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THE EFFECT OF AN ACUTE BOUT OF HIGH INTENSITY RESISTANCE EXERCISE ON RESTING METABOLIC RATE OF APPARENTLY HEALTHY ADULT WOMEN

A Thesis

Submitted to the School of Graduate Studies and Research

in Partial Fulfillment of the

Requirements for the Degree

Master of Science

Julianne N. Reger

Indiana University of Pennsylvania

August 2015

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Title: The Effect of an Acute Bout of High Intensity Resistance Training on Resting Metabolic Rate of Apparently Healthy Adult Women

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Little research has been conducted on the effects of resistance exercise on resting metabolic rate of females of various body mass indexes and ages. The present study examined the effects of a single bout of high intensity resistance exercise on the RMR in apparently healthy adult females (n=18, 18-45 years old, BMI of 18.5 kg/m^2-29.9 kg/m^2). RMR was measured before, immediately post exercise, and 24 hours post exercise to determine if the exercise bout increased RMR. Results indicated a significant increase in absolute RMR from baseline to immediately post exercise (1807.50 kcal/day to 2103.77 kcal/day, p=.000). There was no significant increase in absolute RMR from baseline to 24 hours post exercise (1807.50 kcal/day to 1765.22 kcal/day, p=.789). These results suggest that the high intensity resistance exercise significantly increased the RMR immediately post exercise, but RMR did not remain elevated above baseline 24 hours post exercise.

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CHAPTER I

INTRODUCTION

In the United States, 68% of adults are either overweight or obese, and 33.33% of the population is obese (Miller et al., 2012). Health care professionals are focused on factors that positively affect body composition by facilitating weight loss in overweight and obese individuals, predominantly physical activity and proper diet (Gilliat-Wimberly, Manore, Woolf, Swan, & Carroll, 2001). Physical activity is a component of total energy expenditure, the exchange of energy, necessary to perform biological work (Lee, Blair, Manson, & Paffenbarger, 2009). Total energy expenditure in humans has three components, basal metabolic rate (BMR), thermic effect of feeding (thermogenesis), and energy expenditure of activity (activity thermogenesis) (Levine, 2005). Past research has established that resting metabolic rate represents 60-75% of daily energy expenditure. Physical activity and its effect on energy expenditure is the focus of many research studies. Several research studies have examined the effects of certain components of an exercise program on energy expenditure. For example, Poehlman and Melby (1998), studied the effects of resistance training on energy expenditure while other researchers examined the effect of diet and physical activity on metabolic responses (Akbulut & Rakicioglu, 2011).

Resting metabolic rate, RMR, is the measurement of the energy expended in terms of kilocalories (kcals) to maintain normal physiological functions such as breathing, homeostasis, and immune function. Multiple factors including age, gender, genetics, total body weight, fat free mass (FFM), and fitness level, influence RMR. Fat free mass, maintained by exercise, is the factor most highly correlated to RMR (Broeder, Burrhus, Svanekiv, & Wilmore, 1992). Research has found that by increasing physical activity, caloric expenditure is increased, allowing for an improvement in body composition which can decrease the prevalence of obesity and assist in weight management (Broeder, Burrhus, Svanevik, & Wilmore, 1992). Most of the research involving RMR has been conducted in men to examine the effects of aerobic exercise on RMR. Few studies have been conducted to examine the effects of a single bout of high intensity resistance exercise in women. Therefore, the purpose of this study is to examine the effects of an acute bout of high intensity resistance exercise on the resting metabolic rate in apparently healthy adult females.

Problem Statement

The purpose of this study is to examine the effect of an acute bout of high intensity resistance exercise on the resting metabolic rate in apparently healthy women, ages 18-45 years.

Primary Research Question

Is there an effect of an acute bout of high intensity resistance exercise on resting metabolic rate in apparently healthy adult women, ages 18-45?

Secondary Research Questions

1. Will age affect baseline resting metabolic rate independent of body mass index?
2. Will there be an effect of body mass index on resting metabolic rate at baseline independent of age?

Hypotheses

1. Resting metabolic rate will increase immediately and remain elevated above baseline 24 hours after an acute bout of high intensity resistance exercise.
2. At baseline, resting metabolic rate will be higher in women 18 to 30 years of age compared to women 31 to 45 years of age, independent of body mass index.

