taking any nutritional supplements or ergogenic aids? (If yes, please detail.)
APPENDIX D: INFORMED CONSENTS
The reliability and trainability of a ramp exercise protocol to determine metabolic and neuromuscular fatigue thresholds in adolescents.

Informed Consent

Principal Investigator: Jeffrey R. Stout, Ph.D.
Co-Investigator(s): David H. Fukuda, Ph.D.
Kyle S. Beyer, M.S.
Sub-Investigator(s): Michael J. Redd, M.S.
Kayla Baker, B.S.

Investigational Site(s): University of Central Florida, Institute of Exercise Physiology & Wellness

How to Return this Consent Form: You are provided with two copies of this consent form. If you give consent for your child to participate in the research, please sign one copy and return it to the researcher and keep the other copy for your records.
**Introduction:** Researchers at the University of Central Florida (UCF) study many topics. To do this we need the help of people who agree to take part in a research study. Because you are the parent or legal guardian, you are being asked to allow your child to take part in a research study which will include about 45 people at UCF. Your child is being invited to take part in this research study because he is between the ages of 11 and 17 years old. Prior to participation in this study, you will be asked to fill out a medical questionnaire and this document.

Jeffrey R. Stout, Ph.D.: The person doing this research is a Professor and researcher in the Institute of Exercise Physiology and Wellness at UCF. Dr. Stout will be assisted in this study by Kyle Beyer, a UCF graduate student. This research study will serve as Kyle Beyer’s dissertation.

**What you should know about a research study:**
- Someone will explain this research study to you.
- A research study is something you volunteer for.
- Whether or not you take part is up to you.
- You should allow your child to take part in this study only because you want to.
- You can choose not to take part in the research study.
- You can agree to take part now and later change your mind.
- Whatever you decide it will not be held against you or your child.
- The procedures will have no medical or personal value to your child.
- Feel free to ask all the questions you want before you decide.

**Purpose of the research study:** The purpose of Phase I of this study is to evaluate the reliability of a maximal exercise test at determining fatigue thresholds in adolescents. The purpose of Phase II of this study is to compare how these fatigue thresholds change in response to interval training amongst different maturity groups.

**What your child will be asked to do in the study:** Aside from the current screening visit, your child will be asked to complete Phase I (2 pre-testing visits) and Phase II (8 training visits and 1 post-testing visit). The pre-testing visits will be completed within 7 days of each other. The week after the second pre-testing visit, your child will be enrolled in a 4-week high intensity interval training program. The training program will consist of 2 training visits per week with at least 1 day in between visits. The final post-testing visit will be complete the week after the conclusion of the training program. A detailed description of the procedures being performed during each visit can be seen below:

**Options to complete the study:** Once enrolled in the study, you and your child will choose one of three options to complete the study. Option 1 consists of completing only Phase I, option 2 consists of completing Phases I and II in immediate succession, and option 3 consists of completing Phase I, taking time off, and then completing Phase II. If you and your child choose option 3, there will be an additional pre-testing visits at the start of Phase II.

**Screening Visit (1):**

You will be asked to complete this informed consent document, with your child before any other study-related procedures are performed. Upon completion of the informed consent document, you will be asked to complete a Confidential Medical and Activity Questionnaire to assess health and activity level of your child. This questionnaire will be filled out with your child. We will follow-up with your child to ensure all information is accurate. If your child has had a current (within the last 12 months) EL2 physical form, or equivalent, signed and cleared by a physician, then they will not need physician clearance. However, if this is not the case, we will require physician’s clearance. Upon being admitted to the study your child will be assigned a subject number.
Then, your child’s standing and seated height will be measured to determine their group assignment. Your child’s group assignment will not affect overall time requirements. All groups will complete all testing and training visits. Any participant may schedule testing or training on any day, at any time. The research staff will ensure that participant privacy is maintained during all visits.

Testing Visits (3 or 4):
Your child will be required to complete two testing visits throughout Phases I and one testing visit in Phase II. The first two visits will be completed at least 1 day, but no more than 7 days apart. The third testing session will be completed after a 4-week high intensity interval training session. During each testing visit your child will complete anthropometric, body composition, and exercise testing. You child will be asked to be normally hydrated and four hours fasted for all testing sessions.

