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# An evaluation of cardiorespiratory responses and ventilatory efficiency during treadmill and cycling exercise in overweight adolescents

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An evaluation of cardiorespiratory responses and ventilatory efficiency during treadmill and cycling exercise in overweight adolescents

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## Introduction

Graded exercise testing is commonly employed to evaluate acute cardiorespiratory and hemodynamic responses to dynamic exercise. Data obtained from the traditional graded exercise test provides a valid measure of functional aerobic capacity as well as a means of evaluating improvements in cardiorespiratory fitness following an aerobic training program. In addition to the traditional measures of cardiorespiratory fitness obtained from gas exchange analysis (e.g., maximal oxygen consumption and anaerobic threshold), many clinicians are also evaluating measures of ventilatory efficiency as a means of assessing cardiorespiratory function. While there are several methodologies for assessing ventilatory efficiency, each method assesses some variation of the ventilation ($V_E$) to carbon dioxide output ($VCO_2$) relationship. To date, the assessment of ventilatory efficiency as a clinical measure has typically been utilized to evaluate the prognosis of various chronic disease states, including congestive heart failure and obesity [27]. The assessment of ventilatory efficiency may be more desirable than traditional maximal oxygen consumption measures in various populations as ventilatory efficiency has been shown to be effort independent [27]. While ventilatory efficiency has gained support as a prognostic indicator of cardiorespiratory dysfunction, limited research is available that compares methodologies and exercise testing modes in healthy individuals and/or individuals with chronic disease.

Obesity has been shown to reduce ventilatory efficiency, possibly by altering ventilatory mechanics and/or ventilatory control. Furthermore, in some studies, weight loss has been shown to improve ventilatory efficiency. However, the mode of exercise testing may alter responses in obese individuals due to body positioning and/or variations in external work required for ambulation versus cycling. As there continues to be an increase in obesity in both adult and adolescent populations, further refining the methodologies for assessing cardiorespiratory function, including ventilatory efficiency, is warranted.

This literature review aims to provide a synthesis of the current, relevant scientific literature related to the assessment of the mode-dependency of ventilatory efficiency in obese adolescents. Therefore, this review first provides an overview of obesity, including accepted and functional definitions of obesity, obesity trends, etiological factors, assessment of body composition, and common co-morbid conditions. Of particular interest for this review is adolescent obesity, since the rate of obesity is growing the fastest in this population. Secondly, this review provides an overview of the typical cardiorespiratory parameters during graded exercise testing, including ventilatory efficiency, and the effects of obesity on these parameters. Lastly, this review will provide an overview of the available research comparing the differences in cardiorespiratory responses to treadmill and cycle ergometry, two modes commonly employed to evaluate cardiorespiratory responses to dynamic exercise.

**Obesity**

Defining Obesity

Among adults, overweight is defined as a body mass index (BMI) of 25.0 to 29.9 $kg/m^2$ and obesity is defined as a BMI of 30.0 $kg/m^2$ or higher [10, 18]. Among children and adolescents, obesity is defined as a BMI for age at or above the 95$^{th}$ percentile of a specified reference population and overweight is defined as a BMI for age at or above the 85$^{th}$ percentile [18]. BMI, while a widely used measure of overweight and obesity, has its limitations. BMI does not differentiate between an individual who is overweight and an individual with significant muscle mass and opposed to fat mass. As a result, some individuals with a large muscle mass could be considered overweight or obese utilizing this measure. BMI also does not differentiate between different body types (e.g., adroid or gynoid). This has significance since it is known that the distribution of body weight, or more generally the body shape is a key predictor of health risk. It is now well established that individuals who deposit much of their body weight around their abdominal region (i.e., adroid or “apple-shaped”), are at much greater risk of disease and early mortality in contrast to individuals who carry their weight more peripherally (i.e., gynoid or “pear-shaped”)[7]. Thus, two individuals with a BMI of 32 $kg/m^2$ could have drastically different body shapes, and thus varying risk of disease and early mortality [7]. Additionally, BMI does not always change even though an individual’s health may improve. This is particularly so if a physically active lifestyle, along with a balanced diet and appropriate caloric intake, are adopted. Increasing physical activity results in an associated improvement in cardiorespiratory fitness and profound reductions in coronary heart disease and related mortality, independent of changes in weight or BMI[9]. Also, exercise (even a single session) is associated with substantial reduction in several cardiovascular risk factors, including blood pressure, glucose tolerance, blood lipids, despite minimal or no change in body weight or BMI.

Prevalence and Trends.

*Global Prevalence and Trends*. The definitions of obesity are becoming increasingly well-known and even re-defined, as obesity has become a universal public health challenge. Several studies have attempted to quantify the globalization of obesity, including one study that evaluated data compiled by the International Obesity Task Force. Ford & Mokdad reported a substantial increase in the prevalence of obesity in areas of the Bahamas, Barbados, Brazil, Canada, Chile, Guyana, Mexico, Panama, Paraguay, Peru, St. Lucia, Trinidad and Tobago, the United States and Venezuela. While absolute prevalence of obesity varies greatly among countries (0.7%- 78.5%) [18], most countries are seeing a continual increase in obesity prevalence rates. Additionally, the prevalence of overweight among school age children has been reported as high as 35% in regions of Europe, and it has been estimated that the European Union can expect to see the number of overweight and obese children rising by approximately 1.3 million a year by 2011. A recent review of childhood obesity trends from 25 countries with data on school age children and 42 countries with data on preschool populations showed that obesity has increased in most countries, with the sharpest increases in economically developed countries and urban areas [18]. This may be surprising since the correlation between low SES and obesity has been indicated. The most likely explanation for such rapid increases in obesity is that environmental causes are likely responsible, such as an abundance of high-sugar and high-fat foods and recreation involving energy expenditure being replaced by sedentary activities like computer games and television viewing, all more accessible in developed and urban areas than in Third World Countries and rural areas [13].

*United States Prevalence and Trends*. Obesity among US adults, children, and adolescents have increased markedly since 1980 [29]. Increases in the prevalence of obesity occurred between 1976-1980 and 1988-1994 and again from 1988-1994 to 1999-2000. In 2007-2008, the prevalence of obesity was 32.2% among adult men and 35.5% among adult women. The rate of increases in the prevalence of obesity, however, do not appear to be continuing at the same rate during the past 10 years, particularly for women and possibly for men [10].

Hsu, et al. examined trends in overweight and obesity among 756,269 18-year-old civilian applicants to the US military from 1993-2006 and found that the prevalence of overweight increased from 22.8% in 1993 to 27.1% in 2006. Obesity increased from 2.8% to 6.8% [17]. Some comparative studies have shown the increase (percentage points) in obesity and overweight in adults being faster than in children (0.77 vs. 0.46–0.49), and the increase in women being faster than in men (0.91 vs. 0.65). If these trends continue, by 2030, 86.3% adults will be at least overweight and 51.1% will be obese [46].

Recent data has suggested that the prevalence of obesity among children and adolescents continues to increase at an unacceptable rate [18]. In one representative study, the prevalence of overweight was 15.5% among 12- through 19-year-old adolescents, 15.3% among 6- through 11-year-olds, and 10.4% among 2- through 5-year-old children, compared with 10.5%, 11.3%, and 7.2%, respectively, in 1988-1994 [39]. According to data obtained from the US National Health and Nutrition Examination Survey, the prevalence of obesity in 1976-80 was 6.5% among 6-11 year olds and 5% among 12-17 year olds. In 2003-2004 it was 19% and 17% respectively [18, 30]. It has been predicted that if current trends continue in children, the prevalence of overweight (BMI ≥95th percentile will nearly double by 2030 [46].

Additional stratification studies have shown increases in the prevalence of overweight and obesity among children of all ages and both sexes and for both African Americans and Caucasians [13], though the rates vary by age, gender, race/ethnicity, and SES. Ethnic minority status, non-metropolitan residence, lower SES and social capital, higher television viewing, and higher physical inactivity levels were all independently associated with higher obesity prevalence. Compared with affluent Caucasians children, the odds of obesity were 2.7, 1.9 and 3.2 times higher for the poor Hispanic, Caucasians, and African American children, respectively. Hispanic, Caucasians, and African American children watching television three hours or more per day had 1.8, 1.9, and 2.5 times higher odds of obesity than Caucasian children who watched television less than 1 hour/day, respectively. Poor children with a sedentary lifestyle had 3.7 times higher odds of obesity than their active, affluent counterparts (adjusted prevalence, 19.8% vs. 6.7%). Race/ethnicity, SES, and behavioral factors are independently related to childhood and adolescent obesity. Joint effects by gender, race/ethnicity, and SES indicate the potential for considerable reduction in the existing disparities in childhood obesity in the US [36].

*Cost of obesity*. The rising rates of overweight and obesity are not an isolated health issue. These overweight and obesity are highly associated with co-morbidities that threaten human health, and result in large health care expenditures. Total health-care costs attributable to obesity/overweight are projected to double every decade to 860.7–956.9 billion US dollars by 2030, accounting for 16–18% of total US health-care costs [46]. Co-morbidities related to obesity include diabetes mellitus, cardiovascular disease, nonalcoholic fatty liver disease, an increased risk of disability, and a modest increased risk of mortality[25]. Evidence suggests that even without reaching an ideal weight, a moderate amount of weight loss can be beneficial in terms of reducing levels of some risk factors, such as hypertension. Many studies of dietary and behavioral treatments, however, have shown that maintenance of weight loss is particularly expensive and difficult; however, overcoming the difficulty is imperative due to the high economic cost of obesity and health risks posed to individuals [30]. The high and increasing prevalence of obesity and its associated co-morbidities are likely to continue to pose a serious challenge to the public health and medical care systems around the world [11].

As previously mentioned, overweight and obese individuals are at higher risk than healthy weight individuals for a number of related medical conditions which can lead to further morbidity and mortality [14]. Obesity is known to increase the risk of cardiovascular disease, type-2 diabetes, and certain forms of cancer [14]. Furthermore, a number of studies indicate that obesity is also associated with a higher risk of developing deep vein thrombi, pulmonary emboli, pulmonary hypertension, and pneumonia [29]. Obese patient are at greater risk of aspiration pneumonia, pulmonary thrombosis, and respiratory failure and obesity is the most common precipitating factor for obstructive sleep apnea. Obstructive sleep apnea and obesity hypoventilation syndrome (OHS), are both associated with substantial morbidity and increased mortality [20]. In children, there is a high prevalence of elevated blood pressure and a strong association with BMI and total cholesterol level [21]. Additionally, adolescent obesity is linked to measurable, asymptomatic metabolic and cardiovascular precursors[45].

