6-28-2017

The Validity of Submaximal Exercise Testing in Obese Women

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THE VALIDITY OF SUBMAXIMAL EXERCISE TESTING IN OBESE WOMEN

A Capstone Project Presented in Partial Fulfillment

of the Requirements for the Degree Bachelor of Science

with Honors College Graduate Distinction at

Western Kentucky University

By

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May 2017

*****

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Dedicated to my family, friends, and all the professors who have helped me along the way.

ACKNOWLEDGEMENTS

I would like to thank my parents for always putting their children first. They both gave up so much to give me a better life and I appreciate every opportunity I have been given. To my dad, thank you for showing me that hard work can open many doors and teaching me to continue to pursue my dreams. Mom, many thanks for being my go-to on many occasions and for working tirelessly to help me become my best self.

I also wish to recognize Dr. Rachel Tinius for all of her support and aid in researching for and writing this thesis. Without her passion for the field, I would not have found an interest in this research. Her lectures were extremely thought-provoking and her availability outside of the classroom only aided in the learning process.

Much gratitude to Dr. Jill Maples for her help in pooling participants for this project. Dr. Maples' background in research and interest in my research is a big reason why I asked her to be my secondary reader.

Lastly, thank you so much to all my participants. Without you all, this thesis would not have been possible. I appreciate your time and continued participation throughout my research process.

ABSTRACT

Background: Submaximal exercise tests use heart rate responses to low-to-moderate intensity activity in order to predict cardiorespiratory fitness (VO_{2max}). Currently used tests may be inappropriate for obese populations as obese women have altered heart rate responses to exercise. The purpose of this project is to test the validity of the Modified Bruce Protocol submaximal treadmill test in obese women. **Methods:** Normal-weight (NWG) and obese women (OBG) completed the Modified Bruce submaximal treadmill test (to predict VO_{2max} using previously validated equations) and a maximal graded exercise test on a treadmill using the Standard Bruce Protocol (to obtain an actual VO_{2max}) on two separate occasions. The relationships between actual and predicted VO_{2max} values were analyzed using correlation coefficients. **Results:** 9 NWG (age: 23.1±8.0 y, body fat: 23.5±4.9%) and 9 OBG (age: 22.0±4.8 y, body fat: 36.9±4.4%) women participated. Actual and predicted VO_{2max} values were not correlated among the OBG (r=0.48, p=0.23) but were positively correlated in the NWG (r=0.71, p=0.03). **Conclusions:** Protocols for predicting fitness in NWG women do not appear to be valid in obese women. Separate equations should be considered in order to maximize the accuracy of exercise testing in obese women, and thus improve health care providers' ability to evaluate patients and tailor exercise prescriptions.

Keywords: VO_2 max, Bruce/Modified Bruce Treadmill Test, Obesity

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Ringenberg, G., Tinius, R. (2017, February). *The validity of submaximal exercise testing in obese women.* Poster presented at the SEACSM Regional Conference. Greenville, SC.

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CHAPTER 1

INTRODUCTION

In the United States, approximately 2 in 3 adults are classified as overweight or obese (Fryar & Ogden, 2012), defined as a body mass index (BMI) greater than 25kg/m^2. Reports also show similar statistics for all adult American women, with 38.3% falling into obese categories (Ogden et al., 2015). These statistics rank the USA as the 12th most obese country in the world (WorldAtlas, 2016). In order to combat obesity, many doctors recommend a healthy diet and exercise. There are many health-related benefits of exercising for those who are overweight and obese. These benefits include improvements in strength, blood lipids, blood pressure, plasma glucose, and weight status (Russo et al., 2016); all areas that can predispose overweight/obese individuals to future health issues.

When exercise is prescribed in order to combat obesity, exercise testing is used to establish a baseline fitness level as well as to assess the impact of a prescribed exercise intervention. The goal of exercise testing is to establish an accurate assessment of exercise capacity. The gold standard for assessing cardiorespiratory exercise capacity, or aerobic fitness, in apparently healthy individuals is by measuring maximal oxygen consumption, VO_{2max} (Pescatello, Arena, Riebe, & Thompson, 2014, pp. 114-118), by having a participant/patient exercise until they reach a point of volitional fatigue.

A VO_{2max} can be estimated using an easier, less taxing modality called a submaximal exercise test. These tests are typically used in patients who have increased risk for cardiovascular events and/or other contraindications to high-intensity exercise (i.e. exercising to volitional fatigue is not advisable), or when sophisticated testing equipment (i.e. metabolic gas analyzer) is not available. While most practitioners prefer that those with a history of medical conditions undergo submaximal testing, there are no specific instructions for those who are obese (Pescatello et al., 2014, pp. 127). Submaximal tests are time-efficient and easy to administer, especially in overweight and obese populations. Obese individuals have a lower tolerance to exercise and are less willing to participate in exercise sessions with higher intensities (Mattsson, Larsson, & Rossner, 1997); thus, they will likely be more inclined to participate in a submaximal exercise test.

Not only is submaximal testing more practical, but it is also safer for obese individuals who may be at risk for other obesity-related exercise health conditions. It should be noted that, according to ACSM guidelines, obesity is a positive risk factor for cardiovascular disease (Pescatello et al., 2014, p. 27). Obese individuals may have contraindications to maximal exercise testing, but many of these would be considered relative (e.g. chronic infections, uncontrolled metabolic diseases, tachyarrhythmia's or bradyarrhythmia's, electrolyte abnormalities, severe arterial hypertension), meaning the risks of exercise testing would be outweighed by the benefits gained after an accurate assessment of fitness and long-term health prognosis is established (Pescatello et al., 2014, p. 27-53). Thus, valid submaximal exercise testing is very important among obese individuals as they have much to gain from a high-quality exercise assessment and subsequent tailored intervention. However, most submaximal tests used—the Astrand and Rhyming step test, Astrand-Rhyming cycle ergometer protocol, YMCA cycle protocol, and Modified Bruce treadmill protocol—rely heavily on heart rate responses to exercise to predict fitness (Pescatello et al., 2014, p. 78-85). Because it is well-established that obese women have altered heart rate responses to exercise (Ciolac & Greve, 2011), it is likely that the equations typically used among normal-weight populations that rely on heart rate responses to exercise to predict fitness may not be valid among obese populations. However, these differences in validity have not been studied.

