THE PHYSIOLOGICAL RESPONSES OF OBESE AND NON-OBESE WOMEN TO ARM ERGOMETRY

Charlene M. Henry

A Thesis

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Committee:

Lynn A. Darby, Ph.D. Advisor

Amy L. Morgan, Ph.D.

Todd Keylock, Ph.D.
ABSTRACT

Lynn A. Darby, Advisor

**Purpose:** The purpose of this study was to compare the physiological characteristics and responses of obese and non-obese women to arm ergometry. Some exercises (e.g. walking, cycling, etc.) may be too demanding for obese individuals. Therefore, arm ergometry may be a better exercise in the obese population because it utilizes a smaller muscle mass and is non-weight bearing. This is necessary so that exercise physiologists, physicians, and personal trainers can prescribe individualized exercise programs using the arm ergometer as physical activity in obese individuals who cannot tolerate the stress of other forms of exercise. **Methods:** Twenty, low risk females aged 18 to 22 years old participated in this study. Anthropometric measurements included were: height, weight, abdominal diameter, arm, waist and hip circumferences, skinfolds, and arm volume. The participants also completed a progressive, continuous, multistage arm ergometry exercise test using a modified Monark cycle ergometer to exhaustion. Oxygen consumption, ratings of perceived exertion, respiratory exchange ratio, ventilation, and heart rate were assessed every minute during the exercise test. Independent-samples t test were calculated. **Results:** Significant differences were found between the means for the obese and non-obese groups for body weight (kg) \( t = -5.47, p < .05, df=18, \) BMI (kg/m\(^2\)) \( t = -6.09, p < .05, df=18, \) body fat % \( t = -8.25, p < .05, df=18, \) waist circumference (cm) \( t = -6.27, p < .05, df=18, \) hip circumference (cm) \( t = -5.75, p < .05, df=18, \) waist to hip ratio \( t = -2.66, p < .05, df=18, \) abdominal diameter (cm) \( t = -6.02, p < .05, df=18, \) and HR\(_{max}\) (b min\(^{-1}\)) \( t = -2.15, p < .05, df=18, \) arm circumference \( t = -2.9, p < .05, df=18, \) arm volume \( t = -3.62, p < .05, df=18, \) and upper arm fat mass \( t = -4.92, p < .05, df=18. \) For VO\(_2\) (mL kg\(^{-1}\) min\(^{-1}\)), a significant interaction was found between Group x Time \( F = 7.51, p < .0001, df = 5. \) Differences between the obese
and non-obese groups were found at minutes 8, 9, and 10. **Conclusion:** In this study, the obese participants had more fat mass and arm fat area compared to the non-obese participants. However, this extra fat mass was not associated with more arm muscle area in the obese Group. Furthermore, there were no differences in oxygen consumption between the Groups. The arm ergometer is a non-weight bearing exercise, but is very intense especially for individuals who do not train their upper body. The extra fat weight on the arms of the obese individuals did not significantly affect the exercise responses measured. Therefore, it is recommended that the arm ergometer be prescribed for obese individuals who cannot handle the stresses associated with walking or cycling.
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CHAPTER I
INTRODUCTION

Obesity

Obesity is a serious health problem in the United States (ACSM, 2010) and is reaching epidemic proportions (Parr & Haight, 2006; Atkinson, 1998). This epidemic occurs from a positive energy balance, i.e., more calories consumed than calories expended (ACSM, 2006). The U.S. Department of Health & Human Services reported that about 66% of adults are either overweight or obese in the United States (2007). Obesity is affecting people of all ages, spreading across generations from children to the elderly (Smith et al., 2003).

Body Mass Index (BMI) is the most common tool used to categorize underweight, healthy, overweight, or obese (Dalton, Cameron, Zimmet, Shaw, Jolley, Dunsten, & Welborn, 2003). The U.S. Department of Health and Human Services (1998) has defined overweight as a BMI between 25-29.9 kg/m². Furthermore, obesity is defined as a BMI of 30 kg/m² or greater. However, a limitation of using BMI is that it could classify an individual as overweight, even though they may be very muscular (U.S. Department of Health and Human Services, 1998). A BMI classification of overweight or obese usually increases the risk of developing cardiovascular and other diseases (ACSM, 2010). According to Bray (2004), a curvilinear relationship exists between body mass index and mortality ratio. So, as BMI increases, mortality ratio increases in a J-shaped curve.

An increase in visceral abdominal fat also increases cardiovascular disease risk. Women who have a waist circumference > 88 cm and men who have a waist circumference > 102 cm are at a higher risk for developing cardiovascular diseases (ACSM, 2010). In those who have excess
intra-abdominal fat, the risk of obesity-related morbidity is increased compared to when adiposity is spread throughout the body (Dalton et al., 2003).

Since 1980, obesity rates have been increasing in children, adults, diverse racial groups, and those with differing socioeconomic status (Smith et al., 2005). Furthermore, in the United States, black American women and Hispanic Americans have a higher obesity rate compared to Caucasian Americans (Smith et al., 2005). In 1998, one-third of all U.S. adults were classified as obese (Atkinson, 1998; U.S. Department of Health and Human Services, 1998). Since 1980, obesity rates have continued to increase.

Obesity increases the risk of developing cardiovascular diseases, type 2 diabetes, hyperlipidemia, hypertension, and increased mortality (Yang, Telama, Vikari, & Raitakari, 2006; Parr & Haight, 2006; Flegal, Graubard, Williamson, & Gail, 2005). An increase in fasting glucose, blood pressure, triglycerides and a decrease in high density lipoprotein (HDL) is known as metabolic syndrome (Perry, Wang, & Kuo, 2005). Obesity is the second leading cause of preventable deaths and has been linked to 300,000 excess deaths in the United States (Atkinson, 1998). In order to control obesity, lifestyle modifications need to be made to lead a longer, healthier life. Atkinson (1998) explained that improving diet (i.e., eating vegetables, fruits, and grain products while limiting fat grams) and increasing physical activity by exercising 30 to 45 minutes for four to six times per week, can help reduce the risk of developing obesity.

Exercise and obesity

Exercise is very important in aiding weight loss, especially in obese populations. However, some forms of exercise such as walking, cycling, etc. may not be appropriate for those who are obese. This is because extra stress is placed on the joints due to the extra body weight an obese individual must move during physical activity.
Often times, this extra demand and stress may lead to dropping out of walking programs and other physical activity programs. Mattson, Larsson, and Rossner (1997) found that walking may be too much for an obese individual because they fatigue too quickly, have abnormal gait patterns, and increased discomfort due to increased friction in the lower extremities because of the prevalence of gluteal fat. Also, obese subjects used 57% of their VO$_2$ max values while the non-obese used only 37% of their VO$_2$ max at self-selected, comfortable speeds. If these side effects are too harsh, alternative forms of exercise for this population should be sought (Mattson et al., 1997).

Hulens, Vansant, Lysens, Claessens, and Muls (2001) made conclusions similar to Mattson et al. (1997). Obese individuals were limited in their walking ability due to increased knee pain that was also prevalent during a cycle ergometer test. In addition, the obese subjects’ VO$_2$ (l min$^{-1}$) was significantly greater ($p < 0.0001$) at 78% of their peak, while the non-obese only worked at 69% of their peak at comparable submaximal intensities of 70 W (Hulens et al., 2001).

There are many special populations (e.g., paraplegics, spinal cord injuries, and cardiac patients) who are limited in exercise due to their disabilities. This leads to increased body weight, decreased cardiovascular function and typically, decreased quality of life. However, exercise prescriptions can be developed for these individuals so they can safely and effectively exercise on the arm ergometer to improve cardiovascular function (DiCarlo, Supp, & Taylor, 1983; Gass & Camp, 1984; Levandoski, Sheldahl, Wilkes, Tristoni, & Hoffman, 1999.)

Studying the physiological responses in obese versus non-obese females during arm ergometry exercise is especially important because many exercises (e.g., walking, cycling, etc.) are too difficult or uncomfortable for obese individuals (Mattson, Larsson, & Rossner, 1997;
Hulens et al. 2001). Arm ergometry exercises have been tested in populations with limited function including paraplegics, spinal cord injury clients, and cardiac patients (DiCarlo, Supp & Taylor, 1983, Gass & Camp, 1984; and Levandoski et al., 1999). These researchers have concluded that exercising on an arm ergometer for these populations is safe and important to improve cardiovascular function. It is important to examine the physiological responses (i.e., VO$_2$, HR) between obese and non-obese individuals during arm ergometry because VO$_2$ is dependent on the amount of working muscle mass (McArdle, Katch, & Katch, 1996). For this study, it was hypothesized that VO$_2$max will be greater in obese compared to non-obese women during arm ergometry because the obese women will have more muscle mass than non-obese women.
Purpose

The purpose of this study was to compare the physiological characteristics and physiological responses of obese and non-obese women to arm ergometry.

Hypotheses

Null: It was hypothesized that there will be no differences in physiological responses (i.e., VO$_2$, HR) in obese versus non-obese during arm ergometry.

Directional Hypothesis: Maximal oxygen consumption will be greater in obese compared to non-obese women during arm ergometry.

Significance

Some exercises (e.g. walking, cycling, etc.) may be too demanding for an obese individual. Therefore, arm ergometry may be a better exercise in the obese population because it utilizes a smaller muscle mass and is a non-weight bearing exercise. However, there has been limited research examining the physiological responses of arm ergometry in an obese population. This is necessary so that exercise physiologists, physicians, and personal trainers can prescribe arm ergometry as a safe and effective way to lose weight in obese individuals who cannot tolerate the stress of other weight bearing forms of exercise.
Definitions

The following terms are defined as used in this study.

**Resting Oxygen Consumption** - Mean of minutes three and four during seated non activity; arms not holding handles.

**VO_2max** - “Maximal oxygen uptake (VO_2max) is accepted as the criterion measure of cardiovascular fitness. Maximal oxygen uptake is the product of maximal cardiac output (L blood min^{-1}) and arterial-venous oxygen difference (mL O_2 per L blood).” (ACSM, 2006, p. 66). Maximal oxygen uptake is also defined as “a leveling-off in oxygen uptake with increasing workload, although agreement on a precise standard for this criterion remains elusive” (McArdle, Katch & Katch, 1996, p. 199). In the present study, the mean of VO_2 collected during the last minute of exercise.

**VO_2peak** - “When a leveling off is not seen, or the test performance appears to be limited by local muscular factors rather than central circulatory dynamics, peak VO_2 is used. Peak VO_2 refers to the highest values of oxygen uptake measured during the test.” (McArdle, Katch & Katch, 1996, p. 199). Defined for this study as the final fifteen seconds of exercise.

**Obesity** – A body fat > 35% and/or BMI > 30 kg/m^2.

**Sedentary** – According to the Surgeon General, persons not participating in at least 30 minutes of moderate intensity physical activity on at least 3 days per week. (as cited in ACSM, 2006).
CHAPTER II
REVIEW OF LITERATURE

Leg Versus Arm Ergometry

Leg ergometry has been a consistent and commonly used method to test individuals’ aerobic capacities (ACSM, 2010). However, certain populations may not be able to perform these tests. Arm ergometry can be used not only to test individuals, but as a form of exercise when individuals are not able to cycle or walk. Such as, obese individuals who have excess stresses placed on the body due to increased body weight. There are different physiological responses to arm versus leg ergometry at both submaximal and maximal levels due to the amount of muscle mass involved and biomechanical factors (e.g., crank length, crank height, etc.)

Since there are many individuals who cannot perform exercises on a leg ergometer, several studies have examined the physiological responses and perceived exertions in arm versus leg ergometry (Pimental, Sawka, Billings & Trad, 1984; Franklin, Vander, Wrisley, & Rubenfire, 1983; Borg, Hassmēn, & Lagerström, 1987; Kang, Chaloupka, Mastrangelo, Angelucci, 1999). Pimental et al. (1984) studied the physiological responses during prolonged arm and leg ergometry exercises. For this study, nine male subjects (22±3 yrs; 172±8 cm; 71.4±6.9 kg) were recruited for participation in both maximal and submaximal ergometry exercises in order to determine peak oxygen consumption (VO₂ peak). The maximal arm ergometer test employed a protocol of 70 revolutions per minute (RPM) and the power was increased 17 watts (W) every 3 minutes. The leg ergometer protocol was set at 60 RPM, while increasing the power by 30 W every 3 minutes. Both tests were performed to exhaustion or when pedal rate was not maintained. The subjects then performed progressive intensity, submaximal exercises that lasted for 60 minutes each to determine steady-state oxygen uptake at each power
output. The pedaling rate for both arm and leg ergometry was set at 70 RPM for submaximal exercise.