There are numerous medical and surgical therapies for many of the indicated co-morbidities, in particular obstructive sleep apnea and obesity hypoventilation. Weight reduction in the obese is widely recognized as the most effective of these measures [20]. Maintenance of a healthy weight is important in the prevention of the large disease burden in the future [14]. Making it more difficult to target those who would benefit most from weight-loss intervention is the fact that despite poor overall health, overweight and obese adolescents are less likely to report specific problems that might prompt health intervention. Morbidity has been found to be mainly associated with concurrent, rather than earlier, overweight and obesity [45].

Obesity is recognized as an important risk factor in the development of several respiratory diseases. Of these respiratory diseases, it has already been well established that obesity can lead to obstructive sleep apnea and obesity-hypoventilation syndrome (OHS). More recent data suggest that the prevalence of wheezing and bronchial hyper-responsiveness, two symptoms often associated with asthma, are increased in overweight and obese individual. Indeed, epidemiological studies have reported that obesity is a risk factor for the development of asthma [29].

Obesity places a significant load on the respiratory system, affecting lung volumes, respiratory muscle function, and ventilatory control. Despite this, most morbidly obese individuals maintain encaenia. However, a subgroup of morbidly obese individuals will develop chronic daytime hypercapnia, described as the OHS [32]. Obesity can profoundly alter pulmonary function and diminish exercise capacity by its adverse effects on respiratory mechanics, resistance within the respiratory system, respiratory muscle function, lung volumes, work and energy cost of breathing, control of breathing, and gas exchange [20]. Morbidly obese individuals (as defined by BMI $\geq$ 40 kg/m$^2$) may have pulmonary gas exchange impairment due to the large fat mass surrounding their abdomen, and may have poor compensatory hyperventilation during exercise [48]. Fatness and excess body weight do not necessarily imply a reduced ability to maximally consume oxygen, but excess fatness does have a detrimental effect on sub-maximal aerobic capacity [12]. Some pulmonary co-morbidities of obesity have been shown to affect various sub-populations differently, for example, morbidly obese men have been shown to have poorer pulmonary gas exchange compared to morbidly obese women [49].

Weight loss can reverse many of the alterations in pulmonary function related to obesity [20]. For example, while obesity alone does not account for the development of hypoventilation, weight loss will produce significant improvements in lung function and gas exchange. Such improvements have the potential to substantially reduce morbidity and mortality in these individuals [32]. An improvement in compensatory hyperventilation is most closely related to loss in overall fat mass [48].

**Etiology of obesity.**

Weight gain likely stems from a gene-environment interaction. According to the current epidemiological research, obesity is caused, by a combination of genetic predisposition, and access to an environment conducive to excessive weight gain. This environment is characterized as containing both increased availability of palatable energy-dense foods and reduced opportunities for energy expenditure [30].

Obesity arises only when energy intake exceeds energy expenditure. Our current environment is characterized by an essentially unlimited supply of convenient, relatively inexpensive, highly palatable, energy-dense foods, coupled with a lifestyle requiring only low levels of physical activity [23]. Such an environment promotes high energy intake and low energy expenditure. Under these circumstances, obesity occurs more frequently because, while the body has excellent physiological defenses against the depletion of body energy stores, it has weak defenses against the accumulation of excess energy stores when food is abundant [23].

The environment's contribution to obesity must be thought of in terms of how it increases the frequency of behaviors that increase the risk of positive energy balance. With positive energy balance, body mass increases in order to restore energy balance. Within any given environment, an individual's becoming obese is not a certainty, but an event that occurs with a certain probability. Some individuals can avoid obesity in unsupportive environments by maintaining a pattern of healthy behaviors.

In a society in which food availability is not limited, weight maintenance, whether at normal or an elevated body fat level, is accomplished primarily by the regulation of food intake [15]. One way in which the current environment promotes obesity is by providing more frequent opportunities for the consumption of large quantities of food. A variety of highly palatable, inexpensive foods is available nearly everywhere. Compounding this is a growing trend in the United States toward larger portions. This is especially evident in so-called fast food restaurants, where "super sizing" of menu items is commonplace. Our culture's apparent obsession with "getting the best value" may underlie the increased offering and selection of larger portions and the attendant risk of obesity [33]. The food environment that children are exposed to today is drastically different than it was during the mid $20^{th}$ century. There has been an increase in quantity and availability of food but a decrease in the quality. Increases in energy density, portion sizes and variety have been shown in controlled clinical studies to have an increase in total energy intake at meals [22]. Further, today's children have an increased energy (caloric) intake at every meal but a decreased amount of physical activity, leading to a cumulative energy imbalance and therefore increased prevalence of childhood obesity [22]. Physical activity used to be a critical part of life for children. However, today's conveniences of transportation and easy food access coupled with the inconveniences of crime, lack of time and increased distance to the closest safe playground have all made physical activity and playtime less inviting [22]. As a result, today's children report much less outside playtime such as tag, hide-and-go-seek, neighborhood baseball or kickball games and more time spent inside playing video games or on the computer. Physical inactivity of children has also shown to be a serious cause, and children who fail to engage in regular physical activity are at greater risk of obesity. This is evident by research that studied the physical activity of 133 children over a three week period using an accelerometer to measure each child's level of physical activity. It was discovered the obese children were 35% less active on school days and 65% less active on weekends compared to non-obese children[16]. Additionally, physical inactivity in childhood may result in physical inactivity as an adult[4]. In a fitness survey of 6,000 adults, researchers discovered that 25% of those who were considered active at ages 14 to 19 were also active adults, compared to 2% of those who were inactive at ages 14 to 19, who were now said to be active adults [21].

Within any given environment, there is a certain variation in body fatness among the population. A substantial portion of this variation appears to be attributable to genetic factors. Genetic makeup also plays a role in that it determines the strength of an individual's physiological defense against gaining and maintaining an obese body fat level [4]. Genetic factors are critically important for determining how different individuals respond within a given environment. This is best illustrated by the differences in body weight among individuals living in a common environment. Familial studies have repeatedly demonstrated that body mass index (BMI) is highly correlated among first-degree relatives [4, 43]. In these studies, obese parents produced the highest proportion of obese offspring. In this design, however, it is difficult to separate genetic from environmental influences. Stronger support for the role of genetics in BMI comes from twin studies, in which BMI has consistently been shown to be similar between twins, with the similarity being greater in monozygotic than dizygotic twins [37]. This observation is true whether the twin pairs were raised in similar environments or whether they were raised apart [1]. Adoption studies have also shown evidence of the contribution of genetics to BMI. These studies have demonstrated significant correlations between the BMI of the biologic parents and the BMI of the adoptee in childhood and adulthood [38, 40]. However, the BMI of the adoptive parents has not been found to be correlated with the adult BMI of the adoptee and only weakly correlated with the childhood BMI of the adoptee [38, 40]. These findings suggest a genetic influence on BMI as a child and an adult. Obese mothers are 10 times more likely to have obese daughters, according to new research, and obese fathers are six times more likely to have obese sons, according to a British study of 226 families [43]. The study, published in the International Journal of Obesity, found that 41 percent of eight-year-old daughters of obese mothers were obese, as compared to 4 percent of girls whose mothers were normal weight and in the group, 18 percent of the boys in the group were obese.

Genetic predisposition may not be a health destiny, but studies indicate that inherited genetic variation is an important risk factor for obesity[4]. Genetics is not a cause of obesity, but it can increase a person's chances for becoming overweight or obese. Evidence from twin, adoption and family studies strongly suggests that biological relatives exhibit similarities in maintenance of body weight. Genetic factors also are beginning to be implicated in the degree of effectiveness of diet and physical activity interventions for weight reduction. These genetic risk factors tend to run in the family, but are not inherited in a simple manner; they may reflect many genetic variations, and each variation may contribute a small amount of risk and may interact with environmental elements to produce the clinical condition of obesity.

*Socioeconomic influence***.** Although this pandemic touches individuals from all SES, racial, and ethnic backgrounds, obesity is more prevalent among children from families of lower SES. The causes of this separation in obesity rates by SES background are multifold and possibly include differences in the availability of healthier foods in homes and schools and the availability of safe environments for physical activity [22].

The correlation between obesity and SES is not simple, and most of the discussion is outside the scope of this paper. However, it is worthwhile to mention that one element of the complexity of the matter is the finding that the relationship between SES status and obesity may depend on the stage of economic transition. Early in the transition, the prevalence of obesity is positively related to income whereas at some point during the transition the prevalence becomes inversely related to income [11]. As in adult obesity, co-morbidities are a significant factor in obesity research and treatment. Increases have been found in the diagnosis of type-2 diabetes among certain ethnic groups, and in correlation with discrepancies in health care availability to children of lower SES backgrounds. The bottom line of youth obesity research specifically in relation to SES is that as society attempts to improve the lifestyle of children and decrease rates of obesity, it will be of utmost importance to focus particularly on children of lower SES backgrounds in planning potential interventions [22].

*Racial influences*. Similarly, obesity trends in sub-populations of youth of different races have shown notable trends. The prevalence of overweight adolescents among non-Hispanic African Americans and Mexican-American adolescents increased more than 10 percentage points between 1988-1994 and 1999-2000. The prevalence of overweight among children in the US, as of 2002, was quantifiably continuing to increase, especially among Mexican-American and non-Hispanic African American adolescents [31]. In one representative study, generic and weight-specific measures indicated significant differences by race. Physical, emotional, and social scores, the physical comfort and body esteem scores were significantly higher for extremely obese African American adolescents compared to extremely obese Caucasian adolescents. On the other hand, although racial differences in adolescent body image/esteem have been reported, it is unknown why African American adolescents with extreme obesity have been recorded as reporting less impact of weight on their physical functioning [27].

**Assessment of Body Composition and Obesity Risk**

Body composition refers to the proportion of lean tissue and fat tissue in the body. Lean tissue is composed of muscle, bone, skin, body water, and organs. Fat tissue is composed of three different categories: essential fat, storage fat and non-essential fat. Essential and storage fat are both necessary for the body to function, while non-essential fat serves no real purpose [47]. Body composition will typically be displayed as either a percentage of fat (body fat percentage or %fat) or as a percentage of lean body mass (LBM). There are several ways to measure body compositions. Bioelectrical impedance analysis (BIA) is a commonly used method for estimating body composition. BIA allows the determination of the fat-free mass (FFM) and total body water (TBW) in subjects without significant fluid and electrolyte abnormalities, when using appropriate population or age[47]. BIA measures body composition by sending a low, safe electrical current through the body. The current passes freely through the fluids contained in muscle tissue, but encounters difficulty/resistance when it passes through fat tissue[47]. This resistance of the fat tissue to the current is termed 'bioelectrical impedance', and is accurately measured by body fat scales. When set against a person's height, gender and weight, the scales can then compute their body fat percentage[47].