3. Women with a body mass index of 18.5-24.9 kg/m^2 will have a higher resting metabolic rate compared to women with a BMI of 25-29.9 kg/m^2 independent of age.

Definition of Terms

Activity Thermogenesis: The energy expenditure required during physical activity, accounting for 10% of total daily energy expenditure.

Acute Bout: A single, one time bout.

Adipose Tissue: Fat that insulates and cushions the body.

Basal Metabolic Rate: An individual's energy expenditure at complete rest, typically measured directly after an individual wakes up in the morning. Accounts for approximately 60% of total energy expenditure.

Body Composition: This is used to describe the percentage of fat, bone, and muscle in the human body.

Body Mass Index (BMI): A weight to height ratio calculated by dividing an individuals weight in kilograms by the square of an individuals height in meters.

BodPod™: The BodPod is a machine that uses Air Displacement Plethysmography to measure body density.

Energy Expenditure: The total amount of calories expended as a result of resting metabolic rate, physical activity, and thermogenesis.

Fat Mass: The amount of body weight that is adipose tissue. This is measured in kilograms.

High Intensity Resistance Exercise: Exercise that causes the muscles to contract against an external force such as a weight. High intensity resistance exercise is lifting a weight that is 80% of an individuals one repetition maximum.

Kcal: A kilocalorie, which is the general representation of a food calorie.

Lean Body Mass: The fat free mass or the amount of body weight that is not adipose tissue.

Metabolic Cart: This is a machine that directly measures expiratory gasses (oxygen and carbon dioxide) from an individual. These expired gasses are represented within milliliters per kilogram of body weight per minute.

Normal Weight: Classified as a body mass index of 18.5-24.9 kg/m^2.

Obesity: Classified as a body mass index of greater than or equal to 30.0 kg/m^2. A disease in which an individual's body weight or body mass index is above normal values.

One Repetition Maximum: The maximal amount of force that an individual can generate for one repetition.

Overweight: Classified as a body mass index of 25.0-29.9 kg/m^2.

Resting Metabolic Rate (RMR): This is the caloric energy required to sustain life and basic physiological functions. This can be measured in relative terms (kcal/day/kg) or in absolute terms (kcal/day). For this measurement, individuals must fast for 12 hours, refrain from physical activity for 24 hours prior to the measurement, and must not consume caffeine or nicotine prior to the assessment.

Thermic effect of food: The energy expenditure associated with food digestion and absorption, accounting for 10% of total energy expenditure.

Assumptions

1. All study participants were honest when completing their medical history including their medication use and exercise history.
2. ParvoMedics TrueOne 2400 Metabolic Measurement System™ was a reliable and effective resting metabolic rate testing instrument.
3. All study participants complied to the pre-testing guidelines for determining resting metabolic rate.
4. The sample population was an accurate representation of apparently healthy adult women between the ages of 18 and 45 who have no diagnosis of cardiovascular, pulmonary, or metabolic disease.

Limitations

1. The sample size may have limited the ability to detect statistical differences.
2. The ParvoMedics TrueOne 2400 Metabolic Measurement System™ was an indirect measure of resting metabolic rate; therefore, the accuracy of the values could be potentially skewed since it was not a direct measure.
3. The study participants potentially may not have followed the pre-testing instructions.

Significance

Since resting metabolic rate is an important component of total daily energy expenditure which is affected by physical activity, increasing physical activity is vital to maintaining or decreasing body weight. Since the incidence of obesity is increasing, it is imperative to continue and improve research regarding energy expenditure and physical activity to better prevent and treat obesity. As indicated by previous research, resting metabolic rate can be increased by an acute bout of high-intensity resistance exercise. There are limited studies examining changes in

RMR in women. This is largely attributed to the fact that men are most often recruited as participants in studies of RMR, as well as studies which focus on populations over 50 years old or younger than 25 years old (Gilliat-Wimberly et al., 2001). New research including women as the study participants are necessary. Additionally, there is a lack of research evaluating the effects of high intensity resistance training and its influence on RMR. Lastly, there is a lack of research examining the effect of age RMR. Therefore, the purpose of this study was to examine the effects of an acute bout of high intensity resistance exercise on resting metabolic rate in apparently healthy adult females.