The purpose of this project is to test the validity of submaximal treadmill testing in obese women. We suspect that submaximal exercise tests are currently being used inappropriately in obese populations, as it has been shown that obese women have altered heart rate responses to submaximal exercise compared to normal-weight women. If this is the case, alternate equations should be considered to predict fitness levels in obese populations in order to prescribe accurate exercise programs. The results of this project are clinically important because if a physician or fitness professional wants to prescribe an accurate exercise protocol to an obese woman for weight loss, they will need clinically accurate values to determine her present fitness level.

CHAPTER 2

LITERATURE REVIEW

This chapter is dedicated to examining the studies investigating the validity of estimating VO_{2max} in normal-weight and overweight or obese female populations.

Health Issues Associated with Obesity

Obesity rates are at an all-time high with one-third of the U.S. population being classified as clinically obese (Centers for Disease Control and Prevention [CDC], 2015). Obesity is a serious health concern, as it has a strong relationship with the occurrence of chronic medical conditions (Strum, 2002). These conditions include, but are not limited to, high blood pressure, high cholesterol, Type II diabetes mellitus, coronary heart disease, stroke, gallbladder disease, osteoarthritis, sleep apnea, cancer (breast, endometrial, colon, kidney, gallbladder, and liver), mental illnesses such as depression and anxiety, and overall mortality (CDC, 2015; Strum, 2002). These chronic conditions contribute to high health care costs and poor quality of life. Specifically, obesity contributes to an increase of 36% in health care costs and 77% in medication costs compared to normal-weight population's costs (Strum, 2002). Because obesity has a substantial impact on long-term health as well as health care costs, interventions to reduce obesity and its subsequent disease states are critical.

For the past two decades, obesity has been considered an epidemic in the United States. It has been shown that gaining 11 pounds puts an individual at two times the risk for developing Type II diabetes, while weight gains greater than 44 pounds increases the risk four times compared to normal-weight individuals (Wellman & Friedberg, 2002).

Obesity is highly correlated with depression, as the individuals often encounter prejudice and discrimination. In fact, obese individuals have gone as far to report that they would rather be deaf, dyslexic, blind or have undergone an amputation than be severely obese (Wellman & Friedberg, 2002); thus, the mental and physical challenges of being clinically obese are substantial.

How Does Exercise Improve These Conditions in Obese Populations

Obesity has a significant impact on the risk for subsequent health issues; however, research suggests exercise can improve and even reverse obesity-associated health issues when prescribed properly. One study by Russo et al. (2016) found that an intensive lifestyle intervention in obese individuals promoted favorable anti-atherogenic changes. These subjects underwent nutritional advising and a three-month, two-day a week exercise program. The results of this study found reductions in BMI, blood pressure, plasma triglycerides, and plasma glucose. They also found improvements in muscle strength and maximal oxygen uptake. The researchers concluded that positive changes to diet and exercise could potentially reduce obese patients' cardiovascular risk without pharmacological treatments.

In the year 2000, obesity was the seventh leading cause of death in the US, accounting for nearly 300,000 deaths a year (Wellman & Friedberg, 2002). Being overweight or obese is typically associated with increased risk of death or disease, but reductions in body fat percentage or overall weight reduces risk factors for many diseases. Losing 10 pounds or more has been associated with reductions in triglyceride levels, total cholesterol, and LDL, as well as increases in HDL. A 20-pound loss in patients with Type II non-insulin dependent diabetes restores up to 35% of the reduction of life expectancy due to diabetes. Overall, weight loss could reduce the need for medications that treat preventable disease, as well as reduce mortality associated with obesity (Wellman & Friedberg, 2002).

Interventional therapy including exercise can reduce medical complications and costs associated with obesity. For example, a study by Farah, Berenguer, Prado, Junior, & Dias (2012) found that systolic blood pressure reductions are associated with anaerobic exercise programs and reductions in body mass in obese individuals. These decreases in blood pressure can be attributed to mechanical, metabolic, inflammatory, and neural factors also associated with decreased body mass. The researchers concluded that a well-planned exercise regimen should be set in place, especially for obese populations, to reduce risk for future cardiovascular disease. Another study by Villareal et al. (2006) found that regular exercise combined with a weight-reducing diet in obese populations improves almost all metabolic coronary heart disease risk factors. They also found that inflammation, provoked by obesity, was decreased by moderate weight loss (Villareal, 2006).

Physical activity among obese individuals has also been linked to improvements in quality of life. Higher levels of physical activity in individuals who were subjectively or objectively defined as ‘physically active’ were associated with higher health-related quality of life. Objective measurements of physical activity had a 53% higher health-related quality of life ($r=0.072$)—chi-square statistical significance ≤ 0.10. The results were consistent across all groups considered ‘physically active’ despite weight category (Anokye, Trueman, Green, Pavey, Taylor, 2012).

Health-related quality of life was shown to increase on many subscales following a diet and exercise intervention in a study conducted by Imayama et al. (2011). Compared to the controls, the intervention group increased vitality, physical functioning, and mental health scores. The diet and exercise group also decreased perceived stress, compared to an increase in the control group. Overall, weight loss was shown to have positive impacts on physical functioning, vitality, mental health scores, and depression scores. A linear relationship was seen between aerobic fitness and physical functioning (Imayama et al., 2011).

Purposes of Submaximal Exercise Testing

Submaximal exercise tests were created for many purposes to meet the needs of various populations. An exercise test should generally “produce a sufficient level of exercise stress without physiologic or biomechanical strain” (Noonan & Dean, 2000, p. 784). Many health care providers and fitness experts prefer submaximal exercise testing because there is less risk involved and aerobic capacity predictions and information concerning the subject’s exercise response can still be determined.

Both the Modified and Standard Bruce protocols can be used for clinical exercise testing. Other tests (e.g. walk tests, cycle tests, step tests) can be used for individuals with existing conditions (e.g. orthopedic limitations, chronic airway obstruction, renal disease, and advanced age) to provide a reasonable estimate of aerobic capacity without putting the patient at risk for an adverse event. Many of these submaximal tests are proven reliable and valid in other specific populations (Noonan & Dean, 2000).