Upon completion of the study, the mean peak oxygen uptake for leg cycling was greater compared to arm cycling. The peak heart rate (HR) reached 188±14 b min⁻¹ and 181±17 b min⁻¹ for the leg cycling and arm cycling, respectively. Furthermore, during performances of prolonged exercises at 60% of VO₂ peak, the HR during the arm cycling was significantly lower than the leg cycling (p < 0.05) (Pimental et al., 1984). Also, peak oxygen uptake for the arm cycling was only 60-80% of the leg cycling. Prolonged upper body exercises are important for many populations including athletes and those who have lower body disabilities. Therefore, studying the physiological responses during arm cycling exercise is important for populations who may not be able to use leg cycling or participate in other weight-bearing forms of exercise.

Another study compared oxygen cost in arm and leg ergometry using multistage tests. Franklin, Vander, Wrisley and Rubenfire (1983) recruited 10 male subjects (28±2.4 years). The initial workload was set at 25 W and increased by 25 W at each stage, working at a pedal speed of 50-60 RPM for both arm and leg cycling until exhaustion. They found at the submaximal level that VO₂, HR, ventilatory threshold (V̇E), ratings of perceived exertion (RPE), and respiratory exchange ratio (RER) were all slightly higher during the arm than leg ergometry. The HR results at the submaximal level disagree with the study by Pimental et al. (1984). However, the results may disagree due to different protocols set in each study in terms of both RPM and workload.

Franklin et al. (1983) found that during maximal tests the maximal workload for the arm ergometer (110 W) was significantly lower than the maximal workload for the leg ergometer.
(200 W) \( p < .001 \). Also, \( \text{VO}_2 \text{max} \) during arm ergometry was only 80% of \( \text{VO}_2 \) in leg ergometry \( p < .05 \).

It was concluded that arm fitness is a poor indicator of leg fitness. However, they further explained that arm ergometry exercise is good for special populations. This study found that many physiological responses were higher during the arm ergometry exercise compared to the leg at submaximal levels (Franklin et al., 1983). This could be due to differences in muscle mass between the upper and lower body. The lower body has a larger muscle mass compared to the upper body.

Another study compared physiological responses during arm and leg ergometry (Kang, Chaloupka, Mastrangelo, & Angelucci, 1999). They recruited 17 male and seven female subjects. The subjects completed a treadmill \( \text{VO}_2 \) maximal test to exhaustion and then arm and leg ergometer tests. The initial power outputs for the ergometry tests were 25 W for the arm crank test and 50 W for the leg cycle test. The power output was increased by 25 W every two minutes for the duration of the tests. In males, it was found that \( \text{VO}_2 \), HR, RER, \( V_E \) and RPE were all higher during arm ergometry than leg ergometry at power outputs of 50 and 75 W. In females, the authors found that \( \text{VO}_2 \), HR, RER, \( V_E \), and RPE were all higher during arm ergometry than leg ergometry at 50 W, but the responses did not differ at 25 W. The authors concluded that greater cardiorespiratory and metabolic responses during arm ergometry may be due to the mechanical differences between arm and leg ergometers. They further explained the mechanical difference is that the crank arm on an arm ergometer is half that of the leg ergometer. A shorter crank arm length results in a shorter crank lever. Therefore, a greater muscular effort would have to be produced to maintain the same torque. This leads to greater cardiorespiratory and metabolic responses during arm ergometry, resulting in higher RPE ratings. Therefore, there
are greater physiological responses to arm ergometry compared to leg ergometry at a given power output at the submaximal level.

One study observed perceived exertion during arm and leg exercise and how it related to HR and blood lactate responses (Borg, Hassmen & Lagerstrom, 1987). Eight healthy males participated in the study. The arm cranking tests were performed at 20, 35, 50, 70, and 100 W and at 60 RPM. They found differences between arm and leg exercises expressed in absolute levels. This could be due to the differences in muscle mass between the upper and lower extremities. This study used a new category ratio scale ranging from 0 to 20 (0=nothing at all, 3=moderate, 6=strong, 20=extremely strong) and found that subjects perceive arm exercise “harder” compared to leg. For example, at 100 W for both arm and leg ergometry, the subjects perceived the intensity at 3.6 (i.e., moderate) for leg ergometry compared to 14.4 (i.e., very strong) for arm ergometry.

Borg et al. (1987) explained that “working harder” during arm ergometry versus leg ergometry is due to the difference in muscle mass between the upper and lower extremities. They concluded that in order to maintain the same power output, individuals have to “work harder” which results in increased blood flow and lactate accumulation, resulting in higher degrees of perceived exertion. This study found that RPE increased linearly with power during arm ergometry. The authors concluded that the RPE scale is valid for testing perceived exertion during arm ergometry.

Researchers have found that differences exist in physiological responses and RPE during arm ergometry compared to leg ergometry (Borg et al., 1999; Franklin et al., 1983; Kang et al., 1999). Many populations are limited in their physical activity, therefore, an arm ergometer may be more feasible compared to other exercises.
Arm Ergometer Aerobic Requirements/Estimations

It is important that metabolic equations do not overestimate or underestimate a given workload. Arm ergometry is used for those with neurological disease, disabled, partial or complete paralysis, paraplegia, and amputees (Birkett & Edwards, 1998). Predicting/estimating aerobic consumption is essential for special populations, including those that are obese.

One study examined if submaximal one arm cranking can predict aerobic capacity (Birkett & Edwards, 1998). The subjects participated in three different arm ergometry tests, including a two arm maximal ergometry test, a two arm submaximal ergometry test, and a one arm submaximal ergometry test. For both submaximal tests, subjects worked at 0, 18, and 36 W at a crank of 60 RPM using a discontinuous protocol. Thus, each stage was three minutes long, with two minutes of rest between each stage. For the maximal test, the protocol increased by 18 W each minute.

Upon completion of the study, the heart rate and VO$_2$ were highly correlated during the maximal and submaximal tests in both male and female subjects (Birkett & Edwards, 1998). However, there was a weaker relationship during the one and two arm submaximal tests. Furthermore, no significant differences were reported between VO$_2$ peak during the maximal test and the VO$_2$ peak predicted values from the one arm and two arm submaximal tests. Birkett and Edwards (1998) reported that there were significant differences for VO$_2$ peak between males and females. They found predicted VO$_2$ peak in males was 68% higher than in females. They concluded that both one arm and two arm submaximal tests can predict VO$_2$ peak. Therefore, a one arm ergometer exercise can be used for individuals who are limited in function.

Twenty cardiac rehabilitation patients, performed three forms of exercise: an arm ergometer, a cycle ergometer, and a treadmill to estimate oxygen consumption (Brody, Darby,
Browder, Palmer, & McDougle, 2002). For each of the exercises, ACSM (1995, 2000) has established metabolic equations to estimate VO₂ max. The equations established for arm ergometry were:

\[
\text{VO}_2 (\text{mL} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}) = [3.5 \text{ mL} \cdot \text{kg}^{-1} \cdot \text{min}^{-1} \cdot \text{body mass}^{-1} (\text{kg})] + [\text{kg}^{-1} \cdot \text{min}^{-1} \cdot 3]
\]

\[
\text{VO}_2 (\text{mL} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}) = [18 \text{ Watts} \cdot \text{body mass (kg)}] + (3.5)
\]

During the testing, the arm ergometer was set at 50 RPM and the test lasted for five minutes. They found that the ACSM equation for arm ergometry overestimated VO₂ in cardiac patients. Therefore, other measures of intensity should be used to determine the physiological responses in arm ergometry (Brody et al., 2002).

Another study examined two prediction equations to determine if they properly estimated oxygen consumption in obese women (Andersen & Wadden, 1995). For this study, 51 obese subjects participated in a weight loss program (39.4± 8.5 yr, 96.9±11.7 kg, 163.9± 6.0 cm, and BMI 36.1± 4.2). They performed on a cycle ergometer where each stage lasted three minutes at 0, 50, and 100 W. The two equations they examined are as follows:

ACSM (1992):

\[
\text{VO}_2 (\text{ml} \cdot \text{kg} \cdot \text{min}^{-1}) = (\text{kg} \cdot \text{min}^{-1} \cdot 2 \text{ ml} \cdot \text{kg}^{-1})
\]

+ (3.5 ml·kg⁻¹·min⁻¹·kg body weight).

Latin et al. (1993):

\[
\text{VO}_2 (\text{ml} \cdot \text{kg} \cdot \text{min}^{-1}) = \text{kg} \cdot \text{min}^{-1} \cdot 1.9 \text{ ml} \cdot \text{kg}^{-1}
\]

+ (3.5 ml·kg⁻¹·min⁻¹·kg body weight)

+ (260 ml·min⁻¹)
After the study was completed, they found that the ACSM equation significantly \((p < 0.05)\) underestimated oxygen consumption in obese individuals. These differences were at 0, 50, and 100 W. Furthermore, the Latin equation also significantly \((p < .05)\) underestimated \(\text{VO}_2\) at 0 W. These estimations ranged from 9% to 58% of the values. The ACSM equation is not accurate in an obese population however; the Latin equation was accurately predicted at 50 and 100 W. Therefore, the Latin equation compared similarly to the ACSM equation for predicting oxygen consumption and a different equation should be derived for an obese individual for leg ergometry (Andersen & Wadden, 1995). They found that different prediction equations either overestimate or underestimate \(\text{VO}_2\) in the obese population.

Gender and Age influences during Arm Ergometry

It is well documented that \(\text{VO}_2\text{max}\) values differ due to many factors including age, gender, muscle mass, and ethnicity (ACSM, 2010). Furthermore, other physiological responses have been found to differ between the sexes including HR and power output. Numerous researchers have examined the differences in these and other variables during arm ergometry to determine the influences of gender and age on the physiological response.

Physiological responses were examined during arm ergometry to observe differences due to age and gender (Balady, Weiner, Rose, Ryan & Erario, 1990). There were 60 total subjects consisting of 30 men and 30 women (from 22 to 59 years of age, mean 36±10 years). They were further divided into subgroups according to age.

The protocol began with a power output of 10 W for two minutes and then was increased by 10 W every two minutes with the pedaling rate set at 75 to 80 RPM. The test continued until exhaustion which was when the subjects could no longer continue cranking at 75 RPM. They found significant differences between the genders in their physiological responses. The men
were able to reach a significantly greater power output (95±25 W) compared to the women (56±19 W). Furthermore, they found the men had higher peak oxygen consumption (20.7±3.9) than the women (15.5±3.1 ml·kg⁻¹·min⁻¹, p < 0.0001). Also, the men were able to reach a significantly greater mean peak HR (170±20 BPM) than the women (158±18 BPM, p < 0.0001). Results indicated that the only significant difference that was found between the age groups was the eldest group ranging in age from 40 to 59 years old, had a significantly lower power output (p < 0.02) than the younger groups, ranging in age from 20 to 29 and 30 to 39 years of age (Balady et al. 1990).

Another study examined peak VO₂ in arm versus leg exercise to determine if there was a difference due to gender (Warren, Cureton, Dengel, Graham, & Ray, 1990). Twenty untrained college students and 19 college swimmers participated in the study. They chose swimmers because swimming uses both arms and legs during the activity. The arm ergometer protocol consisted of a power output of 6 to 12 W with an increase of 6-12 W every two minutes. The crank rate was set at 60 RPM and went until the rate could no longer be continued. The leg ergometer protocol had a power output of 30 to 47 W and increased by 18 to 24 W every two minutes. Underwater weighing and water displacement were also used to determine arm and leg volumes. Corrections were then made for subcutaneous fat and fat-free volumes.

They found that both the highly trained and untrained men had a significantly greater arm volume (7.46 vs. 5.61 liters, p < 0.0001) and fat free volume (6.45 vs. 4.33 liters) compared to the women. The untrained men and women differences were statistically significant while the highly trained differed in arm fat free volume, but not total arm volume. The men also had greater peak VO₂ in both the arm and leg tests (46% and 45%) compared to the women. They explained that the major finding of the study was that “the gender difference in peak VO₂ was
not greater for arm exercise than leg exercise in either the swimmers or untrained subjects” (Warren et al., 1990, p. 152). The peak VO$_2$ values for both male groups were 46% and 45% higher than the females for both the arm and leg ergometry tests, respectively. However, there were no gender differences found in either the arm or leg ergometry test when VO$_2$ was expressed relative to fat free mass or limb fat free volume. The authors suggested that the relationship of fat free volume to peak VO$_2$ differs during arm and leg ergometry exercises.

The results of this study were similar to the results found by Balady et al. (1990) who found that men and women have different physiological responses during arm ergometry. The differences due to sex in arm volumes and physiological responses are important because these differences need to be accounted for when comparing obese versus non-obese individuals.

Arm Ergometry in Special Populations

There are physical limitations in individuals who have cardiovascular conditions, spinal cord injuries, paraplegia, and obesity. With these conditions, there are limitations in function, which may lead to sedentary lifestyles. These lifestyles may result in weight gain and an increase in body fat percentage, which increases risks for cardiovascular and other diseases. Therefore, in these populations, exercise is important in order to improve health. However, many of these individuals cannot perform exercises on a treadmill or leg cycle ergometer due to physical limitations. Due to the limitations in these populations, research has examined the physiological responses and effectiveness of arm ergometry in these patients.