The skinfold measurement is another common method for determining body fat composition. Accurate measurement technique is highly important to obtaining an accurate reading in this test, which estimates body fat by measuring skinfold thickness at 3 to 9 different standard anatomical sites around the body[47]. The right side is usually the side of choice for measurement (for consistency). The tester pinches the skin at the appropriate site to raise a double layer of skin and the underlying adipose tissue, but not the muscle. Calipers are then applied 1 cm below and at right angles to the pinch, and a reading in millimeters (mm) is taken two seconds later. Measurements are taken twice and the mean of two measurements should be recorded. If the two measurements differ greatly, a third measurement should be done, then the median value taken[47].

Hydrostatic Weighing is a third way of measuring body composition. The dry weight of the subject is first determined. The subject, in minimal clothing, then sits on a specialized seat, expels all the air from their lungs, and is lowered into the tank until all body parts are emerged[47]. The person must remain motionless underwater while the underwater weight is recorded. This procedure is repeated several times to get a dependable underwater weight measure[47].

Lastly, the Dexa (Dual-Energy X-Ray Absorptiometry) can be used to evaluate body composition. In this evaluation, the subject lays on the whole body scanner, with the x-ray sources mounted beneath a table and a detector overhead[47]. The subject is scanned with photons that are generated by two low-dose x-rays at different energy levels. The body's absorption of the photons at the two levels is measured. The ratios can be then used to predict total body fat, fat-free mass, and total body bone mineral. The procedure can take about 10 - 20 minutes[47].

*BMI*. Body Mass Index (BMI) is an alternative measure to body composition assessment. BMI is calculated by taking a person's weight and dividing by their height squared[47]. Like any of these types of measures it is only an indication and other issues such as body type and shape have a bearing as well. As discussed previously, BMI is just a guide and it has limitations; it does not accurately apply to elderly populations, pregnant women or very muscular athletes such as weightlifters. However, the advantage of using BMI is that it is a simple calculation from standard measurements. The disadvantage of this method is the inaccuracy of the results, for example with large and muscular though lean athletes scoring high BMI levels which incorrectly rates them as obese. Regardless, BMI is the most widely used measure to diagnose obesity [34]. In fact, virtually all social science research related to obesity studies a person's BMI [5].

The discrepancy between BMI and percent body fat measures of obesity has been previously determined. In a study by Burkhausera et al., BMI-defined obesity was present in 19.1% of men and 24.7% of women, while percent body fat-defined obesity was present in 43.9% of men and 52.3% of women. A BMI of 30 had a high specificity (men=95%, 95% confidence interval (CI), 94–96 and women=99%, 95% CI, 98–100), but a poor sensitivity (men=36%, 95% CI, 35–37 and women=49%, 95% CI, 48–50) to detect percent body fat-defined obesity. The diagnostic performance of BMI diminished as age increased. In men, BMI had a better correlation with lean mass than with percent body fat, while in women BMI correlated better with percent body fat-than with lean mass. However, in the intermediate range of BMI, BMI failed to discriminate between percent body fat and lean mass in both sexes. The accuracy of BMI in diagnosing obesity was concluded to be limited, particularly for individuals in the intermediate BMI ranges, in men and in the elderly. These results may help to explain the unexpected better survival in overweight/mild obese patients [34]. Additionally, in a study by Burkhauser and Crawley, BMI was found to misclassify substantial fractions of individuals as obese or non-obese compared to body fat percentage, and that in general, BMI is less accurate classifying obesity in men compared to women [5].

The search for an alternative standard measure of obesity to BMI, such as percent body fat, stems from wide agreement in the medical literature that BMI is seriously flawed due to it not distinguishing fat from fat-free mass like muscle and bone. Many important patterns, including who is classified as obese, group rates of obesity, and correlations of obesity with social science outcomes, are all sensitive to the measure of fatness and obesity used.

**<u>Cardiorespiratory Responses to Graded Exercise</u>**

*$VO_{2max}$*. $VO_{2max}$ is the most commonly reported measure of cardiorespiratory fitness (CRF) and is defined as, "the maximum capacity of an individual's body to transport and utilize oxygen during incremental exercise, which reflects the physical fitness of the individual" [9]. While assessment of maximal oxygen consumption offers important insight into the ability of the cardiovascular, respiratory, and muscular system to deliver and utilize oxygen, several limitations have been reported. Many individuals, especially those that are overweight or deconditioned, will discontinue exercise far below their physiologic maximum ($VO_{2max}$) due to discomfort or localized muscular fatigue [9]. A true $VO_{2max}$ would represent a failure to increase oxygen consumption (plateau) following any subsequent increase in workload. In the absence of a plateau in oxygen consumption, several secondary criteria for attainment of a "true $VO_{2max}$" have been employed.

*Respiratory exchange ratio.* Respiratory exchange ratio (RER) is another variable assessed during a graded exercise tests. RER is determined as the ratio between oxygen consumption and carbon dioxide production. Measuring this ratio can be used as an indicator of whether carbohydrate (ratio of ~1.0 or greater ) or fat (ratio of ~0.7) or both (ratio of about 0.85) is being metabolized to supply energy during a given steady state work rate. A ratio of greater than 1.1 may be used as another secondary criteria in a $VO_{2max}$ test. Some studies have shown that a high respiratory exchange ratio at rest is a weak but significant predictor of substantial weight gain in non-obese men [35] while others have found no association between respiratory exchange ratio and fatness [19].

*Maximal heart rate.* The most well-known and most often utilized measure of exertion is heart rate. The easiest and best known method to estimate maximum heart rate is to subtract age in years from 220. A heart rate during maximal exercise that is at least 95% of age-predicted maximum heart rate is another metric evaluated in graded exercise tests.

*Borg rating of perceived exertion.* The Borg rating of perceived exertion (RPE) is a tool employed to obtain a subjective rating of physical activity intensity level. Perceived exertion is how hard a person feels like he is working. It is a subjective measure based on the physical sensations a person experiences during physical activity. It is meant to combine perceptions of increased heart rate, increased breathing rate, increased sweating, and muscle fatigue. Although it is a subjective measure, a person's exertion rating may provide a fairly good estimate of the actual heart rate during physical activity [2]. The original scale rated exertion on a scale of 6-20; rating of perceived exertion greater than 18 is used as an endpoint in graded exercise testing.

*Ventilatory efficiency*. Ventilatory efficiency is a measure of the responses in ventilation ($V_E$) to a given carbon dioxide output ($VCO_2$) during a graded exercise test. This can be determined mathematically by comparing the arterial $CO_2$ pressure and the physiological dead space or tidal volume ratio [6]. This gives the correlation that exists between $V_E$ and $CO_2$ output. The $V_E/VCO_2$ slope is determined by employing least squares linear regression analysis to evaluate the change in minute ventilation ($V_E$) for any given volume of carbon dioxide produced ($VCO_2$) [9]. The $V_E/VCO_2$ slope therefore represents the responsiveness of ventilation to changing $CO_2$ concentrations and therefore the lung's efficiency at removing $CO_2$ from the pulmonary circulation. The higher the $V_E/VCO_2$ slope at a given workload, the poorer the gas exchange efficiency.

The $V_E/VCO_2$ slope has been employed as an alternative marker to evaluate cardiorespiratory responses in individuals that might be less likely to achieve a maximal effort. Additionally, the $V_E/VCO_2$ slope has been evaluated as a prognostic indicator of both the level of cardiorespiratory dysfunction in congestive heart failure patients as well as a tool to evaluate improvements in cardiorespiratory parameters following an intervention [9].

A study by deJong et al. (2008) found that while a significant inverse relationship existed between BMI and peak $VO_2$ in morbidly obese patients referred for bariatric surgery, no such relationship existed between BMI and $V_E/VCO_2$. Based on their results, the authors suggested that as $V_E/VCO_2$ slope is not impacted by body mass, it may serve as a more useful comparative value to evaluate the cardiopulmonary response to exercise compared with peak $VO_2$ [9].

The majority of studies evaluating the $V_E/VCO_2$ slope relationship and blood gas kinetics during exercise in obese individuals have been performed using cycle ergometery. The cycle ergometer is a preferred method for these types of studies as a non-weight bearing activity standardizes the external work requirement and removes variations in walking efficiency due to abnormal gait mechanics that are often present in obese individuals. Additionally, utilizing the cycle ergometer allows greater ease when obtaining both venous and arterial blood samples for determination of blood gases. While the cycle is a convenient ergometer for this type of application, the ventilatory and cardiorespiratory responses may differ from treadmill exercise as a result of variations in body position, subject familiarity with the activity, and work efficiency. Recently, the Health and Human Performance Laboratory completed a study that evaluated changes in $V_E/VCO_2$ slope during treadmill walking in females before and three months after gastric bypass surgery (J. Herrick, unpublished dissertation). Although the subjects lost an average of 23.0 kg of body mass following surgery, no significant improvement in $V_E/VCO_2$ slope was observed. These findings are in contrast to a 2008 article by Zavorsky, et al. that demonstrated significant improvements in $V_E/VCO_2$ slope during a progressive cycle ergometer test in males and females losing an average of 21 kg of body mass 10 weeks post-surgery [48]. The variable findings between the two studies may be the result of the different populations used (males and females vs. only females) and/or the mode of exercise. Furthermore, a study by Davis, et al. in 2006 evaluated ventilatory efficiency in healthy men and women during treadmill and cycle exercise and observed a significant difference between the two modes of exercise in women but not in men.

**Summary**

Ventilatory efficiency is an increasingly popular tool for assessing cardiorespiratory health, primarily in congestive heart failure patients. However, more recently, measures of ventilatory efficiency are being assessed in individuals with other chronic diseases, including obesity. Obesity has been shown to place an added burden on the cardiac and respiratory systems and the ventilatory response to a given carbon dioxide output has been shown to be altered with elevated body mass. The assessment of ventilatory efficiency is appealing as it has been shown to be effort independent, especially in groups that may have a diminished functional capacity. The evaluation of the current methodology for assessing ventilatory efficiency in obese individuals is warranted as previous studies have reported variable responses depending on the relationship evaluated (overall $V_E/VCO_2$ slope, lowest $V_E/VCO_2$, etc.) and the type of ergometer utilized during the graded exercise testing. Further clarifying these parameters for assessing ventilatory efficiency will allow clinicians to choose the most appropriate graded exercise testing protocol for the population of interest.