CHAPTER II

REVIEW OF LITERATURE

The incidence of obesity has increased over the past several decades. In the United States, 68% of adults are either overweight or obese, and 33% of the population is obese (Miller et al., 2012). Obesity is associated with comorbidities such as hypertension, type I and II diabetes mellitus, cardiovascular disease, and a variety of musculoskeletal disorders. The incidence of obesity and its comorbidities can be prevented and modified with the identification of certain risk factors such as low levels of physical activity and decreased energy expenditure that predispose an individual to obesity. The following research addresses resting metabolic rate (RMR), its effects on caloric balance, and the effects of physical activity.

This review of literature is an initial evaluation of current research and review articles pertaining to this topic. Throughout the literature review, resistance training and its effect on resting metabolic rate is most meticulously evaluated. Additional focuses of the literature review include total energy expenditure, resting metabolic rate, the effect of aerobic exercise on resting metabolic rate, and the benefits of resistance training on resting metabolic rate.

Total Energy Expenditure

Total energy expenditure is the measure of the total amount of calories an individual expends during a 24 hour period. Total energy expenditure is often expressed as kcals/day. In humans, three components compromise total energy expenditure including the thermic effect of food, the energy expenditure of physical activity, also known as activity thermogenesis, and basal metabolic rate (BMR).

The thermic effect of food is the energy expenditure associated with food digestion and absorption, accounting for 10% of total energy expenditure. Activity thermogenesis is the energy expenditure during activity and contributes to 15-30% of total energy expenditure (Levine, 2005). The component of total energy expenditure that an individual can alter the most is activity thermogenesis by increasing ones physical activity levels, allowing for a greater total of large muscle movements (Akbulut & Rakicioglu, 2011). For activity to occur, the body must supply the muscles with adenosine triphosphate, ATP, which is a form of energy that allows processes such as muscle contraction to occur. Calorie expenditure is needed to produce ATP. Energy expenditure during exercise is increased by lengthening the duration and increasing the intensity of exercise (Levine, 2005). The third component of total energy expenditure is BMR. BMR is an individual's energy expenditure at complete rest and typically is measured directly after an individual wakes up in the morning. BMR accounts for approximately 60%-75% of total energy expenditure (Visser, Duerenberg, Staveren, & Hautvast, 1995). Resting and basal metabolic rate are similar and often are used interchangeably. BMR requires the subject to spend the night in a hospital or laboratory. It is measured first thing in the morning after a twelve hour fast, with no previous exercise for at least 24 hours, free from stress, acclimated to the measurement equipment, and completely rested. Resting metabolic rate is usually measured in the morning, after eight hours of restful sleep and a twelve hour fast, with no previous exercise for at least 24 hours. RMR does not require a subject to spend the night prior to the measurement. Some researchers believe RMR is a better indicator of total daily energy expenditure in comparison to BMR (McMurray, Soares, Caspersen, & McCurdy, 2013). Akbulut and Rakicioglu (2011) found that an increase in resting metabolic rate can be achieved through increasing physical activity (Akbulut & Rakicioglu, 2011).

Resting Metabolic Rate

Resting metabolic rate or resting energy expenditure, accounts for the total number of calories an individual expends during a day to maintain body functions and homeostasis (McMurray et al., 2013). Processes involved in maintaining resting metabolic rate include the energy costs of resting cardiovascular and pulmonary functions, energy costs of the central nervous system, thyroid activity, the sympathetic nervous system, and additional biochemical reactions that are constantly occurring within the body. According to Poehlman and Melby, 1998, resting metabolic rate is the largest contributor to total energy expenditure, accounting for 60-75% of total energy expenditure (Poehlman & Melby, 1998).