DiCarlo, Supp, and Taylor (1983) examined the effects of arm ergometry in those with spinal cord injuries. This intervention study lasted five weeks and improvements were seen in cardiovascular function. For this study, four males with spinal cord lesions volunteered for the study. The subjects performed both maximal and submaximal tests prior to the training sessions.
Because these individuals are not able to control their body temperature by sweating, cool water had to be applied during the exercise in order to keep body temperature controlled. The submaximal test protocol was six minutes long with three stages. The workload began at 25 W at 50 RPM with 0.5 kp of resistance. The workloads were increased by 10 RPM each stage. Once the subjects reached 80 RPM, it was kept constant while the workload would increase by 0.5 kp. After the submaximal tests were complete, the authors were able to predict their VO$_2$ max and then could determine a protocol for the maximal exercise testing.

The intervention study consisted of arm ergometry for a total of 37 minutes each day with an intensity of 60 to 80% of their maximal HR (DiCarlo, et al., 1983). The subjects trained three times per week for a total of five weeks. After the five week training session, VO$_2$ max values had significantly increased by 60.5 % while the workloads increased by 64.3 % (F=2.51; $df$=3; $p$ = <.05).

They concluded that arm ergometry is an effective exercise for those with spinal cord injuries and other conditions. They suggested the prescription of the exercise must be established for each individual in order to provide a safe and effective way to increase cardiovascular performance. Even though the authors found that arm ergometry is an effective exercise for those with spinal cord injuries, a limitation to this study is there were only four subjects who participated.

Another study examined the effects of arm ergometry and a wheelchair exercise in male paraplegics (Gass & Camp, 1984). For this study, 10 paraplegic men participated and were divided into two groups of exercise. One group performed an incremental wheelchair exercise while the other performed using an arm ergometer. The wheelchair protocol had the subjects push their wheelchairs on ground level, on a motor driven treadmill, until exhaustion. The
protocol consisted of a beginning speed of 5 km h\(^{-1}\). The speed was then increased by 0.5 km h\(^{-1}\) per minute, while the grade increased by 2% at minute two and six, and then increasing 1% at minute 10. The arm ergometer protocol consisted of a pedal rate at 50 RPM at 30 W with an increase of 5 W every 20 seconds. The patients performed the arm ergometry test until exhaustion, which was when they were no longer able to maintain 35 RPM.

They found significant differences during the wheelchair exercise compared to the arm ergometer exercise. The mean VO\(_2\) for the wheelchair was 2.21±0.17 l min\(^{-1}\), while the arm cranking was 1.96±0.15 l min\(^{-1}\). Furthermore, during arm ergometry, the VO\(_2\) levels were 90% of the wheelchair exercise. Also, \(V_E\) was significantly higher during the wheelchair exercise (81.7±7.41 min\(^{-1}\)) compared to the arm ergometer exercise (66.4±5.81 min\(^{-1}\)). They further pointed out that HR and VCO\(_2\) were also significantly greater \((p<.05)\) during the wheelchair exercise versus the arm ergometer (Gass & Camp, 1984).

Physiological responses also were compared during arm versus leg cycle ergometry in patients with coronary artery disease (Levandoski, Sheldahl, Wilkes, Tristani, & Hoffman, 1990). For this study, 21 men were recruited (60±7 years). First, the subjects performed a peak exercise test on a leg ergometer. The workload began at 25 W and was increased by 25 W for each three minute stage, while maintaining a crank rate of 50 RPM. The test was completed when the subjects could no longer maintain the crank of 50 RPM. The subjects then performed submaximal leg and arm ergometry tests. Both tests workloads were at 30, 50, 70, and 100% of their peak. Upon completion of the study, they reported that during the peak test, subjects reached a significantly \((p<0.01)\) higher peak VO\(_2\) during leg ergometry compared to arm ergometry. During arm ergometry exercises, the peak was 86% of the peak that was attained.
during the leg ergometer. Levandoski et al. (1990) reported that peak cardiac output was also significantly greater on the leg ergometer versus the arm ($p < 0.05$).

The submaximal responses showed that cardiac output during leg ergometry was significantly greater at relative workloads. During arm ergometry, HR and RPE were significantly greater compared to leg ergometry ($p < 0.001$). In addition, diastolic blood pressure during arm ergometry was significantly ($p < 0.001$) greater and ventilatory demand was also significantly greater in arm ergometry ($p < 0.05$). They explained the responses to arm and leg cycle ergometry are similar when expressed relative to exercise intensity. The authors concluded that leg ergometry test can be used to prescribe an arm ergometry exercise prescriptions (Levandoski et al., 1990).

The ability to prescribe water exercises from treadmill and arm ergometry was tested in cardiac patients with coronary artery disease, idopathic hypertrophic subaortic stenosis, and myocardial infarction (Fernhall, Manfredi, & Congdon, 1992). The subjects performed arm ergometry and a treadmill test to exhaustion. The protocol for the arm ergometry test consisted of three minute stages beginning at 20 W and increasing by 20 W for each stage. After the subjects completed the maximal tests, they performed water exercise tests. They performed the water exercises at 60, 70, and 80% of their maximal HR that was obtained during the treadmill tests. After the three tests were over, physiological responses were compared among the three exercises.

They found that HR, VO$_2$ max and $V_E$ were all significantly higher during the treadmill ($p < 0.05$) compared to the arm ergometer and water exercise. They also found other significant differences between the three modes of exercises and at the three different intensities. When the patients exercised at 60% of their HR max, there were significantly higher VO$_2$ values ($p < 0.05$)
during the treadmill compared to the arm or water exercises. However, no significant differences were found in RPE values between the three groups of exercises. At 70% of HR max, the VO\(_2\) levels were once again significantly greater (\(p < 0.05\)), and the treadmill RPE was lower compared to the arm and water exercises. Finally, comparing the exercises at 80%, the treadmill had significantly higher VO\(_2\) compared to the arm and water exercises, however, the water exercises also obtained significantly higher VO\(_2\) levels compared to the arm (\(p < 0.05\)). At 80%, arm ergometry exercise had significantly greater RPE values (\(p < 0.05\)) compared to both the treadmill and water exercises. They concluded that water exercises are safe for cardiac patients and they do not enable greater ischemic episodes compared to treadmill or arm ergometry exercises that take place on land.

Researchers have found that individuals with special conditions such as cardiovascular diseases, paraplegia, and spinal cord injuries can perform exercise on an arm ergometer to help improve their cardiovascular function and overall health. However, there is a lack of research comparing the physiological differences in an obese and non-obese population. It is important to understand the responses in this population so that appropriate exercise prescriptions can be developed.

**Exercise and Obesity**

In order to lose weight, an individual who is obese is often recommended to start out walking at a low intensity for a long duration in order to expend calories. However, the extra weight increases stress on the body and walking may not be an appropriate exercise. Often obese individuals become too tired from walking and may not be able to continue with the program, resulting in no weight loss. Therefore, an alternative, (e.g. arm ergometry) may be a better exercise choice for an obese individual to start losing weight.
Geliebter, Maher, Gerace, Gutin, Heymsfield, and Hashim (1997) examined physiological changes in dieting obese subjects were examined. Overweight (>20% above the desired amount) men and women between the ages of 19 and 48 years of age were recruited for this study. The subjects were placed on a restricted diet and were divided into a strength training group (101.0 ± 21.9 kg; 41.1 ± 6.7%), an aerobic training group (96.0 ± 0 kg; 39.8 ± 5.9%) and a diet only group (97.6 ± 19.9 kg; 41.3 ± 6.4%). The aerobic training group performed exercise on a leg cycle ergometer for the first eight minutes, then on an arm ergometer for another eight minutes, and then finally another eight minutes of leg cycle ergometry.

Upon completion of the study, no significant differences were found between the groups for weight loss. However, they found that fat free mass loss was 8% for the strength training group and 20% for the aerobic group. Peak VO\textsubscript{2} increased significantly ($p = 0.01$) in the aerobic group. They concluded that strength training preserves lean tissue during weight loss (Geliebter et al., 1997).

The physiological responses of walking in obese women were examined to determine if walking could be tolerated as a mode of exercise (Mattsson, Larsson, & Rossner, 1997). Fifty-seven obese females participated in the study (44.1±10.7 years, BMI 37.1±3.4 kg min\textsuperscript{-2}), and a non-obese control group was used. The subjects performed a walking test on a 70 m track at a comfortable walking speed for their ability. A cycle ergometer submaximal test was also performed at a rate of 50 RPM. The workload increased until the HR reached 140 beats min\textsuperscript{-1}, and the submaximal test lasted between four to five minutes. Physiological data were collected for both the walking and cycle ergometer test.

They reported that the obese subjects walked significantly slower (70.9±5.6 m min\textsuperscript{-1}) compared to the non-obese (74-83 m min\textsuperscript{-1}, $p < 0.0001$). The mean VO\textsubscript{2} for the walking test in
the obese subjects was 11.1±1.4 ml kg min⁻¹. Many of the subjects experienced pain in the hip, knee, and ankle joints throughout the walking test. During the bicycle ergometry test, the mean VO₂ reached 21.2 ml kg min⁻¹ which was lower compared to the non-obese. The authors further explained that the cost of walking (mean % VO₂ max), was estimated to be 56±15.3%, which was significantly higher (p < 0.0001) compared to the non-obese (36%).

The HR was also greater in the obese compared to the non-obese. The subjects also had VO₂ max values that were higher than the non-obese population during walking. They also explained that the heart in an obese subject is very well trained because it needs to work harder due to the excess fat. However, this leads to a lower VO₂ max when expressed relative to body weight. During the walking test, the obese subjects used an average of 57% of their VO₂ max values while the non-obese used only 37% of their VO₂ max. In addition, a quarter of the obese patients used a range of 64 to 98% of their VO₂ max values (Mattsson et al., 1997).

Walking as a means to lose weight may be too intense for an obese individual. Mattsson et al. (1997) explained that walking for an obese individual entails training at a moderate to high intensity, which can improve their VO₂ max, but may not allow for fat burning. Because of the higher intensities, walking for an obese person that exceeds 30-40% of their VO₂ max may not be an appropriate exercise because it may be too difficult and may fatigue the individual too quickly. Consequences of walking in an obese population includes the possibility of abnormal gait patterns, and increased friction leading to chafing and sores which make it painful to walk. They concluded that obese women who enjoy walking may continue to do so if they are able to without the painful side effects. However, if walking is painful, an alternate form of exercise should be utilized so that it can be done without any painful side effects and can be performed for longer periods of time in order to stimulate weight loss (Mattsson et al., 1997).
Exercise capacity in obese versus lean women was examined during a maximal cycle ergometer test (Hulens, Vansant, Lysens, Claessens, & Muls, 2001). For this study, 225 obese women between 18 to 65 years of age participated (BMI =38.1±5.6 kg m\(^2\), % body fat=47.1±4.9%). The protocol for this study consisted of a maximal cycle ergometer test working at 60 RPM. The workload began at 0 W and then increased by 10 W every minute until exhaustion.

Hulens et al. (2001) found that at the submaximal level of 70 W oxygen uptake was significantly greater (\(p < 0.0001\)) in obese women, reaching 78% of their peak, while the non-obese only worked at 69% of their peak. HR did not differ between the groups. The peak workload was significantly greater in lean subjects versus obese subjects (+17.5 W). The obese subjects reason for terminating the test was due to more musculoskeletal pain (18.3% in obese versus 3.9% in non-obese, \(p < 0.05\)). The obese subjects’ further pointed out that much of the pain was in the knees versus the lower back, hip, feet, and ankles. Conversely, the non-obese subjects mentioned that leg fatigue was their reason for stopping the test.

Similar to Mattson et al. (1997), Hulens et al. (2001) explained that during submaximal exercise, obese subjects use a larger percent of their VO\(_2\)peak, which increases oxygen cost due to a greater body mass. However, during maximal exercise, the workload at peak was lower in obese versus the non-obese. The authors pointed out that this is not what they expected, considering the obese have a larger body mass and fat-free mass, which should be an advantage.

Browning and Kram (2007) examined the effects of obesity on the biomechanics of walking were examined. A total of 20 people participated in this study, 10 obese subjects and 10 non-obese subjects. The authors compared the different biomechanical factors between the obese and non-obese groups during walking.
The subjects walked at six different speeds on the treadmill (0.50, 0.75, 1.00, 1.25, 1.50, 1.75 m s\(^{-1}\)). Ground reaction forces (GRF), step width, and kinematics were examined. The results showed that the absolute GRF were greater in the obese versus the non-obese, but both groups absolute GRF decreased with slower walking speeds. Peak vertical GRF were significantly greater by 60% for the obese subjects compared to non-obese (\(p < 0.001\)). It was also pointed out that obese subjects were walking at greater joint loads compared to the non-obese. With the results of this study they explained that it may be beneficial for an obese person to walk at slower speeds in order to reduce the aerobic demands, perceived exertion, and “reduce the risk of musculoskeletal pathology in obese adults” (Browning & Kram, 2007, p. 1640).