An evaluation of cardiorespiratory responses and ventilatory efficiency during treadmill and cycling exercise in overweight adolescents


## Abstract

The assessment of ventilatory efficiency ($V_E/VCO_2$ slope) is increasingly being utilized to complement traditional cardiorespiratory fitness testing during graded exercise. The purpose of this study was to compare cardiorespiratory responses and ventilatory efficiency in obese children during a progressive exercise test to volitional fatigue performed on a treadmill and a cycle ergometer. Fifteen obese male (N=3) and female (N=12) adolescents aged 10 to 18 years were recruited in the study and completed both the treadmill and cycle ergometer trials. Mean age and BMI of the sample was 13.3 years and 38.0 kg/m$^2$, respectively. Maximal oxygen consumption ($VO_{2max}$) and ventilatory efficiency were determined during both exercise trials. Subsequently, overall $V_E/VCO_2$ slope and the slope below and above AT for ventilatory efficiency were compared between the two exercise modes. $VO_{2max}$ was significantly ($p<0.05$) greater during the treadmill trial (26.09±5.11 ml/kg/min) compared to the cycle ergometer trial (20.71± 4.31 ml/kg/min). The $VO_2$ at anaerobic threshold (AT) was significantly ($p<0.05$) higher during the treadmill trial, however, the percentage of $VO_{2max}$ at AT was not significantly different between the two modes (treadmill-63.41± 6.29% and cycle ergometer (67.25± 6.99%). While there was no significant difference in the overall $V_E/VCO_2$ slope or the $V_E/VCO_2$ slope above anaerobic threshold obtained from the two modes, the $V_E/VCO_2$ slope below anaerobic threshold was significantly ($p<0.05$) higher in the treadmill trial (25.06±2.10) compared to the cycle ergometer trial (23.34± 2.12). In our small sample of obese adolescents, we observed a greater $V_E$ response for a given $VCO_2$ during treadmill exercise below the anaerobic threshold.

The differences observed may be related to a greater activation of muscle afferents during weight bearing exercise in obese adolescents.

## Introduction

The prevalence of obesity among American children has increased from 5% in the 1980s to 15.3% in 2000 [16]. Recent data suggests that 32% of children and adolescents between the ages of 2 and 19 years are overweight or obese [12]. If the trend of childhood obesity continues at the current rate, the generation born in the year 2000 and later will have a 35% chance of developing diabetes and will be the first generation since the Civil War to have a lower life expectancy than their parents [12]. The significant increase in childhood obesity is troublesome for several reasons, one of which is the increased likelihood that an overweight child will become an obese adult [16, 7]. Gortmaker et al. suggested that 40% of obese children will continue to be obese into adulthood and those adults have the most severe levels of obesity were also obese as a child [8]. Additionally, overweight and obese individuals are at an increased risk of developing co-morbidities such as hyperlipidemia, hypertension, cardiovascular disease (CVD), glucose intolerance and type II diabetes [8, 7].

In addition to the known associated co-morbidities, obesity has been shown to have a negative impact on several ventilatory parameters including respiratory mechanics, pulmonary resistance of air flow, respiratory muscle function, lung volumes, energy cost of breathing, control of breathing, and gas exchange [11, 6]. The increase in mechanical ventilatory constraints and lower lung volumes due to large amounts of abdominal fat causes poor lung function and is thus one factor that could limit work capacity in morbidly obese individuals [27]. It has been suggested that indexes of obesity such as BMI, total body weight, body fat percentage and the waist to hip (W/H) ratio may be related to gas exchange impairments [11, 6]. Individuals with a large W/H ratio have a large portion of fat mass surrounding the thorax which could contribute to ventilation-perfusion abnormalities, an increase in the alveolar-arterial oxygen pressure difference, and a lowering of arterial $PO_2$ [11, 6].

Measures of maximal oxygen consumption offer insight into the ability of the cardiovascular, respiratory, and muscular system to deliver and utilize oxygen; however, several limitations exist when assessing maximal oxygen consumption. Many individuals, especially those that are overweight or deconditioned, will discontinue exercise far below their physiologic maximum ($VO_{2max}$) due to discomfort or localized muscular fatigue [5]. Additionally, the mode of exercise testing has been shown to influence cardiorespiratory values. The two primary modes of dynamic exercise that are used for cardiopulmonary exercise testing are the treadmill and the cycle ergometer. While treadmill testing is more popular in North America, cycle ergometry is more commonly used in Europe. Studies comparing the two modes of exercise have generally revealed a higher peak oxygen uptake ($\dot{V}O_2$) and a higher peak heart rate during treadmill exercise compared to the cycle exercise [25]. Many exercise testing personnel, however, prefer to utilize cycle ergometry since the quality of electrocardiogram recordings and hemodynamic measures are often improved due to less upper body motion [25]. Additionally, some aged and/or obese individuals prefer the cycle ergometer, as less coordination is required and the risk of falling is lower [25].

Recently, the $V_E/VCO_2$ slope has been employed as an alternative marker to evaluate cardiorespiratory responses in individuals that might be less likely to achieve a maximal effort [5]. Additionally, the $V_E/VCO_2$ slope has been utilized as a prognostic indicator of the level of cardiorespiratory dysfunction in congestive heart failure patients as well as a tool to evaluate improvements in cardiorespiratory parameters following an intervention [5]. The $V_E/VCO_2$ slope is determined by employing least squares linear regression analysis to evaluate the change in minute ventilation ($V_E$) for any given volume of carbon dioxide produced ($VCO_2$) [5]. The $V_E/VCO_2$ slope then represents the responsiveness of ventilation to changing $CO_2$ concentrations and therefore the lung's efficiency at removing $CO_2$ from the pulmonary circulation [5]. Therefore, the higher the $V_E/VCO_2$ slope at a given workload, the poorer the gas exchange efficiency. In addition to the overall $V_E/VCO_2$ slope, the slope of the $V_E$ versus $VCO_2$ relationship below and above AT, the $V_E/VCO_2$ at AT, and the lowest $V_E/VCO_2$ are common ventilatory efficiency indices that can be measured during cardiopulmonary exercise testing [4].

The majority of studies evaluating the $V_E/VCO_2$ slope relationship and blood gas kinetics during exercise have been performed using cycle ergometery [13]. The cycle ergometer is a preferred method for these types of studies as a non-weight bearing activity standardizes the external work requirement and removes variations in walking efficiency due to abnormal gait mechanics that are often present in obese individuals [13]. Additionally, utilizing the cycle ergometer allows greater ease when obtaining both venous and arterial blood samples for determination of blood gases. While the cycle is a convenient ergometer for this type of application, the ventilatory and cardiorespiratory responses may differ from treadmill exercise as a result of variations in body position, subject familiarity with the activity, and work efficiency [25]. Recently, the Health and Human Performance Laboratory completed a study that evaluated changes in $V_E/VCO_2$ slope during treadmill walking in females before and three months after gastric bypass surgery (J. Herrick, unpublished dissertation). While the subjects lost an average of 23.0 kg of body mass following surgery, no significant improvement in $V_E/VCO_2$ slope was observed. These findings are in contrast to a 2008 article by Zavorsky, et al. that demonstrated significant improvements in $V_E/VCO_2$ slope during a progressive cycle ergometer test in males and females losing an average of 21 kg of body mass 10 weeks post-surgery [27]. The variable findings between the two studies may be the result of the different populations used (males and females vs. only females) and/or the mode utilized for exercise testing. There is some previous support for a mode-dependency of the $V_E/VCO_2$ slope as Davis, et al. (2006) observed differences in ventilatory efficiency in healthy women, but not men. To date, no studies have evaluated the mode-dependency of the $V_E/VCO_2$ slope in obese adolescents.

Therefore, the purpose of this study was to compare cardiorespiratory responses and ventilatory efficiency ($V_E/VCO_2$ slope) in obese children during a progressive exercise test to volitional fatigue performed on a treadmill and a cycle ergometer. Secondarily, relationships among cardiorespiratory responses and ventilatory efficiency obtained from the two modes, body weight status, body fat percentage, and physical activity participation were evaluated. We hypothesized that there would be no differences in the ventilatory efficiency measured during the two trials. Additionally, we hypothesized that body weight, BMI, and body fat percentage would not be related to measures of ventilatory efficiency, as ventilatory efficiency has previously been shown to be BMI independent [5]. This study may provide clinicians with a better understanding of the ventilatory efficiency responses to these two commonly employed testing modes.

**Methods**

*Subjects*. Male and female adolescents aged 10 to 18 years with a BMI greater than the 85th percentile for age and gender, as determined by the 2000 CDC guidelines, voluntarily participated in the study [2]. Exclusion criteria included any underlying cardiovascular, metabolic, or pulmonary disease that could negatively impact cardiorespiratory responses to graded exercise testing. Additionally, subjects were excluded if they were taking any prescription medications that could alter the cardiorespiratory response to exercise. All procedures were approved by the

Virginia Commonwealth University Institutional Review Board and parental consent and subject assent were obtained before exercise testing.

*Procedures*. Subjects completed two separate trials to evaluate cardiorespiratory responses to graded exercise within approximately one week but separated by at least one day. The first graded exercise trial was completed on a treadmill (TrackmasterTMX425C, Full Vision, Inc., Newton, KS) followed by a second trial performed on a cycle ergometer (VIAsprint 150P, Viasys Healthcare, Yorba Linda, CA). The exercise stages for each mode were equal in duration with the first stage lasting four minutes and subsequent stages lasting two minutes. In an attempt to equate the workloads at each stage on the two modes, subjects first completed the treadmill trial, which allowed the use of the American College of Sports Medicine metabolic equation for cycle ergometry to estimate an equivalent cycle ergometer workload to approximate the oxygen consumption obtained during the last 20 seconds of each stage of the treadmill trial. Subjects were asked to refrain from eating for 3 hours prior to each exercise trial.

*Anthropometric Measures*. Body weight to the nearest 0.25 kg and height to the nearest 0.5 cm were determined prior to each trial on a digital scale (5102-405 Physicians Scale, Scale-tronix, White Plains, NY) and stadiometer, respectively. Body fat percentage was determined utilizing Dual Energy X-Ray Absorptiometry (Hologic 4500a/Discovery Scanner, Bedford, MA).

*7-day Physical Activity Recall*. An interviewer facilitated 7-day physical activity recall was completed by all subjects. Participants were asked to recall time spent in physical activities of moderate, hard, and very hard intensities during the 7 days immediately prior to the interview. Moderate, hard, and very hard intensity descriptions were consistent across interviewers. Hard and very hard intensity physical activity were combined and reported as vigorous activity. An accumulated minimum of 10 minutes of continuous activity in a specific intensity range were required for the activity to be counted toward total physical activity. Time spent in each category was rounded to the nearest 0.25 hours according to standard scoring procedures.[33]

*Treadmill Trial*. Subjects performed a progressive maximal treadmill walking test until volitional fatigue. The treadmill protocol consisted of a 4 minute warm up at 2.5 MPH and 0% grade followed by a 2 minute stage at 3.0 MPH and 0% grade. Subsequent 2 minute stages were held at 3.0 MPH and grade was increased by 2.5% every 2 minutes until the subject was no longer able to maintain the treadmill pace. Heart rate was obtained and recorded at the end of every minute utilizing a heart rate monitor (Model E600, Polar electro, Kempele, Finland). Blood pressure and ratings of perceived exertion (6-20 Borg Scale) were obtained and recorded at the end of every stage. Continuous breath by breath measurement (Vmax Encore 29 System, VIASYS Healthcare Inc, Yorba Linda, CA) of $VO_2$ ($L/min^{-1}$ & $ml/kg/min^{-1}$), $VCO_2$ ($L/min^{-1}$), and RER ($VCO_2/VO_2$) were also obtained and recorded during the exercise test.