Validation of Equations in Normal-Weight/Fit Populations & The Lack of Literature on Exercise Testing in Obese Populations

A VO_{2max} test is the most widely accepted test and is considered the "gold standard" for measuring cardiorespiratory fitness (Pescatello et al., 2014). A study by Bennett, Parfitt, Davidson, and Eston (2016) investigated the validity of several submaximal step tests in determining maximal exercise capacity among healthy adults. The Personalized Step Test and Astrand-Rhyming Step Test were determined to have little standard error and were deemed good predictors of VO_{2max}. This study deemed that overall there was a relatively strong ability for the chosen submaximal step tests to predict the subject's VO_{2max} (Bennet et al., 2016).

Noonan & Dean (2000) sought the validity of the Modified Bruce Treadmill Test in healthy adults and determined the Pearson product-moment correlation coefficient between the predicted and actual VO_{2max}. They found a correlation coefficient (r) of 0.94 for men and 0.93 for women without cardiac conditions. The Standard Bruce Test also reported a standard error of the estimate (SEE) of 3.5 mL/kg/min.

The Single-Stage Submaximal Treadmill Walking Test was cross-validated in individuals aged 20-59 with no health problems. The correlation between the predicted and actual VO_{2max} was strong (r=0.96). These values show high correlations between an individual's predicted and actual VO_{2max} using this specific testing procedure (Noonan & Dean, 2000).

Very few studies have been done to investigate how accurate and valid submaximal tests are in predicting maximal aerobic capacity in obese populations. One study conducted by Wisen, Mao, Christiansen, & Saltin (2015) compared an Astrand submaximal cycle test to a maximal cycle ergometer test. They found the Astrand test to be a poor predictor of fitness levels. They concluded the discrepancies between the values was that the differences between the estimated VO_{2max} and the actual VO_{2max} might be due to already elevated heart rates in obese individuals found during submaximal loading, resulting in a lower estimated value. Their overall conclusion was that the submaximal Astrand cycle test was unreliable when testing obese subjects. This shows that further research must be done to test the validity of, and potentially alter, submaximal equations in obese populations to increase accuracy.

<u>Heart Rate Variability/Responses with Exercise in Overweight/Obese Populations</u>

There are several cardiac and autonomic differences associated with obesity. The findings of a study conducted by Alrefaie (2014) uncovered the loss of protective vagal influences and decreased sympathetic influence on heart rate in overweight and obese adolescent females at rest.

It has also been found that the autonomic nervous system has a diminished ability to respond to changes in body position in obese individuals (Piccirillo et al., 1998). A study by Piccirillo et al. (1998) revealed lowering of sympathetic modulation of the heart after exposure to sympathetic stressors and at rest. Further, the autonomic nervous system is responsible for recovery and the body's ability to respond to stress (such as exercise). Autonomic nervous system alterations are measured by baroreflex sensitivity and heart rate variability—both of which are lower among obese individuals (Ciolac and Greve, 2011). Therefore, it is understood that obese individuals may have an impaired ability for their heart rate to respond to exercise stimuli when compared to normal-weight individuals. Because nearly all prediction equations require the usage of heart rate in submaximal testing equations, it is logical that obese and normal-weight women may require separate equations as they have different heart rate responses to exercise.

Taken together, this data suggests that although submaximal testing based on heart rate can be useful predictors of fitness in normal-weight populations, these tests may not be accurate predictors of fitness among obese populations. It is well-established that heart rate responses are altered in obese populations, and therefore, it is reasonable to believe currently validated equations are not valid for use in obese men and women.

CHAPTER 3

METHODOLOGY

Approval for this study was granted by Western Kentucky University's Institutional Review Board (IRB# 16-247). A study was piloted using 18 female participants (Appendix A) comprised of a normal-weight group and an obese group. From January 25^{th}, 2016 through February 1^{st}, 2017, all 18 participants were recruited, consented, and studied on two separate occasions. These participants were chosen from a convenient sample of college students, ex-students, and/or faculty and staff members. Participants were recruited through emails or through guest speaking at class meetings on campus. Participants were made aware of the risks and benefits of the study, as well as the voluntary nature of the project.

Only female participants were chosen to participate due to the physiologic and hormonal differences between genders that could influence test outcomes. The number of participants (n=18) was chosen based on feasibility for this pilot project. Nine normal-weight (NWG) women age 23.1±8.0 years and nine obese women (OBG) age 22.0±4.8 years participated.

Each participant was asked to attend two different sessions with at least 3-days of rest in-between visits in the Exercise Physiology Laboratory at Western Kentucky University. At visit one, their body fat percentage was measured using Lange Fat Calipers (Lange Skinfold Caliper, Beta Technology, Santa Cruz, CA 2008) on seven sites of the body—the tricep, subscapular, chest, midaxillary, suprailiac, abdomen, and thigh—and these numbers were entered into standardized equations to calculate total subcutaneous percentage of body fat. The American College of Sports Medicine (2014) has a validated body composition equation (Appendix D) for females using the seven sites used in testing. Each site was measured two times and the average of the two measurements was used. If the two measurements were greater than 2mm apart, a third was taken and the closest two measurements were averaged. Each participant's blood pressure was taken, and their height (in centimeters) and weight (in kilograms) were recorded. They were also asked to take a screening questionnaire to ensure they were healthy enough to participate in the study (Physical Activity Readiness Questionnaire [PAR-Q]).

At each visit, the participants performed one of two exercise tests on a treadmill. The maximal testing visit consisted of the Standard Bruce Protocol and the submaximal testing visit consisted of the Modified Bruce Protocol. The order of testing was alternated for each participant. Both protocols were chosen based on validity and reliability among non-obese populations (Noonan & Dean, 2000). Both protocols can be found in Appendix C.