There are many differences in obese and non-obese individuals during leg cycling exercises as well as reported by Lafortuna, Proietti, Agosi, and Sartorio (2006). They compared the differences in obese versus non-obese females during submaximal leg cycling exercise. For the study, there were nine obese females (23.2 years ± 1.6, BMI = 40.4 ± 1.2 kg m\(^{-2}\), fat mass = 50.9 ± 1.4%) and nine females of healthy weight (25.6 years ± 1.8, BMI 21.7 ± 0.6 kg m\(^{-2}\), fat mass = 26.5 ± 1.8%). The protocol for this study consisted of a graded cycle ergometer test working at 40, 60, 80, 100, and 120 W with each stage lasting for four minutes and at a rate of 65 RPM.

They found physiological differences between the obese and normal weights groups. VO\(_2\) (l min\(^{-1}\)) at each submaximal workload was significantly higher (\(p < 0.05-0.01\)) in the obese group compared to the healthy weight group. There were no significant differences found between HR and V\(_E\). Furthermore, they reported higher levels of VO\(_2\) HR in the obese women at the different metabolic levels, however, when adjusted for fat-free mass (FFM) the numbers were comparable in both groups (VO\(_2\) Body mass (BM): 4.24 ± 0.59 and 3.36 ± 0.25 ml min kg,
$p=0.168$, for normal weight and obese, respectively). Also, VO$_2$max relative to body weight was significantly higher ($p < 0.01-0.001$) in the normal weight group. Conversely, HR in the obese subjects was lower compared to the healthy weight subjects during submaximal cycling.

Upon completion of the study, they stated that oxygen consumption was greater in the obese compared to the normal weight group at each workload in gross and net terms. Furthermore, the obese women had a body mass 80% greater compared to the normal weight group. This mass was further divided into fat mass (FM) was 82% and FFM was 18%. They explained that the obese group had a significantly greater VO$_2$ at each workload compared to the normal weight group because the extra fat mass results in greater loading of the muscle, which increases the muscle mass. Therefore, a larger muscle mass leads to greater VO$_2$ levels during submaximal cycling (Lafortuna et al., 2006). They suggested that future research should examine the energy cost of cycling in the obese population of different gender and age in order to develop a specific prediction equation in obese.

Another study examined obese and non-obese populations to determine the impact that extra weight had on aerobic capacity (Goran, Fields, Hunter, Herd, & Weinsier, 2000). Two studies examined the influence that FFM and FM has on VO$_2$. The first study used 129 children, while study two examined adults in a weight loss program. The protocol for the children (9.6±1.3 yrs, 44.1±18.4 kg, 23.5±5.3 kg FFM, and 11.8±8.9 kg FM) consisted of a continuous, progressive, treadmill walking test. The beginning speed was 4 km/hr at 0% grade for 4 minutes. The treadmill grade was then increased to 10% and each level lasted 2 minutes. After each 2 minutes, the grade increased by 2.5%. The speed stayed the same until a grade of 20% was reached, then the speed increased by 0.6km/h until volitional exhaustion. In contrast, the adults (37.3±6.4 yrs, 78.8±6.2kg, 49.4±4.7kg FFM, and 29.3±4.9 kg FM) in the weight loss program
performed a modified Bruce graded treadmill exercise test. The protocol began at 2.5% grade at 4.8 km/h. Each level lasted for one minute, and then the grade was increased to 2.5%, while the speed increased by 0.8 km/h and continued until volitional exhaustion.

After the study was completed, they reported that the children’s maximal oxygen consumption (l/min) was highly correlated with FFM ($r = 0.87$), body weight ($r = 0.78$), height ($r = 0.75$), submaximal oxygen consumption ($r = 0.69$), FM ($r = 0.66$), BMI ($r = 0.61$) and age ($r = 0.59$). FFM was then adjusted, and sub-maximal oxygen consumption remained significantly related to maximal oxygen consumption ($r = 0.29$). On the other side, the adults lost a mean body weight of 13.0 ± 3.6 kg, resulting in a 7% reduction in FFM (3.6±3.4kg) and a 31% reduction in fat mass (9.2 ± 3.3kg, $p < 0.05$). Furthermore, after the weight loss VO$_{2}$max decreased by 3.7%. However, when VO$_{2}$ max was divided by body weight, increased by 15% after weight loss (27.5 ± 2.9) to (31.6 ± 4.6 ml kg$^{-1}$ min$^{-1}$). VO$_{2}$ max was similar when adjusted for FFM before the program and after the program was completed.

They explained that an obese individual does not differ compared to a normal weight individual for VO$_{2}$ max. However, they have a reduced capacity at the submaximal level. Also, when VO$_{2}$ max is expressed relative to body weight, obese have a reduced VO$_{2}$ max. The obese individuals had a higher VO$_{2}$ max in these studies because they had a higher FFM. The reason that obese individuals are limited for aerobic activities is due to their submaximal capacity because obese individuals generally have a higher HR, RER, and % VO$_{2}$ max, and shorter time to exhaustion (Goran et al., 2000). These results are comparable to other studies by LaFortuna et al. (2006) and Hulens et al. (2001).

Several of the studies examining walking and leg cycling exercises found that these exercises may be too difficult and cause too much pain in the joints for the obese population
(Mattson et al., 1997, Hulens et al., 2001). The results of these studies suggest that walking, leg cycling and weight-bearing exercises may be too difficult for an obese individual to use as a form of exercise. In addition, Hulens et al. (2001), Goran et al. (2000), and Lafortuna et al. (2006) found that oxygen consumption was greater in obese individuals with a shorter time to exhaustion. Lafortuna et al. (2006) found that obese women had a greater body mass compared to normal individuals. The researchers also found the obese women have greater fat mass and fat free mass than normal weight groups, resulting in increases in muscle mass, leading to the greater VO$_2$ levels. From the results of these studies, it can be concluded that walking, leg ergometry, and other weight bearing activities may be too difficult for an obese individual who is trying to lose weight.

ACSM prediction equation for energy cost was examined during arm ergometry in women (Mookerjee, Surmacz, Till, & Weller, 2005). The following equation has been established by ACSM to predict the energy cost of upper body exercises:

$$
\text{VO}_2 \text{(ml.kg.min}^{-1}) = 3(\text{work rate}) \text{M}^{-1} + 3.5
$$

Work rate = kg.m.min$^{-1}$ and M is the body mass in kg

In gross metric units the following equation is used:

$$
\text{VO}_2 \text{(ml.kg.min}^{-1}) = (18 \text{ W.M}^{-1}) + 3.5
$$

W=work rate in Watts and M is the body mass in Kg

Sixty subjects were recruited and divided into the equation development group or cross validation group. The arm crank was set at 50 rpm and the work rate was increased by 10 W every two minutes until exhaustion. The other exercise was a submaximal test where the subjects worked at 40% of the maximal work rate that was obtained at the first test for a total of 30 minutes.
They explained that the ACSM metabolic equations (ACSM, 2006) are only appropriate during submaximal aerobic exercises. They found there was significant underestimation by an average of 28% during incremental testing with the ACSM equations. During the steady-state exercise, the error was between 14.7 and 36.4%. It was reported that the ACSM equation is only valid between 25-135 W (ACSM, 2006). Furthermore, the prediction equation needs to be used with caution and should be specific to gender.

For this study, the validation of walking intensity in obese adults was examined with fifty subjects, 30 obese and 20 non-obese (Hills, Byrne, Wearing & Armstrong, 2006). The protocol consisted of the subjects walking on a 2-km track three times. During the first 2 trials, they selected a pace that was considered “walking for pleasure,” while the third trial was performed at a maximum pace. After the study was completed, they found that the obese chose to walk at speeds slower than the non-obese subjects. The obese subjects elicited a greater HR (+15 bpm) compared to the non-obese during the “walking for pleasure” trial. During the “walking for pleasure” protocol, the obese subjects worked at 70% of the HR max, which is considered moderate to hard intensity. The non-obese group worked at 59% of the HR max which was considered moderate intensity. No significant differences were found between the two groups for perceived exertion. Hills et al. (2006) stated that while the subjects were “walking for pleasure” the obese group did have greater cardiovascular stress compared to the non-obese group. Since both groups perceived that “walking for pleasure” was light, the obese subjects stressed their cardiorespiratory system enough in order to maintain further improvements if walking is used for exercise (Hills et al., 2006).

Arm and Leg Volume using Different Methods
Measuring arm volume is important for many populations including those patients recovering from breast cancer. The “gold standard” for measuring arm volume is through water displacement. Arm and leg volumes can be measured directly by water-displacement volumetry or indirectly through circumference measurements, limb girths and segment lengths (Sukul, Hoed, Johannes, Dolder, Benda, 1993; Tewarki, Gill, Bochner, & Kollias, 2008; Warren et al. 1990).

The clinical use of determining either arm or leg volumes are important to monitor edema or hematoma that occurs post-surgery or from a traumatic event (Sukul et al. 1993). However, water-displacement volumetry may be time consuming and may not be appropriate for patients post operation due to the wounds. Therefore, circumference measurements and disc model methods can be used to estimate arm volume (Tewarki et al. 2008; Sukul et al. 1993).

Furthermore, Lette (2006) developed a home based volumetry that was developed based on the water displacement theory. Therefore, arm volume can be easily assessed without the risk of infection or the costs associated with those at hospitals.

One study examined volume displacement compared to circumferential arm measurements in ninety-eight women with breast cancer (Tewarki et al., 2008). The protocol consisted of six circumference measurements made on each arm using a wide tape (15 mm width) and a narrow tape (8 mm width). The volume displacement measurements were done using a large tank, with an overflow pipe, having a height of 500 mm. The large tank then drained into a smaller tank, which measured volumes up to 4000 mL. The arm was then placed in the tank and the volume that was displaced was recorded.

They reported the mean volumes that were estimated from the circumference measurements and found a significant correlation (Pearson’s correlation coefficient 0.95, p<
between the two tapes. The mean volumes reported from the narrow tape were 2291.66±547.86 mL, while the larger tape reported a mean volume of 2319.58±575.77 mL. Tewarki et al. (2008) found the mean volume measured through water displacement was 2067.36±510.01 mL. Also, a significant correlation was found between the narrow tape and volume displacement (95% confidence interval 0.89-0.94, \( p < 0.0001 \)). The equation with the best fit line was \( y = 0.88x + 101.75 \). Furthermore, the authors compared the wide tape and volume displacement finding a 95% confidence interval 0.84-0.91, \( p < 0.0001 \). The equation with the best fit line was \( y = 0.88x + 101.75 \).

Upon completion of the study, they concluded that the circumferential arm measurements were similar to the water displacement even though the circumferential arm measurements overestimated arm volume when compared to water displacement method. They further pointed out that differences in the techniques may be due to the body weight because arm circumference is difficult to measure in obese. However, the use of circumference measurements as a way to estimate arm volume is an appropriate method (Tewarki et al., 2008).

Different methods were examined and compared for measuring leg volume (Sukul et al., 1993). The purpose of this study was to determine if the disk model and frustums sign model methods were comparable to water displacement using the lower leg. For this study, 20 male soccer players volunteered and the lower leg volumes were measured using three different methods. The water-displacement protocol used a tank and two overflow tubes. The distance between the two overflow tubes was 3020 ml, which was known as the reserve volume. The subject would lower one leg into the tube until the water was at the reference point. The spillover water was then measured. The volume of the lower extremity is 3020 ml, added to the amount of water in the cylinder. The steps were then repeated on the other leg (Sukul et al.,
1993). The alternative mode consisted of the disc model method is an indirect method to determine leg volume by dividing the leg into disks, where each disk is 3 cm high. Moreover, the frustum sign model method calculates the truncated cone or frustum.

Sukul et al. (1993) found that the mean volume using water-displacement volumetry was 2771±39 ml. When observing the relationship between water-displacement and the disc model, a correlation coefficient of +0.99 in a straight line with the formula, \( y = -32.13 + 1.030x \). The mean volume that was obtained using the disc model was 2822±39 ml. Furthermore, a relationship existed between water-displacement and the frustum sign model. The correlation coefficient was +0.93 with a straight line where \( y = -201.6 + 0.862x \). The mean volume for the frustum sign model was 2187±119 ml.

The authors discussed the comparisons of water-displacement volumetry to the disc model and frustum sign model. The water-displacement volumetry and frustum sign model showed a high correlation coefficient \( r = +0.93 \). However, there are differences when reporting this method. The water-displacement volumetry and the disc model method are highly correlated as well \( r = +0.99 \), and many other studies are in agreement with these conclusions as stated by Sukul et al. (1993). Upon final analysis, they concluded that the water-displacement volumetry and the disc model are both acceptable to determine leg volume. Water-displacement volumetry and the frustum sign model cannot be used interchangeably like the disk model. This is because there is a discrepancy between the two methods resulting in a great variation of differences (Sukul et al., 1993).