*Cycle Ergometer Trial*. Subjects also performed a graded exercise test on a cycle ergometer until volitional fatigue. The American College of Sports Medicine metabolic equation for cycle ergometry ($VO_2 = 7 + 1.8$ * work-rate / weight (kg)) was utilized to estimate a workload for the cycle ergometer that would closely match the oxygen consumption obtained during the last 20 seconds of each treadmill stage. Stage times were equal to that of the treadmill test. The test was concluded when the subject could no longer maintain a required 60 revolutions per minute. Similar to the treadmill trials, heart rate was obtained and recorded at the end of every minute, and blood pressure and ratings of perceived exertion (6-20 Borg Scale) were obtained and recorded at the end of every stage. Continuous breath by breath measurement of $VO_2$ ($L/min^{-1}$ & $ml/kg/min^{-1}$), $VCO_2$ ($L/min^{-1}$), and RER ($VCO_2/VO_2$) were obtained and recorded during the exercise test.

*Derived variables.* $VO_2$max was determined as the highest 10 second averaged oxygen consumption value. Anaerobic threshold (AT) was determined using a simplified V-slope method to visually determine the first point of departure from linearity of carbon dioxide output ($VCO_2$) plotted against oxygen uptake ($VO_2$) (Figure 1) [25]. The point at which $VCO_2$ departed from a line with a slope equal to 1.00 was visually selected as the gas exchange threshold during incremental exercise [25]. The $V_E/VCO_2$ slope during each trial was determined by least squares linear regression analysis (y = a + bx). Linear regression of the $V_E$ versus $VCO_2$ relation for determination of the slope and y-intercept for each subject on each mode was performed using Microsoft Office Excel (2007). The lowest $V_E/VCO_2$ was determined as the average of the lowest three consecutive $V_E/VCO_2$ values as detailed by Sun et al [23]. The slope below anaerobic threshold was determined as the $V_E/VCO_2$ slope up to the point at which anaerobic threshold occurred. The slope above anaerobic threshold was determined as the $V_E/VCO_2$ slope from the point of AT to the maximal $VO_2$. To determine the slope at the anaerobic threshold, $V_E$ at AT was divided by the $VCO_2$ at AT.

*Statistical Analysis*. All data are presented as means (± standard deviation). Paired samples t-tests were used to compare maximal cardiorespiratory responses (maximal heart rate, maximal RER, relative and absolute $VO_{2max}$, $O_2$ pulse, $VO_2$ at AT, percent of $VO_2$ max at AT, and RPE) and ventilatory efficiency ($V_E/VCO_2$ slope, $V_E/VCO_2$ slope below, at, and above AT, $V_E/VCO_2$ at AT, and the lowest $V_E/VCO_2$). Pearson-product moment correlations were utilized to evaluate relationships among body mass, BMI, body fat percentage, physical activity participation, overall $V_E/VCO_2$ slope, $V_E/VCO_2$ slope below and above AT, $V_E/VCO_2$ at AT, and the lowest $V_E/VCO_2$. Predictive Analytics Software (PASW version 18.0) was utilized to perform all analyses. An alpha level of $p < 0.05$ was utilized for all analyses.

## Results

*Subjects*. Fifteen subjects completed both the treadmill and the cycle ergometer trials. The sample consisted of 12 females (80%) and 3 males (20%). Mean age and BMI of the sample was 13.3 years and 38.0 kg/m$^2$, respectively. Subject demographics, anthropometrics, and reported physical activity are provided in Table 1.

*Cardiorespiratory Variables*. Paired samples t-tests were utilized to evaluate maximal cardiorespiratory responses during the treadmill and cycle ergometer trials (Table 2). The absolute $VO_2$max, relative $VO_2$max, and the $VO_2$ at AT obtained during the treadmill trial were significantly greater compared to the cycle ergometer trial. There were no significant differences in % $VO_2$max at AT, maximal heart rate, maximal RPE, maximal RER, or maximal $O_2$ pulse obtained utilizing the two modes.

*$V_E/VCO_2$ slope.* Paired samples t-tests were utilized to evaluate $V_E/VCO_2$ variables obtained during the treadmill and cycle ergometer trials (Table 3). There was a significant difference in the $V_E/VCO_2$ slope below AT between the cycle ergometer and the treadmill trials. There were no significant differences, however, in the treadmill and cycle ergometer $V_E/VCO_2$ slope above AT, overall $V_E/VCO_2$ slope, $V_E/VCO_2$ at AT, or the lowest $V_E/VCO_2$. Scatter diagrams are provided for the overall $V_E/VCO_2$ slope (Figure 2), the $V_E/VCO_2$ slope below AT (Figure 3), and the $V_E/VCO_2$ slope above AT (Figure 4).

*Pearson Product Moment Correlations.* Correlation coefficients were computed to evaluate relationships among anthropometric measures, reported physical activity participation, and ventilatory efficiency measures obtained during the treadmill and cycle ergometer trials. Table 4 provides the correlation analyses for the cycle ergometer. Of note, body mass was negatively correlated ($p<0.05$) with the overall $V_E/VCO_2$ slope during cycle ergometry. Additionally, overall $V_E/VCO_2$ slope was correlated with $V_E/VCO_2$ slope above AT.  There were no additional significant relationships among variables during the cycling trial.  In contrast to the cycle ergometer trial, there was no significant correlation observed between overall $V_E/VCO_2$ slope and body mass during the treadmill trial (Table 5).  Overall treadmill $V_E/VCO_2$ slope was, however, related to the $V_E/VCO_2$ slope below and above AT.

**Discussion**

To our knowledge, this is the first prospective study to examine a possible mode dependency of the ventilatory efficiency ($V_E/VCO_2$) slope in obese adolescents.  Based on our data, the major finding in this study was that there was a mode dependency of the $V_E/VCO_2$ slope, but only below AT.  There was no significant difference in overall $V_E/VCO_2$ slope, $V_E/VCO_2$ slope above AT, $V_E/VCO_2$ relationship at AT, or the lowest $V_E/VCO_2$ between the two modes of exercise.  While the majority of the available literature evaluating ventilatory efficiency has focused on congestive heart failure (CHF) patients, a limited number of studies have evaluated ventilatory efficiency in obese subjects [14, 27].   The assessment of $V_E/VCO_2$ slope in obese individuals may be beneficial, as it provides an effort-independent adjunctive measure of cardiorespiratory fitness that has also been shown to be independent of BMI [5].  As is commonly reported, obese subjects typically are unable to achieve a "true" $VO_{2max}$ during graded exercise as localized muscle fatigue and/or dyspnea results in cessation of exercise [5].  If the assessment of ventilatory efficiency is to become a complementary measure to traditional cardiorespiratory fitness testing, a comparison of ventilatory efficiency responses obtained on commonly employed ergometers is warranted.

Very few studies have evaluated the mode dependency of ventilatory efficiency [26, 4 ,23]. In a study by Davis et al., a mode dependency for ventilatory efficiency as assessed by the

$V_E/VCO_2$ slope and the lowest $V_E/VCO_2$ was observed in healthy women, but not in healthy men. In their study, the women had slightly higher values on both ventilatory efficiency measures. While the authors did not offer a possible explanation for the mode dependency, they did speculate that the gender differences observed during the study may have been the result of mild arterial hypoxemia coupled with mild arterial hypercapnia, resulting in an increased ventilatory drive in the women [4]. In contrast, Sun et al. found no mode dependency in healthy men and women across three measures of ventilatory efficiency, including the $V_E/VCO_2$ slope, $V_E/VCO_2$ at AT, and the lowest $V_E/VCO_2$ [23]. In CHF patients, a lower ventilatory response has been observed during cycle ergometry as compared to treadmill exercise [26]. Additionally, as observed in our study, the authors reported that CHF patients had a lower "sub" $V_E/VCO_2$ slope during cycle ergometry. While the term "sub" was not explained, the variable was taken to be the $V_E/VCO_2$ slope below AT. Other measures of ventilatory efficiency were not assessed in this CHF group.

The mode dependency of the $V_E/VCO_2$ slope and the sub $V_E/VCO_2$ slope in CHF patients was hypothesized to be the result of increased ergoreflex activation during treadmill walking, which would result in a greater $V_E$ for a given $VCO_2$ [26]. The ergoreflex is an autonomic and ventilatory response activated by myelinated and unmyelinated group III and IV muscle afferents. These afferents, also known to be metaboreceptors and/or mechanoreceptors, are stimulated by perfusion and chemical changes in the periphery, including increased $H^+$, $K^+$, lactic acid, and inorganic phosphate, as well as physical movement [21, 9, 22, 18]. In our obese adolescent subjects, weight bearing exercise below AT may have resulted in an increased ergoreflex activation resulting in an increase ventilatory response during the early time and intensity-matched exercise stages. However, as the exercise intensity increased above AT, there was a trend (p=0.58) toward an increase $V_E/VCO_2$ slope response during cycle ergometry. Since cycle ergometry isolates the leg musculature and cycling is not typically a primary mode of physical activity for our subject population, higher intensity cycling exercise may have contributed to a greater metaboreceptor and mechanoreceptor activation as additional motor units are recruited, therefore a greater ventilatory response. The lower $V_E/VCO_2$ slope below AT was countered by a higher $V_E/VCO_2$ slope above AT resulting in no difference in the overall $V_E/VCO_2$ slope.

In the current study we evaluated the mode dependency of several measures of ventilatory efficiency, including $V_E/VCO_2$ slope, $V_E/VCO_2$ at AT, and the lowest $V_E/VCO_2$ value. These various measures of ventilatory efficiency were not found to be equivalent in patients with heart failure [1]. Additionally, $V_E/VCO_2$ slope to peak exercise was found to be the best predictor of mortality. Lastly, similar to previous reports [5, 27, 14] the ventilatory efficiency responses to the two modes of exercise in our population were independent of subject BMI; however, the overall $V_E/VCO_2$ slope during cycle ergometry was moderately correlated to body mass.

As in previous studies, treadmill exercise resulted in higher absolute $VO_{2max}$, relative $VO_{2max}$, and $VO_2$ at AT [4, 18 ,26]. The differences between $VO_{2max}$ determined from treadmill and cycle ergometry in previous studies have ranged from 1-18% [23]. This wide range in values is likely the result of the different populations utilized, along with the utilization of varying protocols and equipment. Loftin et al. (2004) evaluated responses to treadmill and cycle ergometry in “severely obese youth” and found no differences in peak exercise oxygen consumption. This is in direct contrast to our study, which utilized a subject population with mean BMI values approximately 6 $kg/m^2$ higher and found an approximately 20% higher relative $VO_{2max}$ on the treadmill as compared to the cycle ergometer. Additionally, while the absolute and relative $VO_{2max}$ values for our subject population during treadmill exercise was approximately 5 ml/kg/min higher than those reported by Loftin, et al., the mean cycling $VO_{2max}$ was almost identical (20.7 ml/kg/min vs 20.3 ml/kg/min).