During a measurement of resting metabolic rate, the individual should have had eight hours of sleep the previous night, postprandial for twelve hours, not have exercised for at least twelve hours, and not be in a stressful state of mind (McMurray et al., 2014). There are three methods to determine resting metabolic rate which include indirect calorimetry, direct calorimetry, and non-calorimetric (Levine, 2005). The most common method, indirect calorimetry, estimates energy production by measuring oxygen (O_2) consumption and carbon dioxide (CO_2) production. Metabolic carts are most commonly used to collect and analyze these gases. Typical measurements from indirect calorimetry show that values usually range from 0.7 to 1.6 kcal/min (Poehlman & Melby, 1998). Direct calorimetry is the most precise measurement although extremely expensive and requiring a full time technician. Direct calorimetry measures the heat produced and lost from the body (Levine, 2005). This method requires a human calorimeter, a large respiration chamber, in which an individual essentially spends several hours or days in the chamber while air is drawn from the chamber and flow rate is analyzed for oxygen and carbon dioxide concentrations (Poehlman & Melby, 1998). Non calorimetric methods involve predicting energy expenditure by extrapolating physiological measurements and observations such as heart rate, electromyography, pulmonary ventilation, and thermal imaging (Levine, 2005).

Resting metabolic rate is influenced by a variety of factors including age, gender, body composition, and genetic factors. Resting metabolic rate decreases 2-3% per decade of life in response to the decrease of fat free mass seen with increasing age. A study by Frisard et al. (2007) examined how resting metabolic rate was influenced by age. The study population included 170 individuals who were a subset from the Louisiana Healthy Aging Study. The population was divided into three groups based upon ages of 20-34, 60-74, and 90 or older. Indirect calorimetry was used to measure resting metabolic rate. The results showed that resting metabolic rate was significantly different between the three age groups. For the 20-34 age group, the resting metabolic rate was 1,587 ± 50, 1,465 ± 37 for 60-74 year olds, and 1,165 ± 20 for 90 or older. As age increases, resting metabolic decreases; suggesting a negative linear relationship. The decline in physical activity and its impact on fat free mass has been associated with this decline in resting metabolic rate as age increases (Frisard et al., 2007). Older adults, ages 70 or older, generally have a resting metabolic rate of 20-25% lower than young adults (McMurray et al., 2014).

A study by Aleman-Mateo, Salazar, Hernandez-Triana, and Valencia (2006) was designed to examine if resting metabolic rate varied based on one’s geographical location. Forty subjects 60 and older from rural regions of Cuba, Chile, and Mexico participated. Total energy expenditure, resting metabolic rate, and physical activity levels were measured. The study found that although resting metabolic rate was higher in men than in women, there were no differences between the countries in regards to resting metabolic rate. This suggests that resting metabolic rate is not influenced by the country one resides (Aleman-Mateo, Salazar, Hernandez-Triana, & Valencia 2006). On average, men have a higher resting metabolic rate due to their typically higher volume of fat free mass (Poehlman & Melby, 1998). More research needs to be conducted that include women to validate this finding.

A study conducted by Visser, Duerenberg, Staveren, & Hautvast (1995) investigated the relationship between age, resting metabolic rate, and diet-induced thermogenesis. The study population was composed of 103 (63-33 year olds) and 56 (20-33 year olds). Resting metabolic rate was measured using indirect calorimetry with an open-circuit ventilated-hood system. In the young women, resting metabolic rate was 4.08 ± 0.33 kJ/min and 3.33 ± 0.39 kJ/min in elderly women. In young men, resting metabolic rate was 5.29 ± 0.53 kJ/min and 3.98 ± 0.46 kJ/min in elderly men. This study showed a relationship between age and RMR. The results suggest that there is a negative linear relationship between age and resting metabolic rate (Visser, Duerenberg, Staveren, & Hautvast, 1995).

Body composition is a component that greatly influences resting metabolic rate. Fat free mass consists of metabolically active muscle and organs (Steigler & Cunliffe, 2006). An increase in muscle mass is directly associated with an increase in resting metabolic rate. Those with a high BMI indicating he or she is overweight (25-29.9) or obese (30-39.9), may have a lower resting metabolic rate compared to an individual with a normal BMI (18.5-24.9) because of the decreased muscle mass which is highly metabolically active and increased adipose tissue which is not metabolically active (Miller et al., 2006). Resting metabolic rate is influenced by a variety of factors including age, gender, body composition, and genetic factors. Research also suggests that resting metabolic rate can be increased through exercise.