A study examined arm and leg fat-free volumes (FFV) in order to estimate muscle distribution and make comparisons between males and females (Warren et al., 1990). The participants also completed arm and leg cycling exercises to exhaustion. For this study, 20
untrained college students and nineteen highly trained collegiate swimmers participated. Arm
and leg volumes were calculated through estimation by measuring limb girth and segment
lengths. The men (both highly trained and untrained) had a 33% and 49% significantly greater
arm volume (7.46 vs. 5.61 liters, \( p < 0.001 \)) and arm FFV (6.45 vs. 4.33 liters) compared to the
women. The leg volume and leg FFV were also greater in the men (20.32 vs. 17.24 liters) and
(16.2 vs. 10.86 liters) compared to the women. They further stated that no significant differences
were found when comparing genders and training levels for the arm. The men and women of
both groups did not differ in arm-to-leg FFV ratio (-0.410 and 0.402). The relationship between
peak VO\(_2\) and FFV is different in arm and leg exercise (Warren et al. 1990). Men had a FFV
greater than women by about 49%. However, when peak VO\(_2\) was expressed relative to the
dimensions of the arm and leg volumes, no significant differences were found between the men
and women. From the results of this study, there are differences in limb volumes between men
and women.

An arm volumeter was developed from the water displacement method using 15
volunteers (46 yrs; 65 kg) (Lette, 2006). The participants placed their arm in the volumeter
(water temperature averaged 28°C) until they reached the axilla. All of the participants had each
arm measured three times in order to attain reproducible measurements.

Upon completion of the study, a high degree of correlation was found between the known
and measured volumes of the cast cylinders for both the standard volumeter (\( y = 1.0053x + 
7.8061; R^2 = 0.9999 \) where \( y \) is the known volume and \( x \) is the measured volume) and volumeter
(\( y = 1.0049x + 0.2166; R^2 = 0.9999 \) where \( y \) is the known volume and \( x \) is the measured
volume), and between arm volume measurements by both volumeters (\( y = 1.0099x - 16.256; R^2 \)
\[ y = 0.9974; \text{ where } y \text{ is measurements with the standard Sammons Preston volumeter and } x \text{ is measurements with the volumeter developed by Lette, 2006) (p. 5437).} \]

This method of measuring arm volume is accurate and more precise than the methods used at hospitals. Furthermore, it is inexpensive and can easily be constructed at home. Also, this volumeter helps to eliminate skin infections because it is designed specifically to be used at home. The use of this volumeter is not only important for lymphedema management, but can also be used as a device for an obese population. This tool is essential because it is accurate, easy to use, and cost effective compared to those utilized by hospitals and clinics (Lette, 2006).

**Summary**

In conclusion, researchers have found that some exercise (e.g., walking, cycling, etc.) may be too demanding for an obese population due to the extra stress placed on the joints from excess weight. Therefore, an obese individual may not be able to lose weight using weight bearing exercises. The cost of oxygen consumption at submaximal levels is greater in obese compared to non-obese during walking and cycling. Furthermore, physiological responses differ due to gender during arm ergometry.

Previous studies have examined arm ergometry in many special populations including cardiac patients, paraplegics, spinal cord injuries and others. The researchers have suggested that these populations can safely exercise using an arm ergometer to improve cardiovascular function and improve overall quality of life. However, there is limited research comparing the physiological responses during arm ergometry in obese versus non-obese populations. It is necessary to examine the physiological responses and oxygen cost in the obese population compared to a non-obese population so that safe and effective exercise prescriptions can be utilized for this population who cannot handle the stresses of weight bearing exercises.
CHAPTER III

METHODS

Participants

Twenty sedentary obese and non-obese apparently healthy, low risk women between the ages of 18 to 30 years (ACSM, 2010; see Appendix A) were recruited for this study. Individuals were excluded from the study if they were on any medications used to control hypertension, diabetes, and/or dyslipidemia. Smokers were also excluded from the study.

Equipment

A SECA® stadiometer (Hanover, MD) was used to measure height. Each subject was measured without shoes. With body weight evenly distributed over the feet on the platform facing away from the stadiometer column, the chin was positioned so that it was parallel to the floor. Each subject stood as the movable headboard was brought into position over the most superior portion of the head. Height was measured one time to the nearest 0.1 cm. Body weight was measured on a physician’s scale (Detecto, Webb City, MO) to the nearest 0.1 kg. Each subject was asked to stand on the scale platform without shoes while the investigator moved balance markers into position. Body weight and height were used to calculate body mass index (BMI). The equation BMI = weight (kg)/height (m$^2$) was used.

Waist and hip circumferences were measured two times using a Gulick tape. A third measurement was taken if the first two were not within five millimeters. The average of two measures was used. Waist was defined as a horizontal measure taken at the narrowest portion of the torso (above the umbilicus and below the xiphoid process) and hips were a horizontal measure taken at the maximal circumference of the hip/proximal thigh (ACSM, 2010, p. 65).
Waist-to-hip ratio was determined by calculating circumference of the waist divided by circumference of the hips.

Abdominal diameter was measured for visceral fat according to Parr and Haight (2006). The participants were in a supine position on a hard table. An abdominal diameter apparatus was placed on the abdomen at the level of the umbilicus. Measures were taken from the bottom of the apparatus that was placed underneath the participants to the top of the abdomen at the umbilicus once the participant performed a normal exhalation. The average of three measurements were used (Parr & Haight, 2006).

Resting blood pressure was measured using a mercury manometer. Each subject was asked to sit in a chair with both feet on the floor for approximately five minutes of rest. A blood pressure cuff was attached to the upper arm at the level of the heart aligned at the brachial artery. An appropriate cuff size was used to ensure accurate measurement. The stethoscope bell was placed in the antecubital space over the brachial artery. The pressure was slowly released at 2 to 5 mm Hg per second. Systolic blood pressure is the point at which the first of two or more Korotkoff sounds is heard and diastolic blood pressure is the point before the disappearance of Korotkoff sounds (ACSM, 2010, p. 46). Blood pressure was measured prior to the start of the exercise test during rest and after the exercise test during passive recovery.

Arm circumference was measured with the subject standing erect and arms hanging freely at the sides with hands facing the thigh. A horizontal measure was performed midway between the acromion and olecranon processes (ACSM, 2010, p.65).

Skinfolds were taken [using Lange skinfold caliper (Cambridge Scientific Industries, Cambridge, Maryland)] at the tricep, thigh, and suprailiac on the right side of the body to determine each subject’s percentage of body fat. The caliper was placed directly on the skin
surface, 1 cm away from the thumb and finger, halfway between the crest and the base of the fold. The pinch was maintained while reading the caliper within 1 to 2 seconds. Measures were within 1 to 2 mm. Skinfolds were taken two times at each site. If the first two measures were not within 2 mm, a third measure was taken (ACSM, 2010, p. 67).

To measure arm volume, arm water displacement was performed according to Lette (2006). The volumeter was filled with water to the level of the spout at a temperature of 23 to 39 degrees Celsius (mean temperature for non-obese group=25±4.85°C; mean temperature for obese=23±1.39°C). The water was topped off until overflow began, so that a maximum, consistent water level was achieved. The arm of the participant was slowly submerged in the full volumeter and stopped when the top of the volumeter came into contact with the axilla, leading to water overflow through the spout. The displaced water was collected into a jug and weighed on a digital scale to the accuracy of 1 g. Water volume was derived from the weight based on the simple formula: 1 L of water weight equals 1 kg (Lette, 2006, p. 5435).

Anthropometric measurements of mid-upper arm circumference (C) and triceps skinfold (cm) were used to estimate arm muscle area (cm²) using the equation of Heymsfield, McManus, Smith, Stevens and Nixon (1982) where Arm muscle area (cm²) = [(midarm circumference - (π) * triceps skinfold) 2/4 π] -6.5. Estimates of fat mass of the arm we calculated using the equation of Brown, Karatzas, Nakielny, and Clark (1988) where fat area (cm²) = (C²/4 π) - muscle area.

A Monark cycle ergometer (Ergomedic 894e, Sweden) was used for the progressive arm ergometry exercise test. The cycle ergometer was mounted on an adjustable table (up and down) and the pedals were replaced with handles (see Figure 1).

VO₂, Vₑ, and RER were measured using a Parvo Medics TrueOne® metabolic system (Sandy, UT). A two-way mouthpiece was used so that each subject could breathe in room air
and exhale air into the True One®. A nose clip was placed on the subject. The expired air was analyzed for concentrations of oxygen and carbon dioxide. VO$_2$ was determined using the Haldane transformation:

$$V_1 = V_E \times \frac{F_{EN2}}{F_{IN2}}$$

where $V_1$ equals air inspired, $V_E$ equals air volume expired, and $F_{EN2}$ and $F_{IN2}$ equal the fractional concentrations of nitrogen in the expired and inspired air (McArdle et al., 1996, p. 88).

Heart rate was continuously monitored throughout the exercise test using a 12-lead EKG (Quinton 4000, Seattle, WA) by placing electrodes according to ACSM (2010), [p. 303].

Ratings of perceived exertion (RPE) were assessed using Borg’s RPE scale (i.e., 6-20). Borg’s RPE scale was developed so that the participant could rate his or her feelings of exertion during exercise, taking into account personal fitness level, environmental conditions, and general fatigue levels (ACSM, 2010, p. 83).
Procedures

Participants were recruited from Bowling Green State University (BGSU). Flyers (see Appendix B) were posted in buildings at BGSU and were given to Physical Education General (PEG) instructors to hand out to their students. Additionally, participants were recruited by other graduate students at BGSU. Participants were instructed to send an e-mail to the primary investigator if interested in participating in the study. The procedures, risks, and benefits were explained to the participant prior to each signing an informed consent form (see Appendix C) and completing a Health History Questionnaire (see Appendix D). Each subject was provided with a list of instructions (see Appendix E) for preparing for their exercise test. This study was
approved by the Human Subjects Review Board at Bowling Green State University prior to data collection.

The participants were required to visit the exercise physiology laboratory two times. During the first visit, the orientation session, the participants were familiarized with the measurements and exercise test to be completed. The primary investigator explained the procedures involved in the study and answered any questions. After the procedures were explained, the participants read and signed a consent form (see Appendix C) and Health History Questionnaire (see Appendix D). During the second visit to the exercise physiology laboratory, the participants had all anthropometric measurements taken and performed the exercise test.

A progressive, continuous, multistage arm ergometry exercise test using a Monark ergometer (Ergomedic 894e, Sweden) was completed by each participant. Prior to each exercise test, Parvo Medics TrueOne® metabolic system was calibrated for volume and gases of known concentrations. The arm ergometer was adjusted by turning the handle to lower or raise the table that the ergometer was on so that the axis of the wheel was aligned at each participant’s shoulders at the acromion process. This was done by placing a yard stick at the acromion process to the axis of the wheel. The position of the arms was adjusted so that the elbow was a few degrees less than full extension during each cycle of the arm crank. The distance from the ergometer to the participant was self-adjusted by each participant to comfort (see Figure 1). The participant rested for five minutes without their arms on the ergometer prior to the start of the exercise test. At this time, resting blood pressure (BP), heart rate (HR), and oxygen consumption (VO₂) were assessed.

For the warm-up phase, the participants turned the handles at 50 revolutions per minute (RPM) with no load for three minutes. After the warm-up period, the resistance increased 1 kg
for the first exercise stage and then increased .5 kg every three minutes for each successive stage until the subject reached volitional exhaustion. VO\textsubscript{2}, RPE, and HR were assessed breath by breath but expressed as minute values during the exercise test. After the participant reached maximal effort, they continued cranking with no load for three minutes for active recovery. [i.e., until HR was < 100 beats per minute (bpm)]. The participants continued to crank longer if they did not get their HR < 100 bpm during the active recovery of three minutes. They remained seated and rested for two minutes (passive recovery) so that resting BP and resting HR could be assessed prior to discharge from the laboratory.

Sample Size Determination

The critical rejection region for all tests was \( p \leq 0.05 \). Based on a review of related literature, a Cohen’s \( d = .95 \) was established as the lowest meaningful effect to be detected for differences between \( \text{VO}_{2} \text{ ml kg min}^{-1} \) (Cohen, 1988). “Effect size of 0.2 or less is a small effect size, about 0.5 is a moderate effect size, and 0.8 or more is a large effect size” (Thomas, Nelson & Silverman, 2005, p.116). Using G*Power (Faul, Erdfelder, Lang, & Buchner, 2005) with a statistical power criterion of .80, and a one-tailed test, a sample size of 15 participants was determined as appropriate for each group.