Participants were fitted with a headset and mouthpiece for gas collection. The mouthpiece is connected to the metabolic gas analyzer (TrueOne 2400 Metabolic Analyzer, Parvomedics, Sandy, UT 2011). Among many things, this systems provides time expired, heart rate, VO_2, respiratory exchange ratio, and metabolic equivalents which help the user to determine whether or not the participant has reached a maximal effort. The test conducted during one of the visits was submaximal—where they did not have to work very hard to complete the test—using the Modified Bruce protocol (Appendix C). The test was completed when the participant had two stages with a steady state heart rate of greater than 110 beats per minute but less than 85% of their predicted heart rate maximum. During the other visit, the maximal test required work at a maximal effort—where participants continued the protocol until they reached volitional fatigue—using the Standard Bruce testing protocol (Appendix C). Participants were carefully monitored at each visit by the study team.

Following testing procedures, all data for the participants was plugged into previously determined equations to determine estimated fitness levels. The Center for Disease Control and Prevention (2013) has validated an estimated VO_{2max} equation (Appendix D) that the study team modified to fit the Modified Bruce testing protocol and heart rates attained during the submaximal part of the study. Each participant's VO_{2max} was directly measured using the Standard Bruce treadmill test and the metabolic cart, so VO_{2max} values were directly obtained from the metabolic analyzer. Using a maximal graded exercise test and a metabolic analyzer is the gold standard for directly measuring cardiorespiratory fitness (Pescatello et al., 2014).

Using the directly measured VO_{2max} and the predicted VO_{2max} , Pearson product-moment correlation coefficients were calculated to determine the relationships between the two values in each of the two groups (normal-weight and obese). As the correlation coefficient value (r-value) increases, the strength of the correlation increases. A p-value less than 0.05 is considered to be statistically significant and shows that the relationship was not found by chance. All statistical analysis was performed using SPSS version 24.

CHAPTER 4

RESULTS

The study pre-screened 20 participants and excluded two due to incompletion of the second half of the study. The final study cohort consisted of 18 females. Of these, nine were considered the normal-weight group (NWG) and nine were considered to be the overweight/obese group (OBG). The NWG was considered the control group to test the validity of the tests and chosen equation (Appendix's C & D).

The NWG had a body fat percentage of 23.5 ± 4.9 and the OBG had a body fat percentage of 36.9 ± 4.4 ($p<0.001$). All other demographic variables (besides body weight, NWG: 62.7 ± 7.7kg vs. OBG: 96.9 ± 25.7kg, $p=0.001$) were similar between groups (Appendix A, Table 1). There were no discrepancies between the activity levels of the groups, both being sedentary by ACSM classification standards and determined via the pre-exercise risk classification form.

Table 1. Demographic Characteristics

Variable	***Normal-Weight Group (mean ± SD)***	***Obese Group (mean ± SD)***	***p-value (t-test)***
Age (years)	23.1 ± 8.0	22.0 ± 4.8	0.73
Height (cm)	165.3 ± 7.0	164.9 ± 6.9	0.89
Weight (kg) *	62.7 ± 7.7	96.9 ± 25.7	0.001
Body Mass Index (kg/m^2)*	22.9 ± 2.5	35.5 ± 8.5	0.001
Body Fat (%) *	23.5 ± 4.9	36.9 ± 4.4	<0.001
Systolic Blood Pressure (mmHg)	114.0 ± 5.8	119.5 ± 9.2	0.16
Diastolic Blood Pressure (mmHg)	74.7 ± 6.4	78.8 ± 4.9	0.16

**p<0.05, denotes statistical significance*

Table 2. Exercise Characteristics

Variable	*Normal-Weight Group (mean ± SD)*	*Obese Group (mean ± SD)*	*p-value (t-test)*
Predicted VO_{2max} (ml/kg/min) *	41.6 ± 9.1	29.7 ± 7.9	0.009
Actual VO_{2max} (ml/kg/min) *	40.8 ± 8.2	30.6 ± 4.3	0.004
Maximal RER	1.2 ± 0.04	1.2 ± 0.09	0.80
Maximal Heart Rate (HR)	186.4 ± 10.7	188.3 ± 11.1	0.74
% of Age-Predicted Maximal Heart Rate (%)	95.0 ± 5.1	95.3 ± 4.8	0.89

**$p<0.05$, denotes statistical significance*

The normal-weight group was significantly more fit based on VO_{2max} values (NWG: 40.8 ± 8.2ml/kg/min vs. OBG: 30.6 ± 4.3ml/kg/min, p=0.009). Both groups reached their true VO_{2max} based on objective exercise data. Both groups achieved a respiratory exchange ratio (RER) of ≥1.1 and a maximal heart rate ≥95% of age-predicted maximal heart rate. These are two of the main criteria used to determine whether or not an individual reached a true maximal effort during testing (Pescatello et al., 2014). Not only does it appear our participants reached their true VO_{2max}, but more importantly there were no differences between groups in maximal exercise criteria (Appendix B, Table 2).

Six of the nine participants in the NWG had a difference between their actual and predicted VO_{2max} values of less than five ml/kg/min. An additional two participants in the NWG had the difference between actual and predicted values less than an eight ml/kg/min (Figure 1). Only four out of the nine participants in the OBG had a difference of less than five ml/kg/min between their actual and predicted VO_{2max} values, with all others having value discrepancies greater than eight ml/kg/min (Figure 2).