Exercise and Resting Metabolic Rate

Exercise and physical activity are terms commonly used interchangeably, although they are different. Exercise is planned, structured, repetitive physical activity that is done to improve one or more than one of the components of physical fitness. Physical activity is movement that requires energy. Regardless, both exercise and physical activity impact the resting metabolic rate. A study conducted by Miller et al. (2012) examined if a relationship existed between resting metabolic rate and cardiorespiratory fitness levels in 64 obese individuals. The participants had all been referred to a Missouri hospital for bariatric surgery. If the participant was a diabetic, to be included for the study, his or her BMI had to be greater than or equal to 35 kg/m^2, and if the participant was a non-diabetic and free of other comorbidities, his or her BMI had to be greater than or equal to 40 kg/m^2. Participants with pulmonary disease were not included in the study for their altered ability to safely perform a cardiopulmonary exercise test. Results not only showed that those in the lower resting metabolic rate group had a higher weight and BMI, but also they had a lower level of cardiorespiratory fitness, measured by a peak oxygen uptake test (Miller et al., 2012). This study is one of many that suggest exercise improves cardiorespiratory fitness along with increasing resting metabolic rate.

Akbulut and Rakicioglu (2011) studied the effects of physical activity on resting metabolic rate measured by indirect calorimetry by means of a longitudinal, clinical intervention study of 12 weeks. 37 overweight women (BMI> 25-29.9 kg/m^2) and obese women (BMI> 30 kg/m^2) ages 20-45 years were included in the study. The subjects were divided into either the diet alone (DA) or diet and exercise (DPA) group. The DPA group attended an exercise program of brisk walking 3-5 days a week for 30-45 minutes a session. The results indicated that RMR increased significantly at the end of the study in the DPA group. The initial RMR measurement in the DA group was 1,225.0 ± 54.31 kcal/day and 1,243.0 ± 54.89 kcal/day in the DPA group. At the end of the twelve weeks, RMR in the DA group was 1,122.7 ± 57.40 kcal/day compared to 1,455.2 ± 58.28 kcal/day in the DPA group. These results show that RMR can be affected by both diet and exercise when used concurrently (Akbulut & Rakicioglu, 2011).

An experimental study by Dolezal and Potteiger (1998) examined concurrent resistance and endurance training influence on resting metabolic rate in non-dieting individuals. The study population consisted of thirty physically active men who were randomly assigned to either an endurance trained group, a resistance trained group, and a combined endurance and resistance trained group. The training programs lasted ten weeks and all participants trained three days a week. The endurance group jogged or ran, the resistance group performed both Olympic free weights and machines, and the combined group both ran and performed the resistance exercises. The results indicated that the energy expenditure for the resistance training group increased from 7,613 ± 968 to 8,090 ± 951 kJ/day. The concurrent trained group increased from 7,455 ± 964 to 7,802 ± 981 kJ/day. However, the endurance group decreased 7,231 ± 554 to 7,029 ± 666 kJ/day (Dolezal & Potteiger, 1998).

Potteiger, Kirk, Jacobsen, and Donnelly (2008) examined whether resting metabolic rate would be affected by a 16 month moderate intensity exercise training program in overweight young adults. The 74 participants were between the ages of 17-35 with a BMI of between 25 and 34.9 kg/m^2. The participants were assigned to either the control group or the exercise group in which they walked on a treadmill at 60-75% of heart rate reserve 3-5 days per week for 20-45 minutes each session. The results indicate resting metabolic rate increased from pre to post training in women (1,583 ±221 to 1,692 ± 230 kcal/d) and in men (1,995 ± 184 to 2,025 ± 209 kcal/d). Resting metabolic rate in this age group can be increased through chronic exercise training (Potteiger, Kirk, Jacobsen, & Donnelly, 2008). As previous research suggests, physical activity and exercise is related to resting metabolic rate. Additional research, more specific to the effect of aerobic or resistance training on resting metabolic rate is needed to more specifically quantify physical activity and its effect on resting metabolic rate.

The Effects of Aerobic Training on Resting Metabolic Rate

Aerobic exercise, commonly referred to as cardiorespiratory exercise, is a form of exercise that requires the aerobic energy system to supply energy in the form of ATP during exercise. Aerobic exercise improves the efficiency of cardiorespiratory function. There is a vast variety of aerobic exercises, including walking, running, swimming, and cycling. Individuals who participate in regular aerobic exercise have a resting metabolic rate 5 to 20% higher compared to individuals who are sedentary.