Statistical Analysis

Two-tailed, independent t-tests were used to compare differences for the anthropometric measures (e.g. skinfolds, height, weight, BMI, abdominal diameter, waist/hip ratio, dependent variables) between the obese and non-obese (independent variables) groups. Two-tailed, independent t-tests were used to compare differences in arm volume, arm muscle area, and arm fat area between the obese and non-obese groups.
Means and standard deviations for oxygen consumption, heart rate, respiratory exchange ratio, ventilation, and ratings of perceived exertion by minute for the non-obese and obese groups were calculated. A 2 x 6 (Group x Time) between (non-repeated)-within (repeated) ANOVA for VO$_2$ (l min$^{-1}$) and (ml kg min$^{-1}$) was performed. When significant F values were noted Newman-Keul’s post hoc tests were calculated. Newman-Keul’s post hoc tests were chosen as the post hoc tests because these are appropriate for comparing means from a mixed-model design (Linton, Gallo & Logal, 1975).
CHAPTER IV

RESULTS

Physiological Characteristics by Group

The purpose of this study was to compare the physiological characteristics and responses of obese (N=10) and non-obese (N=10) women to arm ergometry. Means and standard deviations for physiological characteristics for the non-obese and obese groups are provided in Table 1. Independent samples t tests were calculated to compare the means of the physiological characteristics between the groups. Significant differences were found between the means for the two groups for body weight: (kg) \( t = -5.47, p < .05, df=18 \); BMI: \( t = -6.09, p < .05, df=18 \); body fat \( \% \): \( t = -8.25, p < .05, df=18 \); waist circumference: \( t = -6.27, p < .05, df=18 \); hip circumference: \( t = -5.75, p < .05, df=18 \); waist to hip ratio: \( t = -2.66, p < .05, df=18 \); abdominal diameter: \( t = -6.02, p < .05, df=18 \); fat free mass (FFM): \( t = -2.22, p < .05, df=18 \); and HRmax: \( t = -2.15, p < .05, df=18 \). The obese group means for all of these dependent variables were significantly greater than the non-obese group.
Table 1

*Physiological Characteristics for Participants*
Non-obese (N=10); Obese (N=10)

<table>
<thead>
<tr>
<th>Variable</th>
<th>Non-Obese</th>
<th>Obese</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>S.D.</td>
</tr>
<tr>
<td>Age (yrs)</td>
<td>20.0</td>
<td>1.0</td>
</tr>
<tr>
<td>Body weight (kg)*</td>
<td>58.1</td>
<td>5.9</td>
</tr>
<tr>
<td>Body Mass Index* (kg/m²)</td>
<td>20.9</td>
<td>2.0</td>
</tr>
<tr>
<td>% body fat*</td>
<td>27.4</td>
<td>4.5</td>
</tr>
<tr>
<td>Waist Circumference (cm)*</td>
<td>66.9</td>
<td>2.5</td>
</tr>
<tr>
<td>Hip Circumference (cm)*</td>
<td>92.1</td>
<td>4.7</td>
</tr>
<tr>
<td>Waist to Hip Ratio*</td>
<td>0.72</td>
<td>0.03</td>
</tr>
<tr>
<td>Fat-free Mass (kg)*</td>
<td>42.1</td>
<td>3.8</td>
</tr>
<tr>
<td>Abdominal Diameter (cm)*</td>
<td>17.7</td>
<td>.65</td>
</tr>
<tr>
<td>Peak VO₂ (L·min⁻¹)*</td>
<td>1.21</td>
<td>.27</td>
</tr>
<tr>
<td>Peak VO₂ (mL·kg·min⁻¹)*</td>
<td>20.8</td>
<td>3.9</td>
</tr>
<tr>
<td>Peak HR (beats·min⁻¹)*</td>
<td>173.0</td>
<td>8.2</td>
</tr>
</tbody>
</table>

* p < .05
Anthropometric Arm Measurements

Means and standard deviations for anthropometric arm measurements for the non-obese and obese groups are provided in Table 2. An independent samples t test was calculated to compare the means of the anthropometric arm measurements between the non-obese and obese groups. Significant differences were found between the means for the two groups for arm circumference $t = -2.9, p < .05, df = 18$, arm volume $t = -3.62, p < .05, df = 18$ and triceps skinfold $t = -5.91, p < .05, df = 18$. Independent t-tests for muscle area indicated that there were no significant differences (obese $28.5 \pm 10.2$ cm$^2$; non-obese $23.2 \pm 5.4$ cm$^2$) $p = .160$ between the groups. However, there was a significant difference in fat area between the groups (obese $58.8 \pm 17.9$ cm$^2$; non-obese $28.9 \pm 7.1$ cm$^2$) $p = .0001$. The obese group means were greater than the non-obese group for arm circumference, arm volume, and arm fat area.
Table 2

*Anthropometric Arm Measurements*
Non-obese (N=10); Obese (N=10)

<table>
<thead>
<tr>
<th>Variable</th>
<th>Non-Obese</th>
<th>Obese</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>S.D.</td>
</tr>
<tr>
<td>Arm Circumference* (cm)</td>
<td>25.4</td>
<td>2.3</td>
</tr>
<tr>
<td>Arm Volume* (mL)</td>
<td>1440</td>
<td>263.3</td>
</tr>
<tr>
<td>Arm Length (cm)</td>
<td>70.0</td>
<td>3.0</td>
</tr>
<tr>
<td>Upper Arm Length (cm)</td>
<td>28.3</td>
<td>2.0</td>
</tr>
<tr>
<td>Tricep Skinfolds* (mm)</td>
<td>19.8</td>
<td>5.1</td>
</tr>
<tr>
<td>Upper Arm Muscle Area (cm²)</td>
<td>23.2</td>
<td>5.4</td>
</tr>
<tr>
<td>Upper Arm Fat Area* (cm²)</td>
<td>28.9</td>
<td>7.1</td>
</tr>
<tr>
<td>Water Temperature (°C)</td>
<td>25.3</td>
<td>4.8</td>
</tr>
</tbody>
</table>

* p < .05
Oxygen Consumption during Arm Exercise

For the exercise test, all participants completed stage one. Also, one non-obese participant and four obese participants completed stage two. After minute 6 of the arm exercise test, only 16 participants completed minute 7 (10 obese and 6 non-obese); 8 people completed minute 8 (6 obese and 2 non-obese); 5 people completed minute 9 (4 obese and 1 non-obese); and 5 people completed minute 10 (4 obese and 1 non-obese).

Based on the results, post hoc power was .67 and the mean difference was 3 ml·kg·min⁻¹. Means and standard deviations for oxygen consumption by minute for the non-obese and obese groups are provided in Table 3. Three, 2 x 6 (Group x Time) between (non-repeated)-within (repeated) ANOVAs for VO₂ (ml·kg·min⁻¹), (l·min⁻¹) and (ml·kg·FFM⁻¹) were calculated. For VO₂ (ml·kg·min⁻¹), a significant interaction was found for Group x Time $F = 7.51, p < .0001, df = 5$ (see Figure 2). Newman-Keul’s post hoc test revealed significant differences at minutes 4, 5, and 6 between obese and non-obese groups. For VO₂ (l·min⁻¹), no significant interaction was found for Group x Time $F = .506, p > .0001, df = 5$ (see Figure 3). A main effect was found for Time. All the means for each minute regardless of group were significantly different except minutes 8 and 7 were not different. For VO₂ (ml·kg·FFM⁻¹), no significant interaction was found for Group x Time $F = 1.67, p < .0001, df = 7$ (see Figure 4). A main effect was found for Time.
Table 3

Oxygen Consumption by time of arm exercise

<table>
<thead>
<tr>
<th>Exercise Time (Minutes)</th>
<th>1&lt;sup&gt;a&lt;/sup&gt; (N=20)</th>
<th>2&lt;sup&gt;a&lt;/sup&gt; (N=20)</th>
<th>3&lt;sup&gt;a&lt;/sup&gt; (N=20)</th>
<th>4&lt;sup&gt;b&lt;/sup&gt; (N=20)</th>
<th>5&lt;sup&gt;b&lt;/sup&gt; (N=20)</th>
<th>6&lt;sup&gt;b&lt;/sup&gt; (N=20)</th>
<th>7&lt;sup&gt;c&lt;/sup&gt; (N=16)</th>
<th>8&lt;sup&gt;c&lt;/sup&gt; (N=8)</th>
<th>9&lt;sup&gt;c&lt;/sup&gt; (N=5)</th>
<th>10&lt;sup&gt;c&lt;/sup&gt; (N=5)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>VO&lt;sub&gt;2&lt;/sub&gt; (ml·kg·min&lt;sup&gt;-1&lt;/sup&gt;)</strong></td>
<td>3.99</td>
<td>5.70</td>
<td>6.70</td>
<td>7.49&lt;sup&gt;*&lt;/sup&gt;</td>
<td>11.00&lt;sup&gt;*&lt;/sup&gt;</td>
<td>16.10&lt;sup&gt;*&lt;/sup&gt;</td>
<td>17.10</td>
<td>17.13</td>
<td>17.13</td>
<td>17.76</td>
</tr>
<tr>
<td>S.D.</td>
<td>.30</td>
<td>.32</td>
<td>.36</td>
<td>.45</td>
<td>.43</td>
<td>.68</td>
<td>3.64</td>
<td>3.36</td>
<td>3.36</td>
<td>3.32</td>
</tr>
<tr>
<td><strong>VO&lt;sub&gt;2&lt;/sub&gt; (l·min&lt;sup&gt;-1&lt;/sup&gt;)</strong></td>
<td>.281</td>
<td>.391</td>
<td>.456</td>
<td>.510</td>
<td>.747</td>
<td>1.084</td>
<td>1.16</td>
<td>1.27</td>
<td>1.42</td>
<td>1.45</td>
</tr>
<tr>
<td>S.D.</td>
<td>.02</td>
<td>.02</td>
<td>.03</td>
<td>.03</td>
<td>.04</td>
<td>.197</td>
<td>.215</td>
<td>.277</td>
<td>.311</td>
<td></td>
</tr>
<tr>
<td><strong>VO&lt;sub&gt;2&lt;/sub&gt; (ml·kg·FFM&lt;sup&gt;-1&lt;/sup&gt;)</strong></td>
<td>6.22</td>
<td>8.72</td>
<td>10.36</td>
<td>11.49</td>
<td>16.62</td>
<td>24.27</td>
<td>26.59</td>
<td>28.59</td>
<td>31.27</td>
<td>31.62</td>
</tr>
<tr>
<td>S.D.</td>
<td>2.28</td>
<td>2.63</td>
<td>3.56</td>
<td>3.92</td>
<td>3.76</td>
<td>4.82</td>
<td>4.07</td>
<td>5.01</td>
<td>6.45</td>
<td>8.89</td>
</tr>
</tbody>
</table>

<sup>*</sup><i>p < .001; S.D. = standard deviation</i>

<sup>a</sup> Unloaded arm cycling at 50 RPM

<sup>b</sup> Loaded arm (1 kg resistance) cycling at 50 RPM

<sup>c</sup> Loaded arm cycling at 1.5 kg resistance at 50 RPM

<sup>d</sup> Loaded arm at 2.5 kg resistance at 50 RPM
Figure 2. Oxygen Consumption (ml·kg·min⁻¹) means by minute of arm exercise (Minutes 1-3- unloaded arm cycling; minutes 4-6 loaded cycling at 1 kg of resistance; minutes 7-9 loaded cycling at 1.5 kg of resistance; minute 10 loaded cycling at 2kg of resistance).
Figure 3. Oxygen Consumption (l\text{min}^{-1}) means by minute of arm exercise (Minutes 1-3 unloaded arm cycling; minutes 4-6 loaded cycling at 1 kg of resistance; minutes 7-9 loaded cycling at 1.5 kg of resistance; minute 10 loaded cycling at 2 kg of resistance).
Figure 4. Oxygen Consumption (ml·kg·FFM⁻¹) means by minute of arm exercise (Minutes 1-3 unloaded arm cycling; minutes 4-6 loaded cycling at 1 kg of resistance; minutes 7-9 loaded cycling at 1.5 kg of resistance; minute 10 loaded cycling at 2 kg of resistance).
Physiological Responses (HR, $V_E$, RER, RPE) during Arm Exercise

Means and standard deviations for HR, $V_E$, RER, and RPE by minute for the non-obese and obese groups are provided in Table 4. A 2 x 6 (Group x Time) between (non-repeated)-within (repeated) ANOVAs for HR, $V_E$, RER, and RPE were performed. For HR, no significant interaction was found for Group x Time $F = .406$, $p < .0001$, $df = 6$. A main effect was found for Time $F = 73.26$, $p < .0001$, $df = 6$. For $V_E$, no significant interaction was found for Group x Time $F = 1.090$, $p < .0001$, $df = 6$. A main effect was found for Time $F = 1.090$, $p < .0001$, $df = 6$. For RER, no significant interaction was found for Group x Time $F = 2.782$, $p < .001$, $df = 6$. A main effect was found for Time $F = 2.78$, $p < .0001$, $df = 6$. For RPE, no significant interaction was found for Group x Time $F = .511$, $p < .0001$, $df = 2$. A main effect was found for Time $F = 45.86$, $p < .0001$, $df = 2$. There was no main effect for Group for any of these variables.
**Table 4**