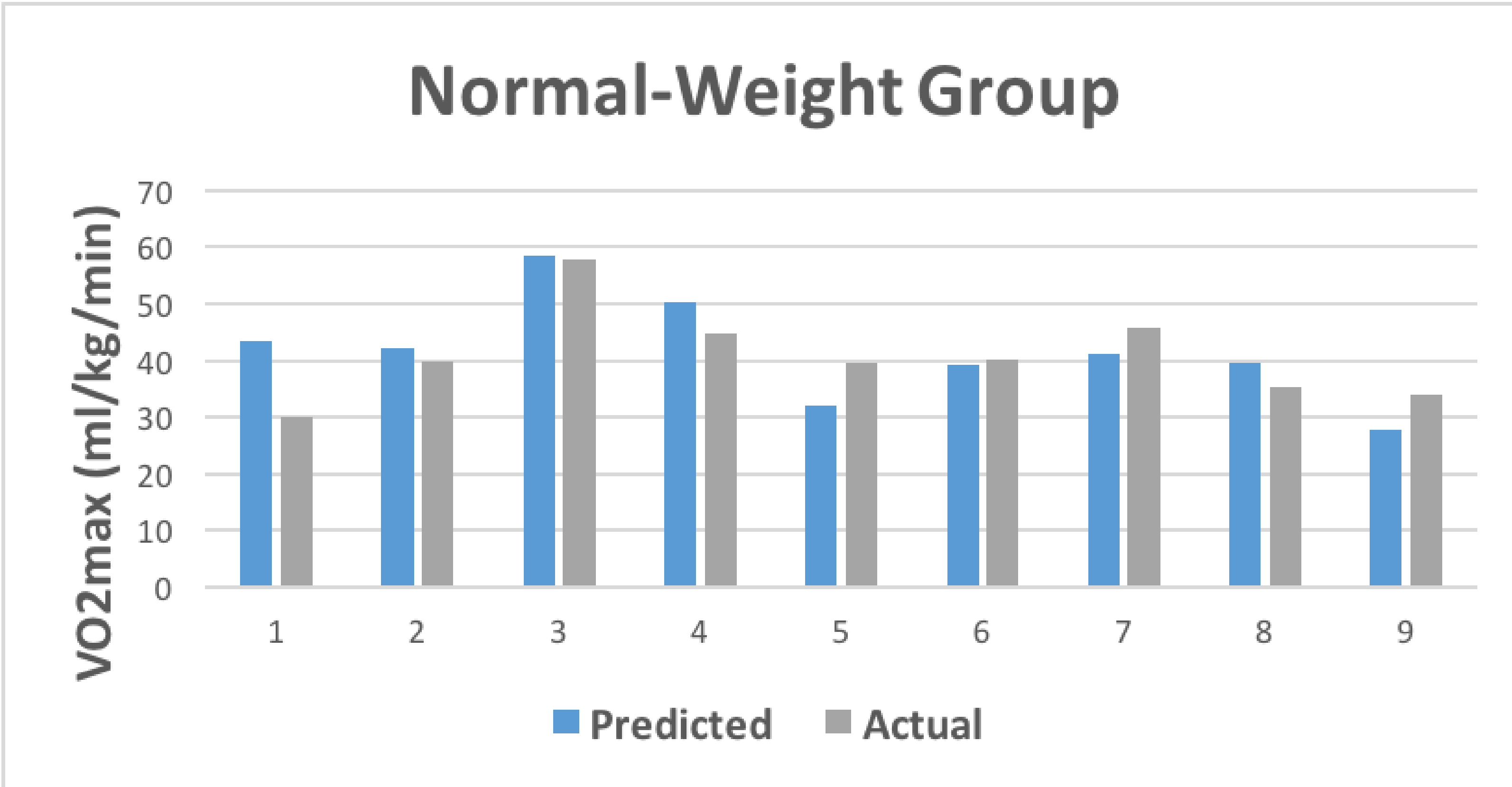

Figure 1. Actual and predicted VO_{2max} values for individuals in the normal-weight group

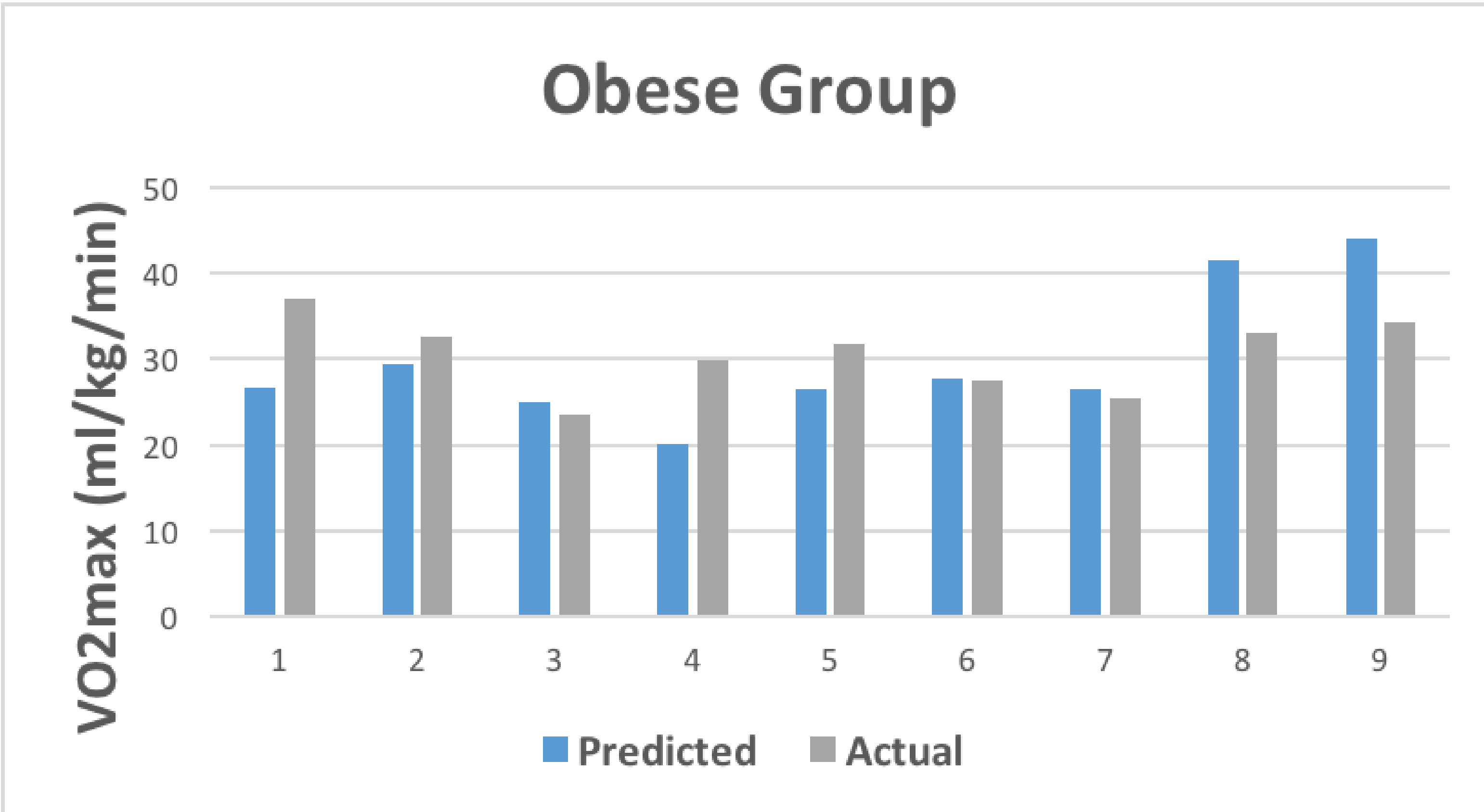

Figure 2. Actual and predicted VO_{2max} values for individuals in the obese group

Pearson product-moment correlations were run and significant predictors were found at or below the 0.05 level. The actual and predicted VO_{2max} values were found to be significantly positively correlated in the NWG (r=0.71, p=0.03), as shown in figure 3. Contrary to the NWG, the OBG had no correlation between actual and predicted VO_{2max} values (r=0.48, p=0.23), as shown in figure 4.