Broeder, Burrhus, Svanevik, and Wilmore (2013) examined whether a 12 week high intensity endurance training program would affect resting metabolic rate in 47 males aged 18-35 years. Participants were assigned to a control group or endurance trained group. The endurance trained group participated in a walk and/or jog program four days a week for 40 minutes at an intensity of 70% of their VO_2max. Resting metabolic rate before the training program was 5.23 ± .13 kJ/min compared to 5.32 ± .13 kJ/min post-training in the endurance trained group. These results demonstrate that an endurance training program can increase resting metabolic rate in men ages 18-35 years old (Broeder, Burrhus, Svanevik, & Wilmore, 2013).

In a cross-sectional study by Shook et al. (2014), 423 participants between the ages of 21 to 35 with a body mass index between 20 and 35 kg/m^2 were examined to determine if moderate cardiorespiratory exercise is associated with elevations in resting metabolic rate. The participants were administered a fitness test and from those results, the participants were classified into tertiles (low, moderate, or high level of cardiorespiratory fitness (CRF). The results showed that those classified as having a high level of CRF had the highest resting metabolic rate compared with the low CRF level participants by 51.2 kcal/day. Those in the moderate level of CRF, expended 39.7 kcal/day more than those in the low level of CRF. These results suggest that moderate and vigorous cardiorespiratory exercise is independently associated with resting metabolic rate (Shook et al., 2014). A review by Steigler and Cunliffe (2006) indicates that while some research reports aerobic training positively affects resting metabolic rate other aerobic training studies did not. The discrepancy appears to be that those studies were not of long enough duration to elicit such effects from participants' pre training resting metabolic rate measurements (Steigler & Cunliffe, 2006). Further research is necessary to confirm the findings that aerobic training positively affects resting metabolic rate.

Resistance Training

Free weight circuit weight training improves aerobic capacity, body composition by increasing fat free mass, and muscular strength and endurance (Beckham & Earnest, 2000). Hartman, Fields, Byrne, and Hunter (2007) examined the effects of resistance training on functional tasks in older adults. As individuals age, unfavorable changes in body composition and distribution of fat occur such as the increase in fat mass and the decrease in fat free mass. The loss of fat free mass is troublesome for older adults because it plays a critical role in physical function of everyday tasks. 29 men and women 66.7 ± 4.4 years participated in a 26 week resistance training program 3 times a week for 45 minutes a session. Prior to the program, the participants were tested for three functional tasks that mimicked commonly performed activities of older adults. These tasks included walking at a 0% grade at 3mph for 4 minutes stair climbing at 60 steps per minute for 4 minutes, and level walking carrying a loaded box to stimulate carrying groceries at 0% grade at 2mph for 4 minutes. During these tests, metabolic economy was measured through the use of a metabolic cart (Sensormedics 2900, Yorba Linda, CA). Isometric strength was measured using a universal shear beam load cell. Strength testing was conducted to determine 1 RM on all resistance exercises that would be used in the program. The resistance training program was closely monitored by exercise physiologists. Each participant completed 2 sets of 10 repetitions for the 10 exercises, with two minutes of rest in between sets. At the conclusion of the 26 week program, there were significant increases in the fat free mass (pre, 49.4 ± 11.2 kg to post, 51.3 ± 12.0 kg) and decrease in fat mass (pre, 22.9 ± 8.8 kg to post, 21.0 ± 8.8 kg). Muscular strength significantly increased in all of the exercises, but was greatest in the exercises requiring multi-joint movements. After the training program, the three functional tasks were measured and oxygen uptake after training decreased 6% (pre, 10.4 2.1 vs. post, 9.8 2.2 mlO2· kg/min) while walking carrying a loaded box. The oxygen uptake while walking decreased 1% and 3% while climbing the stairs. Resistance training can increase the ease of performing functional tasks in older adults. Resistance training was shown to increase strength, maintain body weight, and increase fat free mass in older adults (Hartman, Fields, Byrne, & Hunter, 2007).