*Physiological and Subjective Responses by Minute*

<table>
<thead>
<tr>
<th>Non-obese (N=10)</th>
<th>Exercise Time (Minutes)</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Rest 1^a 2^a 3^a 4^b 5^b 6^b</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>HR</td>
<td>88 106 112 114 146 161 169</td>
<td>7.4 13.4 18.5 21.1 12.9 8.4 6.1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>S.D.</td>
<td>.9 1.8 1.5 2.3 3.2 4.4 5.2</td>
<td>.13 .08 .07 .04 .04 .04 .06</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$V_E$</td>
<td>9.1 8.8 13.1 14.6 15.9 23.5 37.8</td>
<td>.855 .882 .882 .840 .856 .886 1.08</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>S.D.</td>
<td>.9 1.8 1.5 2.3 3.2 4.4 5.2</td>
<td>.13 .08 .07 .04 .04 .04 .06</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>RER</td>
<td>.885 .882 .882 .840 .856 .886 1.08</td>
<td>.13 .08 .07 .04 .04 .04 .06</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>S.D.</td>
<td>.13 .08 .07 .04 .04 .04 .06</td>
<td>.13 .08 .07 .04 .04 .04 .06</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>RPE</td>
<td>12 13</td>
<td>1.7 .8</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>S.D.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Obese (N=10)</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>88 103 107 113 142 158 155</td>
<td>12.0 10.2 10.7 21.8 15.2 11.1 9.9</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$V_E$</td>
<td>10.2 11.6 15.4 16.4 18.1 23.9 35.2</td>
<td>3.6 5.2 4.8 7.6 10.6 11.7 12.5</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>S.D.</td>
<td>.9 1.8 1.5 2.3 3.2 4.4 5.2</td>
<td>.13 .08 .07 .04 .04 .04 .06</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>RER</td>
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</table>

^a Unloaded arm cycling at 50 RPM
^b Loaded arm cycling at 1kg resistance at 50 RPM

Note. HR=heart rate (beats min^-1); $V_E$=ventilation (liters min^-1); RER=respiratory exchange ratio; RPE=ratings of perceived exertion (Borg 6-10 scale- Borg et al., 1987).
Table 4 (cont.)

*Physiological and Subjective Responses by Minute*

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<tr>
<th></th>
<th>Non-obese</th>
<th>Exercise Time (Minutes)</th>
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<td>7&lt;sup&gt;c&lt;/sup&gt;</td>
<td>8&lt;sup&gt;c&lt;/sup&gt;</td>
<td>9&lt;sup&gt;c&lt;/sup&gt;</td>
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<td>(N=16)</td>
<td>(N=8)</td>
<td>(N=9)</td>
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<td>HR</td>
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<tr>
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<tr>
<td>V&lt;sub&gt;E&lt;/sub&gt;</td>
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<td>.8</td>
<td>1.5</td>
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<sup>c</sup> Loaded arm cycling at 1.5kg resistance at 50 RPM
<sup>d</sup> Loaded arm cycling at 2kg resistance at 50 RPM

Note. HR=heart rate (beats min<sup>-1</sup>); V<sub>E</sub>=ventilation (liters min<sup>-1</sup>); RER=respiratory exchange ratio; RPE=ratings of perceived exertion (Borg 6-10 scale-Borg et al., 1987)
CHAPTER V

DISCUSSION

The purpose of this study was to compare the physiological characteristics and responses of obese and non-obese women to arm ergometry. It was hypothesized (null) that there would be no differences in physiological responses (i.e., VO$_2$, HR) in obese versus non-obese women during arm ergometry. Second, it was hypothesized that maximal oxygen consumption (relative to body weight) would be greater in obese compared to non-obese women during arm ergometry.

For the present study, all the subjects completed a graded arm cycling protocol. The exercise test was stopped due to muscular fatigue and pain and the inability to maintain a pedaling cadence at 50 revolutions per minute. VO$_2$ was increased minute by minute rather than by stage (i.e., 3 minute increments; steady state) because the intensity of the arm exercise was greater than expected for this group of participants.

In this investigation, the obese and non-obese groups were significantly different ($p<.05$) for physiological characteristics and anthropometric arm measurements. Specifically, the two groups differed in body weight, BMI, % body fat, waist circumference, hip circumference, waist to hip ratio, abdominal diameter, fat-free mass, arm circumference, arm fat area, and arm volume. For these dependent variables, the obese group means were significantly greater than the non-obese group, which was expected. It was important to validate that these physiological characteristics were significantly different in order to compare the physiological responses between two different groups that differed by fat mass during the arm exercise test.

VO$_2$ Expressed Relative to Body Weight

As exercise intensity increased, VO$_2$ expressed relative to body weight for obese group did not increase similarly to the non-obese group. The most important group comparisons during
exercise would be comparisons of minutes 4-7. Minute four was representative of unloaded cycling, minute five represented initial application of 1 kg resistance, and minute seven was the final minute when all subjects completed the exercise test. For minutes four through six, mean VO$_2$ (ml kg$^{-1}$ min$^{-1}$) was greater in the non-obese compared to the obese. When expressed per kg of body weight the VO$_2$ of obese group appears smaller when compared to the non-obese group because they have a greater body weight over which oxygen consumption is theoretically distributed.

The obese women had a significantly greater body weight compared to the non-obese, but the obese individuals did not have a greater peak VO$_2$ (ml kg$^{-1}$ min$^{-1}$) compared to the non-obese. The obese women also had a significantly greater FFM compared to the non-obese. These results contradict the findings of Balady et al. (1990) who compared both men and women (20 to 29 years) during an arm ergometry test and found that men had a greater mean body weight, achieved a greater peak oxygen consumption (20.7±3.9 versus 15.5±3.1 ml kg$^{-1}$ min$^{-1}$) and had a greater power output (103±34 versus 58±18 W) compared to the women. For the current study, peak VO$_2$ (ml kg$^{-1}$ min$^{-1}$) was 20.8±3.9 for the non-obese and 17.9±2.7 ml kg$^{-1}$ min$^{-1}$ for the obese. For peak VO$_2$ (ml kg$^{-1}$ min$^{-1}$) the values for both groups in the current study were slightly greater compared to the women’s results from Balady et al. (1990). However, for the current study the power output began at 50 W which was approximately the peak power output reached by the women in the study by Balady et al. (1990).

**VO$_2$ Expressed in Absolute Terms**

There were no differences for VO$_2$ (l min$^{-1}$) when VO$_2$ was not expressed relative to body weight during any minute of exercise. Therefore, the same amount of oxygen was being used
during each minute of exercise regardless of group. In addition, there were no differences in peak VO$_2$ (l min$^{-1}$) between the groups.

Enders, Hopman, and Binkhorst (1994) examined the relationship between upper arm dimensions and oxygen uptake and found that the men in their study reached a peak VO$_2$ of 2.54 ± 0.33 l min$^{-1}$. It is to be expected that the values in the Enders et al. (1994) study were greater than those in the current study because men generally have higher VO$_2$ values compared to women. The men in their study also reached a higher power output of 125 ± 17.4 W compared to the current study. Enders, Hopman, and Binkhorst (1994) found that peak VO$_2$ was best explained by the cross sectional area of the muscles plus bone of the upper arm ($r = 0.65$, $p < 0.005$). Therefore, they explained that to standardize peak VO$_2$, upper arm dimensions should be used rather than body mass or fat free body mass for arm ergometry. These results are similar to the conclusions of Hintzy, Grappe, and Perrey (2008) who stated that VO$_2$ during unloaded arm cycling were significantly and positively correlated with the circumference of the arm. They concluded that the specific anthropometric characteristics of the upper body recruited during arm ergometry affected VO$_2$ considerably compared to anthropometric measurements of the entire body. The results of these studies are different from the current study because the differences in arm anthropometric measurements between the obese and non-obese groups did not lead to differences in VO$_2$.

**VO$_2$ Expressed Per Kg of FFM**

When VO$_2$ was expressed per kg of FFM no differences in VO$_2$ were present between the groups. These results were similar to the findings of Warren et al. (1990) who examined FFM (kg) and made comparisons between men and women. Warren et al. (1990) found that men had a greater FFM (61.3 vs. 40.8 kg) compared to the women. These differences for the groups for
FFM did not lead to differences between the genders for VO₂ ml·kg·FFM⁻¹. In the current study, FFM was statistically different for the non-obese and obese groups (42.1 vs. 46.8 kg), but there were no differences for VO₂ and VO₂ peak when expressed as ml·kg·FFM⁻¹.

**Effects of Arm Volume and Upper Arm Muscle Mass on Peak VO₂**

Even though there were differences for FFM between the groups, but no differences for VO₂ ml·kg·FFM⁻¹, the current study also estimated upper arm volumes and upper arm muscle area because generally, the greater the active muscle mass during physical activity, the greater the max VO₂ (McArdle, Katch & Katch, 1996).

As expected, upper arm volumes were significantly greater in the obese (2260±665) compared to the non-obese (1440±263). However, the greater arm volumes did not lead to greater upper arm muscle area or peak VO₂ for the obese. The findings for arm volume and upper arm muscle area from the present study are similar to the findings of Warren et al. (1990) who reported untrained men had significantly greater arm volume and arm fat free volume (FFV) compared to the women. The larger arm FFV led to significantly greater peak VO₂ during arm cranking for the men compared to the women. Although FFV in the present study were similar to Warren et al. (1990) peak VO₂ results conflicted with their findings. For the current study, peak VO₂ results were not significantly different between the obese and non-obese groups.

These differences in peak VO₂ between Warren et al. and the present study may be due to the different exercise protocols. The Warren et al. (1990) protocol began at 6-12 W with the power output increasing by 6-12 W every two minutes, while for the current study, the load added for the first stage was 50 W with an additional 25 W added for each successive stage (i.e., every 3 minutes). These findings by Warren et al. (1990) suggested that the percentage variance of peak VO₂ explained by muscle mass was only 2-4% of the variance in arm-to-leg peak VO₂.
differences. Warren et al. (1990) also suggested that they over estimated the active musculature during the exercise test using arm volume because arm volume includes bone and other tissues and not just the active muscles. The same can be stated for the current study. There were no differences for upper arm muscle area between the groups unlike the arm volumes which were significantly greater in the obese versus the non-obese. Therefore, other physiological factors that have not been examined in this study may explain more of the variance in VO$_2$. These factors for future research might include cardiac output and the ability of the active muscles to utilize the oxygen.

In this study, peak HR was significantly different between the obese (181±9) and non-obese (173±8). This may be because more obese individuals completed more stages during the exercise test and therefore worked at a greater power output, eliciting a greater HR response. These results were similar to Balady et al. (1990) who found that men reached a greater peak HR compared to the women (170±20 versus 158±18 beats min$^{-1}$). It should be noted that the men reached a greater power output so it would be expected that they had a higher peak HR.

No difference in RPE was found between the obese and non-obese groups. These results were similar to the results of Hills et al. (2006) for a walking test. Both the obese and non-obese groups perceived the exercise test to be difficult. In this study, all of the participants final RPE reached 17-20 for Borg’s 6-20 scale. These high ratings of perceived exertion were expected for the exercise test because previous research found ratings of perceived exertion to be greater during an arm exercise test compared to the leg exercise test (Borg, Hassmen, & Lagerstrom, 1987). Borg, Hassmen and Lagerstrom (1987) explained that “working harder” during arm ergometry versus leg ergometry is due to the difference in muscle mass involvement between the upper and lower extremities. The authors concluded that in order to maintain the same power
output, individuals have to “work harder” which results in increased blood flow and lactate accumulation, resulting in higher degrees of perceived exertion. Borg, Hassmen, and Lagerstrom (1987) found that RPE increased with power output during arm ergometry. Therefore, the authors suggested the RPE scale is valid for testing perceived exertion during arm ergometry.

Limitations

A factor that may limit interpretation of the results of this study is that the protocol progressed too intensely for these participants. After the warm-up phase with no load, 1kg was added for the first stage. This was the initial load because the basket was 1 kg for Monark 874e which was used to standardize the workload rather than the friction braked table arm ergometer. After this stage, each subsequent stage consisted of an additional 0.5kg. However, not all of the participants were able to complete two full stages (i.e., each stage was 3 minutes of exercise). The participants did not reach a steady-state; as a result, this test was considered a VO$_2$ peak test. After the exercise test was completed, the participants stated they could not continue due to shoulder and arm fatigue and wrist and forearm pain. Even though the arm ergometer is a non-weight bearing exercise, it is still very difficult for individuals who do not normally do arm work. It should be noted that during the exercise test, when the weight became too difficult for many of the subjects, there was much assistive upper body movement (i.e., shoulder girdle) from side to side in order to continue cranking at 50 RPM.