Limitations. The results of this study must be viewed within the context of several limitations. First, the order of the two ergometer trials were not randomly chosen, which may have resulted in the observed differences. However, by scheduling the treadmill trial first, we were able to determine an equivalent cycle ergometer workload for each stage utilizing the ACSM metabolic equation for cycle ergometry. Secondly, while we encouraged our subjects to provide a maximal effort, many of our subjects discontinued exercise prior to a obtaining a "true" $VO_{2max}$. While the ventilatory efficiency slope has been found to be effort-independent, variations in the percentage of "true" maximum obtained may have resulted in the observed responses in the overall ventilatory slope and the slope above AT. Lastly, our subject population included both males and females. As previously mentioned, the $V_E/VCO_2$ relationship may be mode dependent in females but not males [4]. Therefore, our small subject number (N=15) and the small number of male participants (N=3) precluded us from separating our sample by gender.

In conclusion, we observed a mode dependency in the $V_E/VCO_2$ slope below AT but not in any other measure of ventilatory efficiency. The assessment of ventilatory efficiency may provide a beneficial complementary measure to traditional cardiorespiratory testing in obese individuals as the measure is thought to be effort and BMI-independent. Continued evaluation of the most appropriate methodology for determining ventilatory efficiency in obese individuals is warranted.

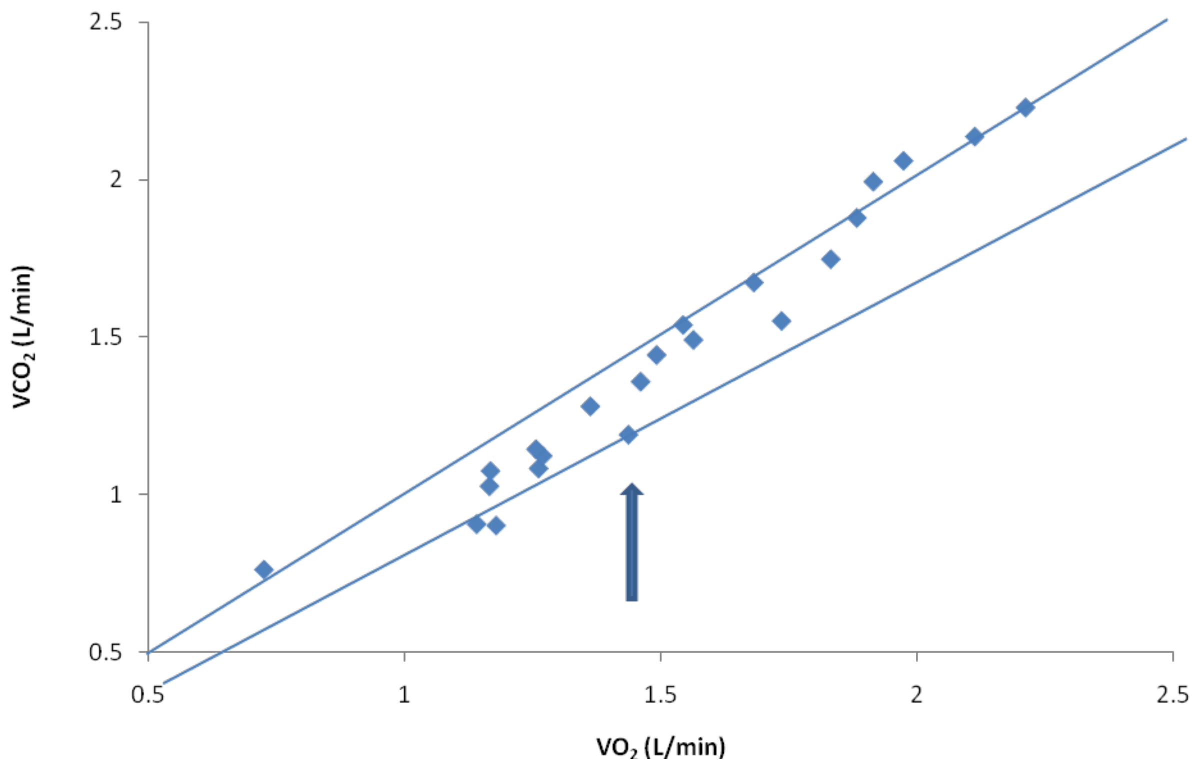


**Figure 1. The V-slope method of carbon dioxide output ($VCO_2$) plotted against oxygen uptake ($VO_2$) for subject 6 in the treadmill test.**

**Table 1: Subject demographics, anthropometric measures, and physical activity participation of 12 Females and 3 Males**

| | Mean (±SD) |
|---|---|
| Age (Years) | 13.3 (± 1.8) |
| Body Weight (kg) | 99.5 (± 19.0) |
| BMI (kg/m$^2$) | 38.0 (± 4.4) |
| Body Fat (%) | 40.8 (± 5.5) |
| Moderate PA (hrs/wk) | 1.5 (±1.6) |
| Vigorous PA (hrs/wk) | 0.2 (± 0.7) |

BMI – Body Mass Index; PA- Physical Activity

**Table 2: Paired samples analysis of selected cardiorespiratory variables obtained during the treadmill and cycle ergometer trials.**

| | Treadmill | Cycle Ergometer | p-value |
|---|---|---|---|
| Absolute $VO_2$ Max (L/min) | 2.59 (± 0.60) | 2.04 (± 0.43) | <0.001 |
| Relative $VO_2$ Max (mL/kg/min) | 26.09 (±5.11) | 20.71 (± 4.31) | <0.001 |
| Max Heart Rate (bpm) | 188.27 (±13.81) | 179.93 (± 11.68) | 0.10 |
| $VO_2$ at AT (mL/kg/min) | 16.45 (± 3.10) | 13.83 (± 2.70) | <0.001 |
| % $VO_2$ Max at AT | 63.41 (± 6.29) | 67.25 (± 6.99) | 0.07 |
| Maximal RER (L/min) | 0.99 (± 0.10) | 1.02 (± 0.08) | 0.38 |
| Maximal RPE | 16.00 (± 2.78) | 15.67 (± 2.50) | 0.59 |

AT – Anaerobic Threshold; Max – Maximal; RER – Respiratory Exchange Ratio; RPE – Rate of Perceived Exertion

**Table 3: Paired samples analysis of selected $V_E/VCO_2$ slope variables obtained during the treadmill and cycle ergometer trials.**

| | Treadmill | Cycle Ergometer | P-Values |
|---|---|---|---|
| $V_E/VCO_2$ Slope | 26.00 (±2.43) | 25.63 (± 2.38) | 0.470 |
| $V_E/VCO_2$ Slope Below AT | 25.06 (±2.10) | 23.34 (± 2.12) | 0.034 |
| $V_E/VCO_2$ Slope Above AT | 26.66 (± 3.30) | 28.45 (± 4.02) | 0.058 |
| $V_E/VCO_2$ at AT | 27.50 (± 2.07) | 27.15 (± 2.31) | 0.548 |
| Lowest $V_E/VCO_2$ | 26.57 (± 1.80) | 26.55 (± 2.03) | 0.979 |