A study conducted by DiPietro, Yeckel, and Dziura (2008) examined how lower intensity resistance versus moderate intensity aerobic training effects improvements in glucose tolerance in older women. 20 women, 65 and older, were recruited from private older adult residential communities in Connecticut. In order to be included in the study, they had to have not participated in regular physical activity for the previous 6 months, be nonsmokers, and not on glucose lowering medication. Their body mass index had to less than 30 kg/m^2. The women were randomly divided into a high volume, moderate intensity aerobic or a lower intensity resistance training group. During a nine month period, they exercised under supervision four times a week. The intensity was determined by calculating target heart rate zones. The aerobic trained group exercised at an average heart rate of 113bpm for 60 minutes while walking on a treadmill. The average heart rate for the resistance trained group was 90 bpm while exercising for 45 minutes using Thera-Balls and hand weights. The participants were studied for 9 months at which 2-hour glucose concentrations were measured at 3,6, and 9 months. An OGTT test and blood samples 48 hours after exercise were used to measure glucose, free fatty acid content, and plasma insulin. The results of the resistance trained group indicate that fasting glucose levels decreased by 20% at all testing periods (152 at baseline, 134 at 3 and 6 months,130 at 9 months). Also, the prevalence of impaired glucose tolerance decreased to 25% in the resistance training group, while it increased to 62% in the aerobic group. Free fatty acid concentration decreased 18% in the resistance group and increased in the aerobic group. This study determined that moderate intensity resistance training can improve glucose levels, insulin levels, and free fatty acid levels in adults (DiPietro, Yeckel, & Dziura, 2008).

A study by Gerage, Forjaz, Nascimento, Januario, Polito, and Cyrino (2013) studied if elderly postmenopausal women would have cardiovascular adaptations to resistance training. In the study, 29 untrained, non-hypertensive elderly women were randomly assigned to either an intervention group that underwent a resistance training program or a control group that participated in a stretching program for 12 weeks. The resistance training program group trained 3 times a week performing 2 sets of 10-15 repetitions of 8 exercises. The results showed that systolic blood pressure was significantly reduced in the resistance training group from pre to post training program. The average systolic decrease was 5mmHg from baseline (baseline, 125 ± 8 to post training 120 ± 7) (Gerage, Forjaz, Nascimento, Januario, Polito, & Cyrino, 2013). All of these studies suggest that there are numerous benefits of participating in resistance training.

The Effects of Chronic Resistance Training on Resting Metabolic Rate

Previous research suggests that chronic (regular) resistance training can result in increases in resting metabolic rate. A review article published by Poehlman and Melby (1998) stated that resting metabolic rate was 16% higher in chronic resistance trained individuals than untrained individuals (Poehlman & Melby, 1998). Ballor and Poehlman (1992) studied the effect of resistance training on resting energy expenditure in 13 women who reported participated in resistance training three or more times per week compared to the resting energy expenditure of 48 sedentary women. After a 12 hour fast, resting metabolic rate was measured via indirect calorimetry immediately after awakening in the morning. The participants were told to refrain from any exercise 36 hours prior to the measurement. The resting metabolic rate or the resistance trained women was 7% higher than those for the sedentary participants. The resistance trained women expended 4.25 ± .09 kJ/min compared to the expenditure of the sedentary women of 3.99 ± .05 kJ/min.

A study by Potteiger, Kirk, Jscobsen, and Donnelly (2008) examined changes in resting metabolic rate at the conclusion of a 16 month exercise training program in overweight adults. 74 participant's ages 17-35 years with a body mass index between 25 and 34.9kg/m^2 and previously sedentary were enrolled and randomized into the control group or the exercise training group. Participants reported for resting energy expenditure testing at baseline, after 9 months, and after 16 months of the training protocol. TheSensorMedics 2009 metabolic measurement cart was used for data collection. The participants trained 3-5 times per week for 45 minutes a session. At baseline, the mean fat free mass in kilograms was 49.5 ± 5.8 in women and 67.1 ± 8.3 in men in the exercise group. After the 16 month training program, the fat free mass in women was 50.4 ± 5.8 kg and 66.9 ± 7.8 kg in men in the exercise group. In men, the training program resulted in a significantly higher amount of fat free mass than at baseline, and the results were not significant in women, despite a small increase in fat free mass. Resting metabolic rate increased significantly by 174 ± 243 kcal/day for the men in the exercise group and 129 ± 154 kcal/day for women in the exercise group from baseline to 16 months. There were no significant changes in the resting metabolic rate in the control group over the 16 month period. Resting metabolic rate expressed per kilogram of fat free mass per day increases 1.98 ± 2.6 in men and 1.33 ± 3.6 in women in the exercise groups. These results further validate that chronic resistance training and exercise can increase resting metabolic rate in adults (Potteiger et al., 2008).