Anthropometric and Body Composition Testing
Anthropometric testing will consist of standing height, seated height, and body weight. Body composition testing will consist of bioelectrical impedance analysis and BOD POD testing. Bioelectrical impedance analysis will require your child to remove their footwear, including socks, and stand on a platform while holding two handles out to the side. Your child’s hands and feet will be placed in contact with a machine that will send electricity (that is safe and cannot be seen or felt) through the body to determine body composition. BOD POD testing will require your child to sit in an enclosed, air-filled chamber (see picture) for approximately two minutes as the machine determines body fat percentage. In order to accurately measure body fat percentage it is required for your child to dress down to spandex-style shorts, remove footwear, including socks, put on a swim cap to cover their hair. The BOD POD testing will take place in a private room with only the research personnel present. Your child will also fill out a sports mental toughness questionnaire, which is a 14-item questionnaire assessing their perception of stress during physical activity and sports. There are no risks associated with either anthropometric, body composition testing, or the questionnaire.

Exercise Testing
After completion of anthropometric and body composition testing, your child will be asked to complete a ramp exercise protocol on a cycle ergometer. The cycle ergometer seat will be adjusted to a comfortable position for your child, who will begin the test with a 3-minute warm up against no resistance. Once the warm up is complete, your child will continue to pedal against a resistance that is constantly increasing until they can no longer continue at a certain pace. During this test, your child will have their heart rate, expired air, neuromuscular recruitment, and tissue oxygenation levels measured. There are no reported risks with any of the measurements being obtained during this test and all of the methodologies are considered non-invasive.

Training Visits (8):
During Phase II of the study, your child will be asked to complete 4 weeks of high intensity interval training. All training session will occur in the Strength and Conditioning Laboratory, 2 times per week for a total of 8 training visits. There will be at least 24 hours between your child’s training sessions to allow for proper recovery. Your child’s training load will be set at 7.5% of your child’s body weight. Each training sessions will consists of a 5-minute warm up at a self-selected resistance, followed by a protocol of 4-7 30-second exercise bouts. There will be a 4-minute rest interval in between exercise bouts. On the first and last training session, your child will also be asked to complete a skeletal muscle ultrasound exam before and after the exercise. For this, your child will be asked to lie flat on their back on an examination table with their legs extended. A lubricated probe will be placed over their thigh to collect images of their muscle. The images will be collected and store on a laptop, then
transferred to a desktop for analysis. There are no risks or dangers associated with the ultrasound exam.

**Location:** All testing will be conducting in the Human Performance Lab in the College of Education and Human Performance building at the University of Central Florida. All training sessions will be completed within the Strength and Conditioning Laboratory in the College of Education and Human Performance building at the University of Central Florida.

**Time required:** In addition to the current screening visit (lasting approximately 20 minutes), we expect that your child will be in this research study for approximately 6 weeks and will consist of 12 total visits (13 if choosing option 3 to complete the study). The testing visits will each last approximately an hour and a half. Training visits will last no more than an hour. All visits to the Human Performance Lab will be scheduled with Kyle Beyer. It will be expected that your child provide their own transportation to and from the Human Performance Lab. It is not required for you, the parent to attend; however, if you are present you will be welcome to observe any testing/training.

**Risks:** There is minimal risk involved with participation in this study. Participants may experience muscle fatigue, muscle strain, and elevated heart rate during the exercise testing and training protocols. All testing and training will be overseen by Certified Strength and Conditioning Specialists who are also certified in CPR and to use an automated external defibrillator (AED). An AED is located in the building where testing and training will occur. If immediate assistance, such as first aid, CPR, or AED, is needed it will be provided, but you must seek your own physician for any further medical treatment. Participants are instructed to notify the research team if they feel uncomfortable at any time.

**Benefits:** We cannot promise any benefits to your child from taking part in this research. Any information or data obtained will be made available to you at your request. However, your child will be receiving four weeks of personalized high intensity interval training from a Certified Strength and Conditioning Specialist.

**Compensation or payment:** There is no compensation or other payment to you or your child for your child’s part in this study.

**Confidentiality:** We will limit your personal data collected in this study. Efforts will be made to limit your child’s personal information to people who have a need to review this information. We cannot promise complete secrecy. Organizations that may inspect and copy your information include the IRB and other representatives of UCF.

The results of this study will be published as a group as part of a scientific publication. No individual results will be published or shared with any person or party. All information attained from the Confidential Medical and Activity questionnaires or performance tests will be held in strict confidence. Individual results will remain confidential and only be relayed to the participant upon request. All Confidential Medical and Activity questionnaires, as well as data collection sheets will be kept in a locked cabinet during and following the study. All information will be destroyed five years from the end of the study and not used for other research purposes. Participant folders will be marked with an I.D. number to protect against a breach of confidentiality, and the ID number will be removed upon disposal. Any information or data obtained will be made available to you at your request.