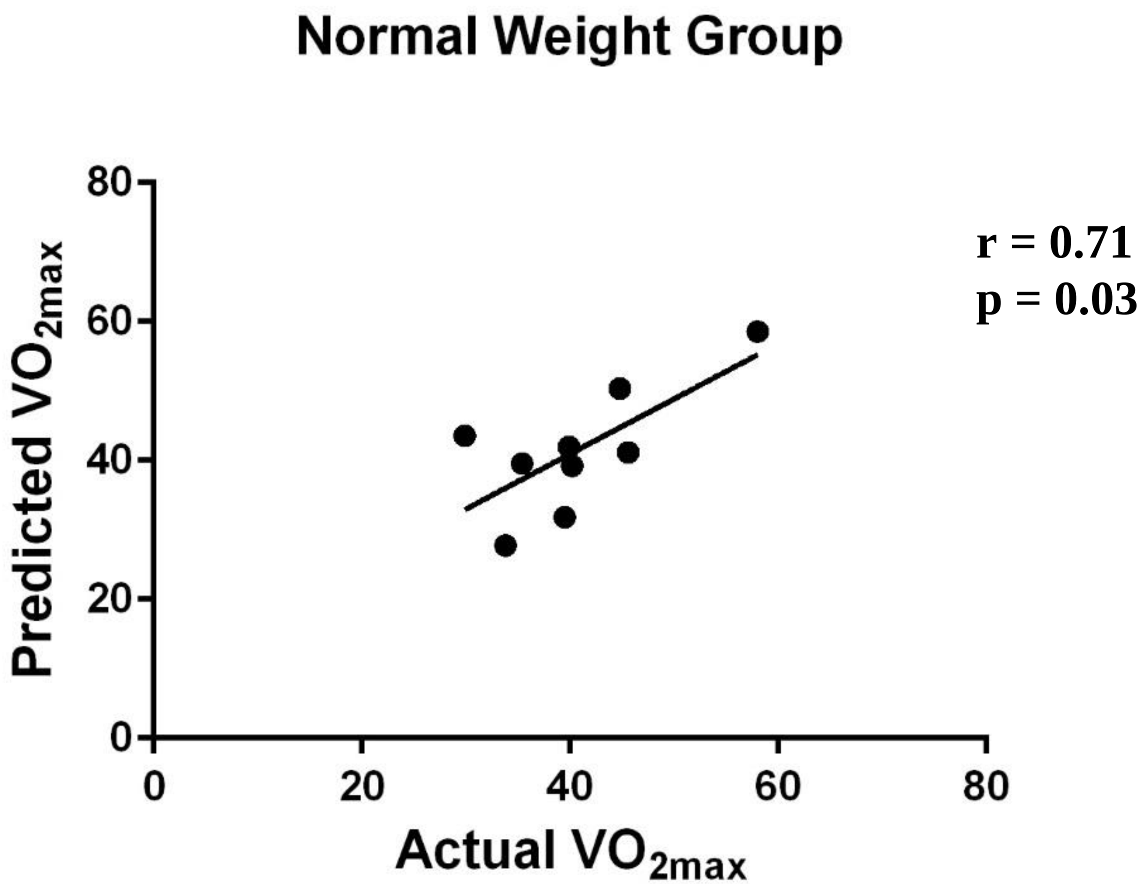

Figure 3. Correlation between actual and predicted VO_{2max} values for the normal-weight group