AT – Anaerobic Threshold

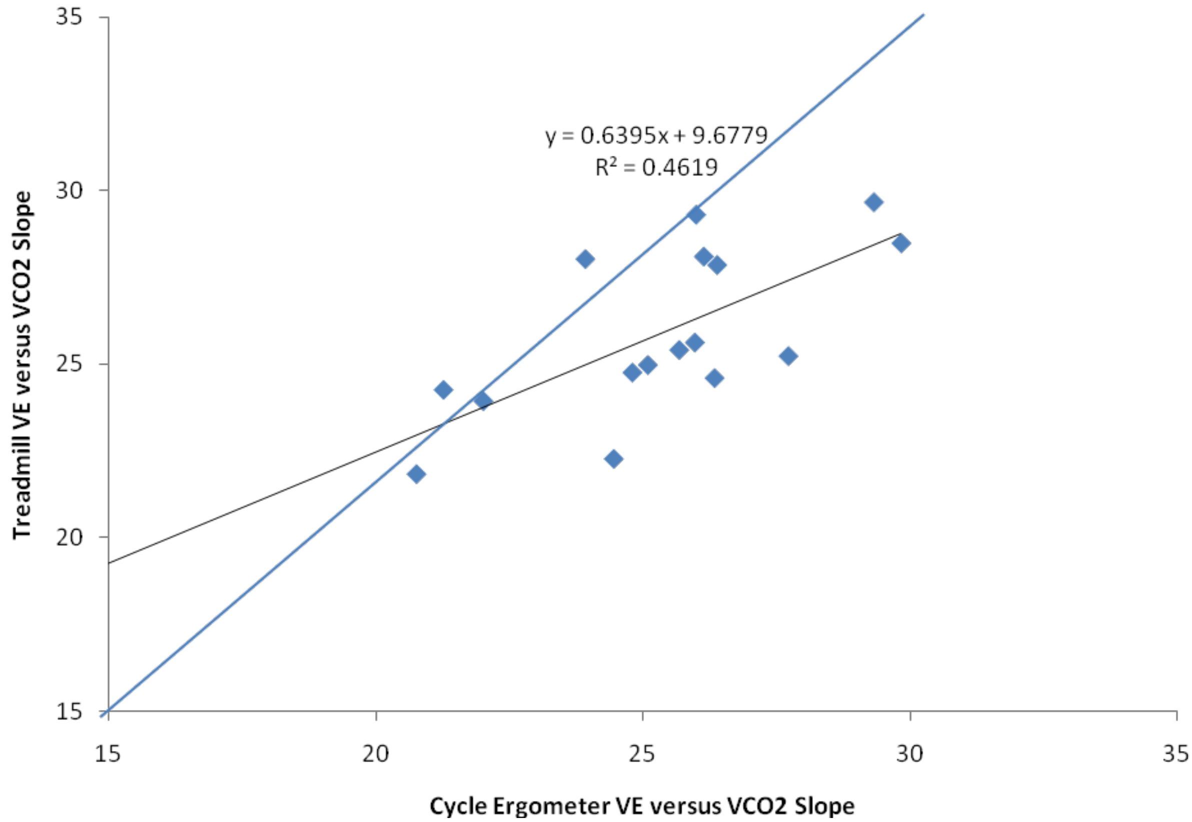


**Figure 2. Scatter diagram of the overall $V_E/VCO_2$ slope for the treadmill and cycle ergometer**

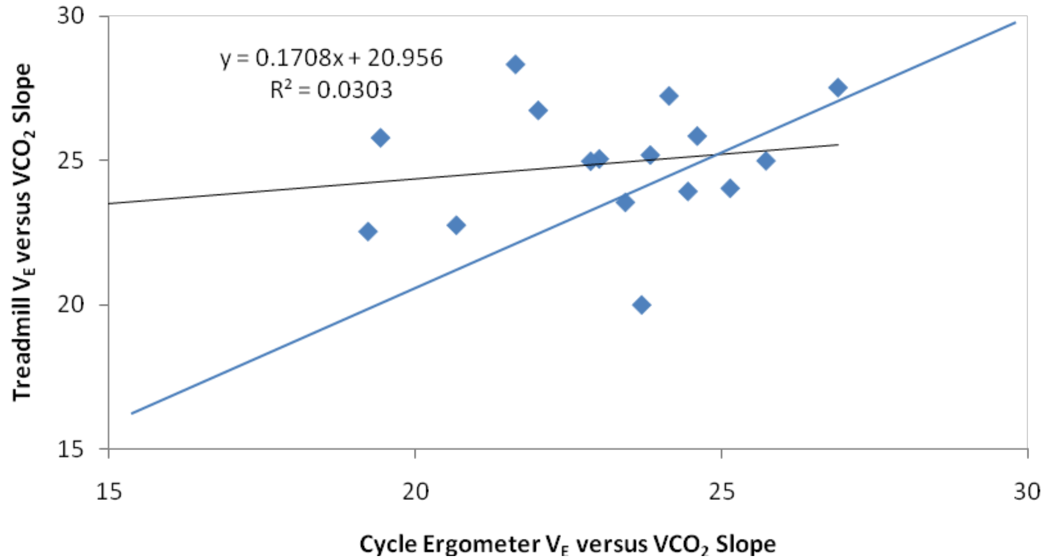


**Figure 3. Scatter diagram of the $V_E/VCO_2$ slope below AT for the treadmill and cycle ergometer.**

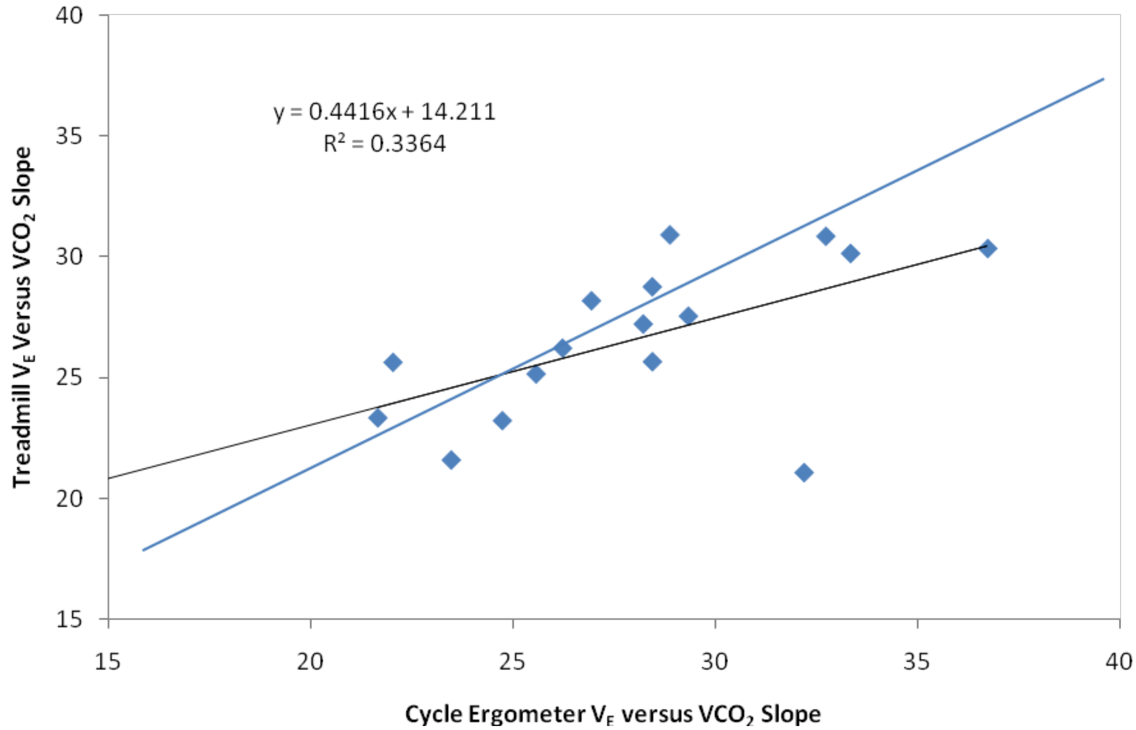


**Figure 4. Scatter diagram of the overall $V_E/VCO_2$ slope for the treadmill and cycle ergometer.**

**Table 4: Pearson product-moment correlations for the anthropometric variables, reported physical activity, and cycle ergometer ventilatory efficiency**

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|---|
| 1. BMI | __ | | | | | | | |
| 2. Body mass | *0.834 | __ | | | | | | |
| 3. body fat | 0.493 | 0.237 | __ | | | | | |
| 4. Moderate Activity | -0.361 | -0.197 | -0.498 | __ | | | | |
| 5. Vigorous Activity | -0.072 | -0.157 | 0.135 | 0.504 | __ | | | |
| 6. $V_E/VCO_2$ Below AT | -0.510 | -0.498 | -0.272 | -0.134 | -0.223 | __ | | |
| 7. $V_E/VCO_2$ Above AT | -0.276 | -0.464 | -0.116 | 0.246 | 0.029 | 0.332 | __ | |
| 8. $V_E/VCO_2$ Slope | -0.359 | *-0.524 | -0.317 | -0.374 | 0.043 | 0.456 | *0.882 | __ |
| 9. $V_E/VCO_2$ at AT | -0.154 | -0.328 | 0.177 | -0.238 | -0.150 | 0.486 | 0.047 | 0.307 |

* Correlation is significant at the 0.05 level
AT – Anaerobic Threshold; BMI – Body Mass Index; Max – Maximum

**Table 5: Pearson product-moment correlations for the anthropometric variables, reported physical activity, and treadmill ventilatory efficiency**

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|---|
| 1. BMI | __ | | | | | | | |
| 2. Weight | *0.834 | __ | | | | | | |
| 3. body fat | 0.493 | 0.237 | __ | | | | | |
| 4. Moderate Activity | -0.361 | -0.197 | -0.498 | __ | | | | |
| 5. Vigorous Activity | -0.072 | -0.157 | 0.135 | 0.504 | __ | | | |
| 6. $V_E/VCO_2$ Below AT | 0.070 | 0.025 | 0.119 | 0.392 | 0.431 | __ | | |
| 7. $V_E/VCO_2$ Above AT | -0.233 | -0.358 | -0.271 | 0.236 | 0.355 | 0.366 | __ | |
| 8. $V_E/VCO_2$ Slope | -0.222 | -0.347 | -0.133 | 0.288 | 0.373 | *0.661 | *0.870 | __ |
| 9. $V_E/VCO_2$ at AT | -0.264 | -0.331 | 0.047 | 0.083 | 0.314 | *0.576 | 0.442 | *0.032 |

* Correlation is significant at the 0.05 level
AT – Anaerobic Threshold; BMI – Body Mass Index; Max – Maximum

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# VCU Memo

Virginia Commonwealth University

**Office of Research Subjects Protection**
BioTechnology Research Park
BioTech One, 800 E. Leigh Street, #114
P.O. Box 980568
Richmond, Virginia 23298-0568
(804) 828-3992
(804) 827-1448 (fax)

DATE: January 27, 2010

TO: Ronald K. Evans, PhD
Health and Human Performance
Box 842020

FROM: Lisa M. Abrams, PhD
Chairperson, VCU IRB Panel B
Box 980568

RE: **VCU IRB #: HM12642**
**Title: An Evaluation of Cardiorespiratory Responses and Ventilatory Efficiency during Treadmill and Cycling Exercise in Overweight Adolescents**

The following study involving the research use of human subjects was ***approved*** by the VCU IRB on January 7, 2010, according to 45 CFR 46.108(b). This research involves children and is approved under 45 CFR 46. 404. The changes requested by the Panel received in the Office of Research Subjects Protection on January 21, 2010, satisfactorily meet the stipulations set forth in the January 7, 2010, IRB Panel meeting. The approval also reflects the revisions received in the IRB office on January 7, 2010. This approval includes the following items reviewed by this Panel:

**RESEARCH APPLICATION/PROPOSAL:** None

**PROTOCOL (Research Plan):** An Evaluation of Cardiorespiratory Responses and Ventilatory Efficiency during Treadmill and Cycling Exercise in Overweight Adolescents, received 1/7/10, version date 1/7/10

- Health and Human Performance Laboratory Emergency Procedures, received 11/24/09, version 1, dated 11/24/09
- 7-Day Physical Activity Recall (PAR), received 1/21/10

**CONSENT/ASSENT (attached):**

- Research Subject Information and Consent Form, received 1/21/10, version date 1/21/10, 4 pages
- Youth Assent Form: Use for Subjects 10 through 17 Years, received 1/7/10, version date 1/7/10, 3 pages

**ADDITIONAL DOCUMENTS:** None

**This approval expires on January 6, 2011.** Federal Regulations/VCU Policy and Procedures require continuing review prior to continuation of approval past that date. Continuing Review report forms will be mailed to you prior to the scheduled review.

If you have any questions, please contact Dr. Lisa Abrams, Chairperson, VCU IRB Panel B, at lmabrams@vcu.edu and 827-2627; or you may contact Jennifer Rice, IRB Coordinator, VCU Office of Research Subjects Protection, at jlrice@vcu.edu and 828-3992.

***Conditions of Approval:***

In order to comply with federal regulations, industry standards, and the terms of this approval, the investigator must *(as applicable)*:

1. Conduct the research as described in and required by the Protocol.

2. Obtain informed consent from all subjects without coercion or undue influence, and provide the potential subject sufficient opportunity to consider whether or not to participate (unless Waiver of Consent is specifically approved or research is exempt).

3. Document informed consent using only the most recently dated consent form bearing the VCU IRB "APPROVED" stamp (unless Waiver of Consent is specifically approved).

4. Provide non-English speaking patients with a translation of the approved Consent Form in the research participant's first language. The Panel must approve the translated version.

5. Obtain prior approval from VCU IRB before implementing any changes whatsoever in the approved protocol or consent form, unless such changes are necessary to protect the safety of human research participants (e.g., permanent/temporary change of PI, addition of performance/collaborative sites, request to include newly incarcerated participants or participants that are wards of the state, addition/deletion of participant groups, etc.). Any departure from these approved documents must be reported to the VCU IRB immediately as an Unanticipated Problem (see #7).

6. Monitor all problems (anticipated and unanticipated) associated with risk to research participants or others.

7. Report Unanticipated Problems (UPs), including protocol deviations, following the VCU IRB requirements and timelines detailed in VCU IRB WPP VIII-7):

8. Obtain prior approval from the VCU IRB before use of any advertisement or other material for recruitment of research participants.