**Study contact for questions about the study or to report a problem:** If you have questions, concerns, or complaints, or think the research has hurt your child talk to Kyle Beyer or Dr. Jeffrey Stout, Human Performance Laboratory, Sport and Exercise Science (407) 823-2367 or by email at or jeffrey.stout@ucf.edu.
IRB contact about you and your child’s rights in the study or to report a complaint: Research at the University of Central Florida involving human participants is carried out under the oversight of the Institutional Review Board (UCF IRB). This research has been reviewed and approved by the IRB. For information about the rights of people who take part in research, please contact: Institutional Review Board, University of Central Florida, Office of Research & Commercialization, 12201 Research Parkway, Suite 501, Orlando, FL 32826-3246 or by telephone at (407) 823-2901. You may also talk to them for any of the following:

- Your questions, concerns, or complaints are not being answered by the research team.
- You cannot reach the research team.
- You want to talk to someone besides the research team.
- You want to get information or provide input about this research.

If your child is harmed because he or she takes part in this study: If your child is injured or made sick from taking part in this research study, medical care will be provided. Depending on the circumstances, this care may be provided at no cost to you. Contact the investigator for more information.

Withdrawing from the study: You may decide not to have your child continue in the research study at any time without it being held against you or your child. Participation in the study may also be terminated at any time by the researchers in charge of the project. This could be based upon your refusal to follow study instructions or follow the study protocol.

Results of the research: Upon request, results will be shared with parent or legal guardian of the participant at the conclusion of all data collection and analyses.

Your signature below indicates your permission for the child named below to take part in this research.

DO NOT SIGN THIS FORM AFTER THE IRB EXPIRATION DATE BELOW

__________________________
Name of participant

__________________________
Signature of parent or guardian

__________________________
Date
- [ ] Parent
- [ ] Guardian (See note below)

__________________________
Printed name of parent or guardian

- [ ] Assent Obtained

My signature and date indicates that the information in the consent document and any other written information was accurately explained to, and apparently understood by, the participant or the participant’s legally authorized representative, and that informed consent was freely given by the participant or the legally authorized representative.

Note on permission by guardians: An individual may provide permission for a child only if that individual can provide a written document indicating that he or she is legally authorized to consent to the child’s general medical care. Attach the documentation to the signed document.
APPENDIX E: UCF IRB LETTER
 Approval of Human Research

From: UCF Institutional Review Board #1
FWA0000365, IRB0000138

To: Jeffrey Ray Stout and Co-PIs: David Fukuda, Kyle S. Beyer

Date: January 27, 2016

Dear Researcher:

On 01/27/2016 the IRB approved the following human participant research until 01/26/2017 inclusive:

Type of Review: Submission Response for UCF Initial Review Submission Form
Expedited Review
Project Title: The reliability and trainability of a ramp exercise protocol to determine metabolic and neuromuscular fatigue thresholds in adolescents
Investigator: Jeffrey Ray Stout
IRB Number: SBE-15-11910
Funding Agency: N/A
Grant Title: N/A
Research ID: N/A

The scientific merit of the research was considered during the IRB review. The Continuing Review Application must be submitted 30 days prior to the expiration date for studies that were previously expedited, and 60 days prior to the expiration date for research that was previously reviewed at a convened meeting. Do not make changes to the study (i.e., protocol, methodology, consent form, personnel, site, etc.) before obtaining IRB approval. A Modification Form cannot be used to extend the approval period of a study. All forms may be completed and submitted online at https://iris.research.ucf.edu.

If continuing review approval is not granted before the expiration date of 01/26/2017, approval of this research expires on that date. When you have completed your research, please submit a Study Closure request in IRIS so that IRB records will be accurate.

Use of the approved, stamped consent document(s) is required. The new form supersedes all previous versions, which are now invalid for further use. Only approved investigators (or other approved key study personnel) may solicit consent for research participation. Participants or their representatives must receive a copy of the consent form(s).

All data, including signed consent forms if applicable, must be retained and secured per protocol for a minimum of five years (see HIPAA applies) past the completion of this research. Any links to the identification of participants should be maintained and secured per protocol. Additional requirements may be imposed by your funding agency, your department, or other entities. Access to data is limited to authorized individuals listed as key study personnel.

In the conduct of this research, you are responsible to follow the requirements of the Investigator Manual.

On behalf of Sophia Dziegielewski, Ph.D., L.C.S.W., UCF IRB Chair, this letter is signed by:
Signature applied by [Signature] on [Date].

IRB Coordinator.