Future Research

The purpose of using a progressive three minute stage protocol was so that the participants would reach steady state. However, the resistance added was too difficult for this population. It is suggested that future studies only incrementally add 0.25kg resistance for the stages and that the stages only last one minute (i.e., use a ramp protocol) in order to maximize
the cardiovascular responses and perhaps investigate ventilatory threshold during arm cycling. It would be important to change the progression of adding resistance so that a VO\textsubscript{2} max test can possibly be attained and to minimize ending the exercise test due to muscular fatigue and pain. Also, future studies should determine a way to minimize the movement of the upper body including the shoulder girdle and trunk which was especially prevalent in the current study when the load was added.

Conclusion

In this study, the obese participants had more fat mass and arm fat area compared to the non-obese participants. However, this extra fat mass was not associated with more arm muscle area in the obese group. Furthermore, there were no differences in oxygen consumption for the groups. The arm ergometer is a non-weight bearing exercise, but is very intense especially for individuals who do not train their upper body. The extra fat weight on the arms of the obese individuals did not significantly affect the exercise responses measured. Therefore, it is recommended that the arm ergometer be prescribed for obese individuals who cannot handle the stresses associated with walking or cycling.
References


APPENDIX A:

LOW RISK INDIVIDUALS
Low Risk Individuals

According to ACSM (2006) low risk is anyone who has no more than one risk factor threshold, including: a family member who had a myocardial infarction, coronary revascularization, or sudden death before 55 years of age in father or other male first degree relative, or before 65 years of age in mother or other female first-degree relative; a current cigarette smoker or one who quit within the previous 6 months; systolic blood pressure ≥ 140 mm Hg or diastolic ≥ 90 mm Hg, confirmed by measurements on at least two separate occasions, or on antihypertensive medication; low-density cholesterol ≥ 130 mg dL⁻¹ or high-density lipoprotein cholesterol ≤ 40 mg dL⁻¹; fasting blood glucose >100 mg dL⁻¹ confirmed by measurements on at least two separate occasions; body mass index ≥ 30 kg m⁻² or waist girth > 102 cm for men and > 88 cm for women or waist/hip ratio > 0.95 for men and > 0.86 for women; persons not participating in a regular exercise program or not meeting the minimal physical activity recommendations from the U.S. Surgeon General’s Report.
APPENDIX B:

FLYER
Are you a female between the ages of 18 to 30 years?

If so, how would **YOU** like to participate in research a study?

**Benefits of this study:**

- Find out your body fat %
- Learn about your overall health at rest and your responses to exercise

![Photo](www.ncpad.org/get/images/gallery/normal/6a.jpg)

To learn more about this study, please e-mail

**cmhenry@bgsu.edu**
APPENDIX C:

INFORMED CONSENT FORM
INFORMED CONSENT STATEMENT

PROJECT TITLE: Physiological Responses of Obese and Non-obese Women to Arm Ergometry

Investigator: Charlene M. Henry, Graduate Student, BGSU

Please read this entire document carefully. It will explain procedures for which your consent and participation are requested. Feel free to ask questions at any time during the study.

AGREEMENT TO PARTICIPATE: You are being asked to participate in this research study because you are a female between the ages of 18 and 30 years and are apparently healthy. This signed consent form is to certify that you are willing to participate in this research study. Approximately 30 subjects will be asked to participate. Your participation is voluntary and you have the right to withdraw at any time without penalty.

PURPOSE OF THE STUDY: The purpose of this study is to compare physiological responses of obese and non-obese women to arm ergometry.

PROCEDURES: All testing procedures will be performed in the Exercise Physiology Laboratory, 124 Eppler South, in the Kinesiology Division of the School of Human Movement, Sport, and Leisure Studies. The research procedures will consist of your voluntary involvement in two visits to the laboratory. You are asked to follow and complete the procedures outlined below for the visits.

The following pre-exercise tasks will be completed (Visit 1):

1. Complete a medical history questionnaire (standard questionnaire for the Exercise Physiology Laboratory; see attachment.
2. Read and sign this consent form. The primary investigator will explain the procedures involved in the study and answer any questions you may have.
3. You will be familiarized with the equipment that will be used in the study.
4. Schedule an appointment for your second visit.

The following exercise tasks will be completed (Visit 2):

Exercise Test: You will complete arm cycling to exhaustion. You will hold the handles and turn the wheel at 50 rpm with no load for three minutes. After this warm-up period, we will make it harder to pedal every three minutes until you can no longer pedal. After you can no longer pedal, the load will be taken off and you will continue to pedal for 3 minutes until your heart rate...
recovers to a lower value. You will stay seated and rest for two minutes while we measure your blood pressure and oxygen consumption.

MEASUREMENTS TAKEN PRIOR TO EXERCISE TEST

- Height and Weight
- Waist, Hip and Arm Circumferences—Measurements will be taken at the smallest portion around your waist, the largest portion around your hips, and your upper arm using a tape measure.
- Abdominal Diameter—Measurements will be taken by having you lay on a table while using yardsticks to measure from the table to the top of your stomach.
- Blood Pressure
- Skinfolds—Measurements will be taken by gently pinching three areas where fat normally accumulates. The three areas that will be pinched are the tricep (back of upper arm), above the hip, and thigh.
- Arm Volume—Measurements will be taken by having you submerge your arm into a tube filled with water from your fingertips to your armpit. The amount of water that spills out will be measured.

MEASUREMENTS TAKEN DURING THE EXERCISE TEST

- Oxygen Consumption: You will wear a special mouthpiece during the exercise test to measure oxygen consumption.
- Heart rate will be continuously monitored throughout the exercise test using an EKG.
- Ratings of Perceived Exertion: You will rate your feelings of how hard you are working using a scale from 6-20 every 3 minutes during exercise.

RISKS: Before beginning the test, you should understand the possibility that adverse changes and responses to exercise may occur. These may include fatigue, injury while exercising, and, though extremely unlikely, sudden death. You may also experience muscle soreness, especially 1-2 days following the arm crank ergometer exercise. In the unlikely event of physical injury, appropriate emergency measures will be taken such as CPR, First Aid, and calling 911. If necessary, medical treatment will be obtained at Wood County Hospital, Bowling Green, Ohio. The cost of such treatment will be at the financial expense of the participant.

BENEFITS: The benefits from your participation in this study are that you will receive an assessment of your physiological status at rest and exercise. You will also receive assessment of your physical characteristics.

CONFIDENTIALITY: Information you provide will remain confidential and your identity will not be revealed. Only the investigator will have access to this information. Individual results and data will be combined with other subjects’ data for summarizing. Your identity will not be revealed in any published results. Information will be stored and locked in my office.

VOLUNTARY PARTICIPATION: Your participation in this study is voluntary and you can refrain from answering any or all questions without penalty or explanation. You are free to
withdraw your consent and to discontinue participation at any time. Your relationship with BGSU or the primary investigator will not be affected whether you decide to participate or not.

CONTACT INFORMATION: If you have any questions or comments about this study, you can contact Charlene Henry at cmhenry@bgsu.edu or (419) 372-2878 or Lynn Darby, advisor at ldarby@bgsu.edu or (419) 372-6903. If you have questions about the conduct of this study or your rights as a research participant, you may contact the Chair, Human Subjects Review Board, Bowling Green State University, (419) 372-7716 (hrsb@bgsnet.bgsu.edu).

Authorization: I have read this document and the study has been explained to me. I have had all of my questions answered. I volunteer to participate in this study.

A copy of this document will be made for you if requested.

_________________________________________  ____________________________
Participant’s Signature  Date

_________________________________________  ____________________________
Printed name  Phone # and email
APPENDIX D:

HEALTH HISTORY QUESTIONNAIRE
EXERCISE PHYSIOLOGY LABORATORY
124 EPFLER SOUTH, SCHOOL OF HUMSLS
BOWLING GREEN STATE UNIVERSITY

MEDICAL HISTORY QUESTIONNAIRE

All information given is personal and confidential. It will enable us to better understand you and your health and fitness habits. In addition, we will use this information to classify your health status according to the American College of Sport Medicine in ACSM’s Guidelines for Exercise Testing and Prescription (2006). Please let us know if and when you have changed your medication (dose & type), diet, exercise or sleeping habits within the past 24 or 48 hours. It is very important for you to provide us with this information.

NAME_________________________________ AGE______ DATE___________________
OCCUPATION______________________________________________________________

1. FAMILY HISTORY

Check each as it applies to a blood relative:

* Heart Attack yes____ no____ unsure____
  If yes, age at onset________ years

* Sudden Death yes____ no____ unsure____
  If yes, relation to you__________
  Age of relative at onset________ years

Father’s Age_________ Deceased________
Age at death________

Mother’s Age_________ Deceased________
Age at death________

2. PERSONAL HISTORY

Check each as it applies to you:

* Current Cigarette Smoking yes____ no____ unsure____

* High Blood Pressure yes____ no____ unsure____
  Systolic Blood Pressure ≥140mmHg
  or diastolic ≥90mmHg
  If yes, give value if known: ____________mmHg

* High Blood Cholesterol yes____ no____ unsure____
  Total Serum Cholesterol ≥200 mg·dl⁻¹
  If yes, give value if known: ____________mg·dl⁻¹

* Diabetes Mellitus yes____ no____ unsure____
  If yes, age of onset: ____________ years

* Obesity – BMI >30 kg·m⁻²
  yes____ no____ unsure____
  If yes, give value if known: ____________kg·m⁻²

* Sedentary Lifestyle yes____ no____ unsure____

Persons not participating in a regular exercise program or not meeting the minimal physical activity recommended from the U.S. Surgeon General’s Report.

Have you ever had:

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<td>Back Pain</td>
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<tr>
<td>Leg Cramps</td>
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<tr>
<td>Low Blood Pressure</td>
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<tr>
<td>Insomnia</td>
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</tr>
</tbody>
</table>

For Office Use Only:

___ Number of coronary heart disease risk factors* (according to Table 2-4 ACSM (2006))

NOTE: All risk factors are explained verbally to each person completing the questionnaire.
Classification according to ACSM (2006): ___ Low risk; ___ Moderate risk; ___ High risk

3. MEDICAL HISTORY

Name of your physician

Date of your most recent physical examination

What did the physical examination include?

Have you ever had an exercise EKG? Yes No

Are you presently taking any medications? Yes No

List name and dosage

(Include over-the-counter medications and/or herbs)

Have you ever taken:

<table>
<thead>
<tr>
<th>Medication</th>
<th>Yes</th>
<th>No</th>
<th>Unsure</th>
<th>Yes</th>
<th>No</th>
<th>Unsure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Digitalis</td>
<td></td>
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<td></td>
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<tr>
<td>Nitroglycerin</td>
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<tr>
<td>High Blood Pressure</td>
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<td></td>
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<tr>
<td>Medication</td>
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<tr>
<td>Sedatives</td>
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<tr>
<td>Inderal</td>
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</tbody>
</table>

Insulin

Pronestyl

Vasodilators

Other

If yes, list medications:

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________
4. EXERCISE HISTORY

Do you exercise? Yes____ No____ What activity__________________________________________

How long have you been exercising?____________________________________________________

How many days do you exercise?________ How many minutes per day?_______________________

What kinds of shoes do you work out in?__________________________________________________

Where do you usually exercise?__________________________________________________________

Do you monitor your pulse during your workout?____________________________________________

5. HEALTH HISTORY

<table>
<thead>
<tr>
<th>At Age 20</th>
<th>At Age 30</th>
<th>At Age 40</th>
<th>One Year Ago</th>
<th>Most Weighed</th>
<th>Least Weighed</th>
<th>After Age 20</th>
</tr>
</thead>
</table>

Height____ Weight____

Do you use Health Foods? Yes____ No____ List____________________________________________________

Do you take Vitamin pills? Yes____ No____ List____________________________________________________

Approximate your daily intake: Coffee____ Tea____ Coke____ Beer____ Wine____ Liquor____

Do you smoke or use tobacco products? Yes____ No____

If yes, approximate your daily usage: Cigarettes____ Cigars____ Pipes____ Chewing Tobacco____

Did you ever smoke? Yes____ No____ How many years?______ Age when you quit______

Approximate the number of hours you work per week______ Vacation weeks per year________

Home Status: Very happy____ Pleasant____ Difficult____ Problem____

Work Status: Very happy____ Pleasant____ Difficult____ Problem____

Do you feel you are stressed? Yes____ No____ Unsure____

Are you worried about your health? Yes____ No____ Unsure____
6. APPROXIMATE A TYPICAL 24 HOUR DAY FOR YOU

Number of hours:

Work
TV
Relaxation/Leisure Activities
Driving/Riding
Eating
Exercise
Sleep
TOTAL

Additional information from client interview to further assess health/coronary risk status:

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________

Signature of Tester

Date

Revised 10/22/08
1/12/06
APPENDIX E:

PRE-EXERCISE TEST INSTRUCTIONS
Pre-Exercise Test Instructions

- Please refrain from caffeine, alcohol, nicotine, or food 2-3 hours prior to the exercise test.
- Please avoid strenuous physical activity 24 hours prior to the exercise test.
- Please wear a sports bra and comfortable attire (e.g., shorts, t-shirt, sneakers).
- Please do not put on any lotion the day of the exercise test.