9. Promptly report and/or respond to all inquiries by the VCU IRB concerning the conduct of the approved research when so requested.

10. All protocols that administer acute medical treatment to human research participants must have an emergency preparedness plan. Please refer to VCU guidance on http:/www.research.vcu.edu/irb/guidance.htm.

11. The VCU IRBs operate under the regulatory authorities as described within:
    a) U.S. Department of Health and Human Services Title 45 CFR 46, Subparts A, B, C, and D (for all research, regardless of source of funding) and related guidance documents.
    b) U.S. Food and Drug Administration Chapter I of Title 21 CFR 50 and 56 (for FDA regulated research only) and related guidance documents.
    c) Commonwealth of Virginia Code of Virginia 32.1 Chapter 5.1 Human Research (for all research).

OFFICE OF RESEARCH SUBJECTS PROTECTION
JAN 21 2010

## RESEARCH SUBJECT INFORMATION AND CONSENT FORM

**TITLE:** A comparison of cardiorespiratory responses and ventilatory efficiency during treadmill and cycling exercise in overweight adolescents

**VCU IRB NUMBER: HM12642**

This consent form may contain words that you do not understand. Please ask the study staff to explain any words or information that you do not clearly understand. You may take home an unsigned copy of this consent form to think about or discuss with family or friends before making your decision.

**PURPOSE OF THE STUDY:**
The purpose of this research study is to compare heart rate and breathing responses during exercise tests performed on a treadmill and on an exercise bike. Your child is being asked to participate in this study because he/she is between the ages 10-17 years with a Body Mass Index (BMI) above the 85th percentile and is enrolled in the TEENS program. The BMI used to determine your child's eligibility was calculated from your child's height and weight measurements. The percentile is determined by charting the BMI value against your child's age on a standardized growth chart.

**DESCRIPTION OF THE STUDY AND YOUR CHILD'S INVOLVEMENT:**
If you decide to allow your child to participate in this research study, you will be asked to sign this consent form and your child will be asked to sign an assent form after you both have had all your questions answered and understand the research procedures. If you decide not to allow your child to participate in this study, your decision will in no way negatively influence your child's participation in the TEENS program.

During this study your child will participate in two exercise testing trials, one will be performed on a treadmill and one will be performed on an exercise bike. The treadmill test is already part of the standard TEENS fitness testing that your child will complete upon enrolling in the program; therefore, the only additional test will be an exercise test performed on an exercise bike. We will then compare the responses obtained from the two types of exercise. An exercise test is commonly utilized to determine the maximal capacity of the heart and lungs to deliver oxygen-rich blood to the muscles. The test involves having your child exercise on either the treadmill or the exercise bike while breathing into a plastic tube and wearing a heart rate monitor. At several time points, the required effort will be increased, so that the heart will beat faster. The approximate time of each exercise test is 12 minutes and they will be performed on different days. Both sessions will be scheduled during a time when your child would be visiting the TEENS gym. Your child may be very tired at the end of this test. If your child becomes distressed in any way or develops any abnormal responses, the test will be stopped.

**RISKS AND DISCOMFORTS:**
Prior to being allowed to participate in this study, your child must be cleared to undergo exercise testing by the VCU TEENS program physicians. As with any exercise testing, there is the slight chance of an abnormal blood pressure response, fainting, and disorders



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of heart beat during the test. Additionally, there is a chance of injury if your child falls during the treadmill test. To minimize these risks, a staff member, who has been trained in the appropriate procedures for performing exercise testing, will be present during the testing session. The staff member will also be trained in CPR and first aid and be aware of appropriate emergency procedures. Your child will be given instruction on how to walk on the treadmill prior to starting the test to minimize the risk of falls.

Some children with asthma may experience wheezing or shortness of breath during or after exercise testing. All participants with a history of asthma are cautioned to bring the appropriate medications (inhaler) to the exercise testing sessions. Testing will be postponed if required medications are not brought to the testing session.

**BENEFITS TO YOU AND YOUR CHILD:**
There are no direct medical benefits from being in this study. The information from this research study may lead to a better understanding of responses to different types of exercise in overweight children. The TEENS staff will also utilize the information obtained during both tests to set appropriate treadmill and exercise bike workloads for your child's exercise session.

**COSTS:**
There are no costs associated with participating in this study other than the time you will spend to bring your child to the testing session.

**PAYMENT FOR PARTICIPATION:**
There is no payment of participation in this study.

**ALTERNATIVE TREATMENT:**
This is not a treatment study. The only alternative is to decide not to allow your child to participate in the study.

**CONFIDENTIALITY:**
Potentially identifiable information about your child will consist of demographic information, body measurements (height and weight), measures of physical activity participation and fitness measures. Data is being collected only for research purposes. Confidentiality of personal information about your child – including his/her medical records and personal research data gathered in connection with this study – will be maintained in a manner consistent with federal and state laws and regulations. Your child's data will be stored separately from medical records in a locked research area. All personal identifying information will be kept in password protected files. Data queries will have names removed.

Information from the study and information from the consent form signed by you may be looked at or copied for research or legal purposes by Virginia Commonwealth University.

What we find from this study may be presented at meetings or published in papers, but your child's name will not ever be used in these presentations or papers.



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1-7-10 / LMA / JR

**IF AN INJURY HAPPENS:**
Virginia Commonwealth University and the VCU Health System (also known as MCV Hospital) do not have plans for providing long-term care or money in the event that your child suffers injury because of his or her participation in this study.

If your child is injured because of being in this study, tell the study staff right away. The study staff will arrange for short-term emergency care or referral if it is needed.

Bills for treatment of an injury may be sent to you or your insurance. Your insurance company may or may not pay for treatment of injuries that happen because of being in this study.

**VOLUNTARY PARTICIPATION AND WITHDRAWAL:**
Your child does not have to participate in this study. If you do decide to allow your child to participate, he/she can withdraw from the study at any time without any penalty. Your decision will not change your future medical care at this site or institution.

Your child's participation in this study may be stopped at any time by the study staff without your consent. The reasons might include:

- the study staff thinks it is necessary for your child's physical health and safety;
- your child has not followed study instructions;

**QUESTIONS:**
In the future, you may have questions about your child's study participation. You may also have questions about a possible side effect of participation or a possible research-related injury. If you have any questions, contact:

Dr. Ronald K. Evans
3600 West Broad Street
Box 842020
(804) 828-7798

If you have questions about your child's rights as a research subject, you may contact:

Office of Research Subjects Protection
Virginia Commonwealth University
Bio-Tech Research Park, Building 1
800 E. Leigh St., Suite 113
Richmond, VA 23298-0568
(804) 827-2157

You may also contact this number for general questions, concerns or complaints about the research. Please call this number if you cannot reach the research team or wish to talk



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to someone else. Additional information about participation in research studies can be found on http://www.research.vcu.edu/irb/volunteers.htm.

**CONSENT AND PERMISSION:**

I and my child have been given the chance to read this consent form carefully. I understand the information about this study. Questions that I asked about the study have been answered. My signature says that I am willing to allow my child to participate in this study. I will receive a copy of the consent form once I have signed it.

______________________________
Name of Child

______________________________ ______________________________ __________
Child Name Printed    Child Signature    Date

______________________________
Name of Parent of Legal Guardian (printed)

______________________________ __________
Parent or Legal Guardian Signature    Date

______________________________ __________
Name of Person Conducting Informed Consent Discussion/Witness (Printed)    Date

______________________________ __________
Signature of Person Conducting Informed Consent Discussion/Witness    Date

______________________________ __________
Investigator Signature (if different from above)    Date



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OFFICE OF RESEARCH SUBJECTS PROTECTION
JAN 7 2010

## YOUTH ASSENT FORM
**Use for Subjects 10 through 17 years**

**TITLE:** A comparison of cardiorespiratory responses and ventilatory efficiency during treadmill and cycling exercise in overweight adolescents

**VCU IRB NUMBER: HM12642**

This form may have some words that you do not know. Please ask someone to explain any words that you do not know. You can take home a copy of this form to think about and talk to your parents about it before you decide if you want to be in this study.

**What is this study about?**

The purpose of this study is to compare heart rate and breathing responses during exercise performed on a treadmill and on an exercise bike.

**What will happen to me if I choose to be in this study?**

If you decide to participate in this study, you will be asked to perform an exercise test on an exercise cycle in addition to the exercise test that you will perform on a treadmill as part of the TEENS program.

If you decide to be in this study, you will be asked to sign this form. Do not sign the form until you have all your questions answered, and understand what will happen to you.

**What might happen if I am in this study?**

During this study you will complete two exercise tests, one on a treadmill and one on an exercise bike. You will do these tests on different days. During the exercise test, your heart will beat faster and you will breathe faster and deeper. You will be asked to continue the test as long as you are able, and you can ask to stop the test at any time. You might feel tired or sore after you complete these tests. If a part of your body starts to hurt after you finish the test, you should tell one of the program staff and your parent about it.

If you have asthma, your wheezing, or shortness of breath may become worse during or after the exercise tests. If you have one, you will need to bring your rescue medications (inhaler) to both exercise testing sessions. Tell the exercise staff at the gym if your asthma becomes worse during the exercise test



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**Will you tell anyone about my tests?**

We will not tell anyone that is not part of the study team the information about your tests. If we talk about this study in speeches or in writing, we will never use your name.

**Do I have to be in this study?**

You do not have to be in this study. If you choose to be in the study, you may stop at any time. No one will blame you or criticize if you drop out of the study. You do not have to be in this study to be in the TEENS program.

**Questions**

If you have questions about being in this study, you can talk to the following persons or you can have your parent or another adult call:

Dr. Ronald K. Evans
3600 West Broad Street
Box 842020
(804) 828-7798

If you have questions about your rights as a research subject, you may contact:

Office of Research Subjects Protection
Virginia Commonwealth University
Bio-Tech Research Park, Building 1
800 E. Leigh St., Suite 113
Richmond, VA 23298-0568
(804) 827-2157



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Do not sign this form if you have any questions. Be sure someone answers your questions.

**Assent:**

I have read this form. I understand the information about this study. I am willing to be in this study.

| | | |
|---|---|---|
| Youth name printed | Youth signature | Date |

Name of Person Conducting Informed Assent Discussion/Witness (printed)

Signature of Person Conducting Informed Assent Discussion/Witness — Date

Investigator signature (if different from above) — Date



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VITA60

## Vita

Amanda Cary Scheps was born on January 12, 1985, in Alexandria, Virginia, and is an American citizen. She graduated from Park View High School in Sterling, Virginia in 2003. She received her Bachelor of Science in Clinical Exercise Science from Virginia Commonwealth University in Richmond, Virginia in 2007. She received a Master of Science in Health and Human Performance from Virginia Commonwealth University in 2010.