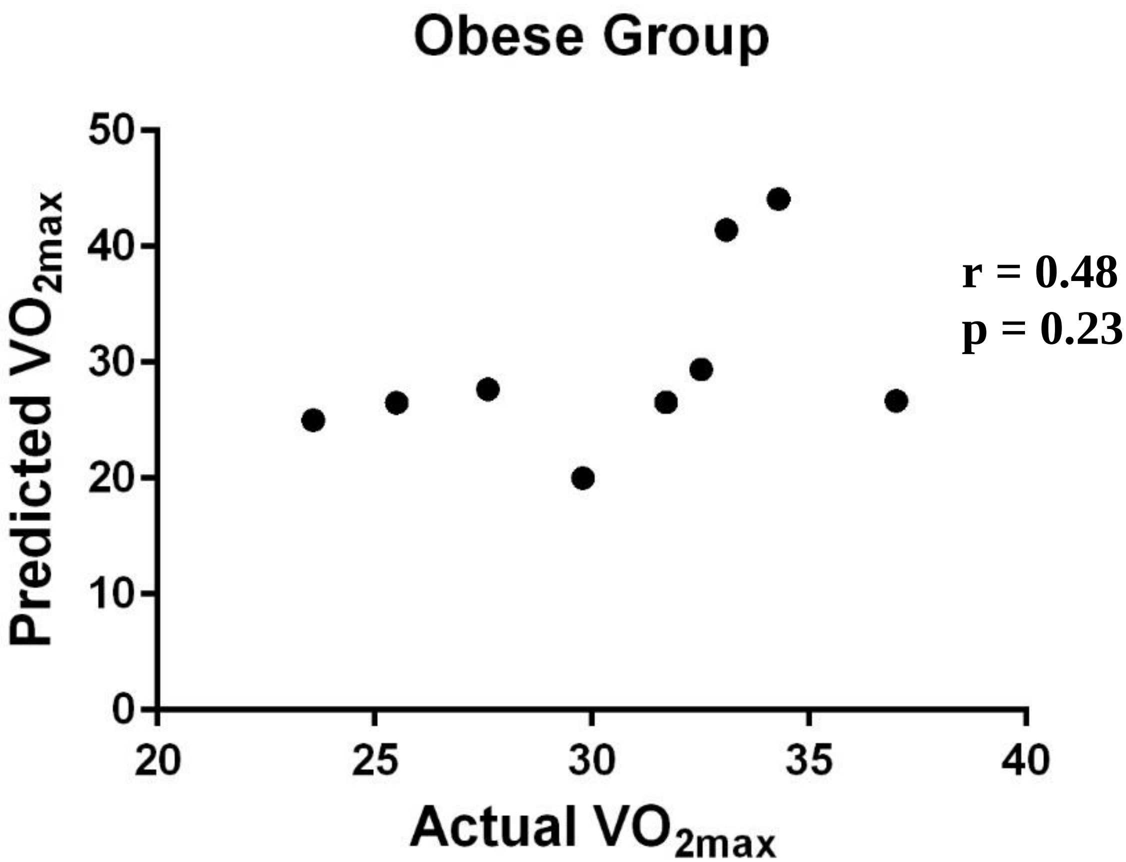

Figure 4. Correlation between the actual and predicted VO_{2max} values for the obese group

CHAPTER 5

CONCLUSION

This study confirms that standardized equations for predicting fitness in normal-weight populations may not be valid in overweight and obese female populations. This is consistent with the only previous study looking at the accuracy of VO_{2max} prediction in cycle protocols for obese individuals (Wisen, Mao, Christiansen, & Saltin, 2015). This study furthers this finding to show that submaximal treadmill protocols also do not appear to be accurate predictors of cardiorespiratory fitness levels in obese populations.

According to this research, separate equations should be considered in order to maximize the accuracy of exercise testing (and thus, prescription) in overweight and obese women. Obese women's predicted fitness cannot be accurately calculated using the CDC's validated equation (Appendix D) alongside the Modified Bruce treadmill protocol (Appendix C).

The current study had several limitations. First, the sample size was small due to the pilot nature of this project. Only female participants were chosen to participate due to the physiologic and hormonal differences between genders that could influence test outcomes; therefore, these findings may not be generalizable to male populations. In addition, our results may or may not be generalizable to active obese populations, as we only tested sedentary obese women.

Future research should be conducted to test the validity of submaximal exercise testing in overweight and obese men using the same protocol—thus, making these results more generalizable. In addition, future research projects could explore the validity of other submaximal protocols in obese populations such as cycle tests, the 6-minute walk test, step tests, and field tests.

Researchers should also make an effort to create new equations for submaximal exercise testing that are specific for overweight and obese individuals and thus would be valid in the overweight and obese populations. These improvements to existing equations would increase tests' accuracy and therefore allow for more accurate exercise prescriptions.

With obesity being a very serious health concern, the need for valid prediction equations is essential in this population. Validated equations will allow health care providers and fitness experts to better assess fitness levels in obese patients. This will allow them to make better personalized intervention plans, better assess fitness goals, and ultimately, better the health of their patient. Validated tests will allow for health care providers to maximize the achievement of the well-established benefits of exercise in obese individuals (Russo et al., 2016; Wellman & Friedberg, 2002).

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APPENDIX A: PARTICIPANT DEMOGRAPHICS

Normal-Weight Participants:

Participant ID	Age (yrs)	Height (cm)	Weight (kg)	Systolic BP (mmHg)	Diastolic BP (mmHg)	Body Fat %	Predicted VO2 (ml/kg/min)	Actual VO2 (ml/kg/min)
002	18	167.5	69.01	108	78	30.11	43.58	29.9
003	20	165	52.66	118	76	22.33	41.98	39.9
004	22	154.94	64.9	124	86	22.45	58.55	58
007	44	176	72.4	112	82	24.87	50.37	44.8
010	20	163.4	60.8	120	66	21.94	31.85	39.5
011	23	162	65.6	112	70	28.67	39.23	40.2
012	23	169.4	64	108	70	13.62	41.14	45.6
016	19	172.9	66.2	116	72	26.49	39.59	35.4
017	19	156.5	48.4	108	72	20.7	27.8	33.8

Overweight/Obese Participants:

Participant ID	Age (yrs)	Height (cm)	Weight (kg)	Systolic BP (mmHg)	Diastolic BP (mmHg)	Body Fat %	Predicted VO2 (ml/kg/min)	Actual VO2 (ml/kg/min)
001	19	169.5	81.72	116	74	32.98	26.69	37
005	34	165.5	113	118	82	42.98	29.38	32.520
006	20	165.8	137.8	[redacted]		42.73	25	23.58
008	21	171	127.8	130	86	41.56	20.01	29.8
009	18	166.8	63.6	136	78	34.94	26.56	31.7
013	19	171.1	108.6	116	78	37.78	27.68	27.6
018	21	149	79.2	110	76	33.22	26.52	25.5
019	22	165	85.2	110	72	33.46	41.43	33.1
020	24	160	75.2	120	84	32.73	44.11	34.3

APPENDIX B: EXERICSE CHARACTERISTICS

Normal-Weight Participants:

Participant ID	Age (years)	Maximal RPE	Maximal RER	Maximal HR (bpm)	% Age-Predicted Max HR
002	18	11	1.20	198	98%
003	20	N/A	1.18	189	94.5%
004	22	19	1.25	190	96%
007	44	N/A	1.23	178	101.1%
010	20	19	1.16	196	98%
011	23	17	1.23	181	91.9%
012	23	17	1.14	166	84.3%
016	19	12	1.13	193	96%
017	19	12	1.20	Malfunction	Malfunction

Overweight/Obese Participants:

Participant ID	Age (years)	Maximal RPE	Maximal RER	Maximal HR (bpm)	% Age-Predicted Max HR
001	19	14	1.18	201	100%
005	34	17	1.07	177	95.2%
006	20	17	1.15	172	86%
008	21	120	1.21	198	99.5%
009	18	17	1.35	Malfunction	Malfunction
013	19	12	1.20	202	100.5%
018	21	14	1.03	185	93%
019	22	14	1.24	185	93.4%
020	24	13	1.21	186	94.9%

APPENDIX C: TREADMILL PROTOCOLS

Standard Bruce Protocol GXT

Stage	Speed (MPH)	Grade (%)	Duration (Min.)
I	1.7 mph	10%	3 min.
II	2.5 mph	12%	3 min.
III	3.4 mph	14%	3 min.
IV	4.2 mph	16%	3 min.
V	5.0 mph	18%	3 min.

Modified Bruce Protocol GXT

Stage	Speed (MPH)	Grade (%)	Duration (Min.)
I	1.7 mph	0%	3 min.
II	1.7 mph	5%	3 min.
III	1.7 mph	10%	3 min.
IV	2.5 mph	12%	3 min.
V	3.4 mph	14%	3 min.
VI	4.2 mph	16%	3 min.

APPENDIX D: LIST OF EQUATIONS

Estimating VO_{2max} using (Modified) CDC equations:

$$Estimated\ VO_{2max} = \frac{PMHR - Intercept}{Slope}$$

- PMHR = Predicted Maximal Heart Rate
- Slope = Change in Heart Rate/Change in VO2 consumption between Stage 2 and 3 of Assigned Protocol → Modified Bruce Protocol
- Intercept = Y#-(Slope)*X#
    - Y# = mean of End of Stage 2 Heart Rate and End of Stage 3 Heart Rate
    - X# = mean of End of Stage 2 $VO_2$and End of Stage 3 VO_2

Source:

Centers for Disease Control and Prevention. (2016). *Key concepts about estimating VO2 max*. Retrieved from https://www.cdc.gov/nchs/tutorials/PhysicalActivity/Preparing/CVX/Info4_Step2. Htm

ACSM Women's Skinfold Seven-Site Formula:

Body Density = 1.097 – 0.00046971 × (sum of seven skinfolds) + 0.00000056 × $(sum\ of\ seven\ skinfolds)^2$ - 0.00012828 × (age)

Source:

Pescatello, L. S., Arena, R., Riebe, D., & Thompson, P. D. (Eds.). (2014). *ACSM's guidelines for exercise testing and prescription* (9th ed.). (pp.68). Philadelphia, PA: Wolters Kluwer Health, & Lippincott Williams & Wilkins.

APPENDIX E: INFORMED CONSENT

Project Title: Testing the validity of a submaximal exercise test in overweight women

You are being asked to participate in a project conducted through Western Kentucky University. The University requires that you give your signed agreement to participate in this project.

The investigator will explain to you in detail the purpose of the project, the procedures to be used, and the potential benefits and possible risks of participation. You may ask any questions you have to help you understand the project. A basic explanation of the project is written below. Please read this explanation and discuss with the researcher any questions you may have.

If you then decide to participate in the project, please sign on the last page of this form in the presence of the person who explained the project to you. You should be given a copy of this form to keep.

1. **Nature and Purpose of the Project:**
   The obesity epidemic is significant public health concern in the United States and abroad. It is well-established that one of the best ways to combat obesity is through exercise.[1] The best way to administer an exercise program is through exercise testing and prescription with a trained fitness professional. Exercise testing is a valuable tool used by health and fitness professionals to assess the health status of an individual, provide a basis for exercise prescription, as well as track the progress of fitness interventions. This study plans to test the validity of a commonly used "easy" exercise test in overweight women and compare it to test results in in normal-weight women. If the test is not valid in overweight women as we suspect it is not, we will attempt to create an equation that can be used in exclusively overweight women.

2. **Explanation of Procedures:**
   You will be asked to come in for two study visits. At visit 1, your body fat percentage will measured using skinfold calipers. You will also be asked to take a screening questionnaire to ensure you are healthy enough to participate in the study.
   At each visit, you will perform an exercise test on a treadmill (each will take about 15minutes). One will be submaximal (i.e. you will not have to work very hard to complete the test). The other test will require you work to a maximal effort (participate in the test as long as you are able to). You will be carefully monitored at each visit by the study team.

3. **Discomfort and Risks:**
Potential risks from participation in the program are typical of those related to participating in physical activity. Specifically, there is a risk of physical injury or discomfort, including muscle soreness. However, we will do our best to ensure that the program progresses gradually and that you are given ample instructions as to how to perform exercises safely. You understand also that it is not possible to identify all potential risks and you believe that reasonable safeguards have been taken to minimize both the known and potential but unknown risks.

4. **Benefits:**
The direct benefits to you include the potential to improve physical health, including improvement in your cardiorespiratory fitness. In addition, you will gain the knowledge of your cardiorespiratory health as well as how to increase it. Indirect benefits to you include research for health and fitness professionals who may use results to create more accurate testing and training for various populations.

   You will be paid $25 for each visit, for a total of $50 for participating in the study.

5. **Confidentiality:**
A hard copy file will be kept on subjects and stored in a locked cabinet in Dr. Tinius' locked office. Participants will be assigned a study specific identifying number (PID) upon entry to the study, after which all medical information is referenced by this number. There will be an electronic master data list kept on a locked computer. Databases that contain private health, medical or research information are behind firewalls, require password/username for access, are maintained using the PID, and only the Faculty Sponsor will have access to these files. All hardcopy data records are stored in locked file cabinets and kept in a locked office.

6. **Refusal/Withdrawal:**
Refusal to participate in this study will have no effect on any future services you may be entitled to from the University. Anyone who agrees to participate in this study is free to withdraw from the study at any time with no penalty.

I have read this Informed Consent form, fully understand its terms, understand that I have given up substantial rights by signing it, and sign it freely and voluntarily, without inducement.

You understand also that it is not possible to identify all potential risks in an experimental procedure, and you believe that reasonable safeguards have been taken to minimize both the known and potential but unknown risks.

____ _______________
Participant's Name (Printed) Date

____ _______________
Signature of Participant Date

____ _______________
Witness Date

THE DATED APPROVAL ON THIS CONSENT FORM INDICATES THAT
THIS PROJECT HAS BEEN REVIEWED AND APPROVED BY
THE WESTERN KENTUCKY UNIVERSITY INSTITUTIONAL REVIEW BOARD
Paul Mooney, Human Protections Administrator
TELEPHONE: (270) 745-2129