Gilliat-Wimberly et al. (2001) examined the effects of habitual physical activity on the resting metabolic rate of women aged 35 to 50 years old. 18 active and 14 sedentary adult women participated in the study. In order to be classified as active, the women had to report exercising for a minimum of six hours per week and have maintained this level of activity for at least five years. To be classified as sedentary, a woman had to exercise less than two hours a week and have maintained this lifestyle for at least five years. Resting metabolic rate was measured twice after a 12 hour fast at the same point of the menstrual cycle and 48 hours after exercise. If the results from the first measurement were not reproducible in the second measurement, the subject returned on another morning for a third measurement. The results suggested that resting metabolic rate was significantly higher in the active group compared with the sedentary group. Mean adjusted resting metabolic rate was 1,510 kcal/day for the active and 1,443 kcal/day for the sedentary women. The active women had significantly lower body fat levels (19% vs. 29%) and total fat mass (11 kg vs. 19 kg) than the sedentary women. These results suggest that middle-age women who exercise regularly can maintain lower body fat levels and higher resting metabolic rates relative to fat free mass than their sedentary counterparts (Gilliat-Wimberly, 2001).

Lemmer et al. (2001) examined age and gender effects of strength training on resting metabolic rate. Resting metabolic rate was measured before and after 24 weeks of strength training in 10 younger men and 9 younger women all 20-30 years old and 11 older men and 10 older women. The strength training program utilized both upper and lower body muscles and was performed 3 days a week for 24 weeks. The analysis showed that there was a training by gender effect. The men showed a 9% increase (6,645 ± 1,073 vs. 7,237 ± 1,159) in absolute resting metabolic rate whereas the women showed no significant increase (5,170 ± 884 vs. 5,366 ± 692 kJ/day), even though both men and women showed similar increases in fat free mass (Lemmer et al., 2001).

The Effects of Acute Resistance Training on Resting Metabolic Rate

As the previously stated research results indicate, resistance exercise training can increase resting metabolic rate; therefore increasing total daily energy expenditure. Related research has assessed the effects of acute bouts of resistance training on resting metabolic rate. Osterberg and Melby (2000) conducted a study to determine the effects of an acute resistance exercise bout on resting metabolic rate and post-exercise oxygen consumption in young women. The study included seven apparently healthy women ages 22-35. The goal was to examine changes in resting metabolic rate following a prolonged recovery period. The participants had their resting metabolic rate measured at 7:00 a.m. following a twelve hour fast. After the measurement, they were given a standardized breakfast and were allowed to leave the laboratory having been instructed to remain sedentary and not to eat. Six hours after the first measurement, participants returned to the lab and began a 100 minute resistance exercise session followed by a standardized dinner. They left the lab and were to refrain from exercise and food or beverage consumption, with the exception of water and to get a minimum of eight hours of sleep. The acute bout of resistance exercise was a circuit consisting of 5 sets of ten different exercises, 10-15 repetitions per set. The weight lifted was 70% of the individual's one repetition maximum. The next day at 7:00 a.m., the participants came back to the lab for a second resting metabolic rate measurement. Resting metabolic rate was measured using the SensorMedics, Yorba Linda metabolic cart. Differences in resting metabolic rate from day 1 (pre exercise) to day 2 (16 hours post exercise) were measured. From day 1 to day 2, the mean increase was 4.2%. The mean value for day 2 was 1,479 ± 65 kcal/24 hr compared to the mean value for day 1,419 ± 58 kcal/24 hr. Respiratory exchange ratio was also measured and the results indicate that there was a 62% increase in resting fat oxidization measured on day 2 (.071 g/min) compared to day 1 (.044 g/min) (Osterberg & Melby, 2000). This study demonstrates that an acute bout of resistance exercise can increase resting metabolic rate and fat oxidization.

Beckham and Earnest (2000) determined if caloric expenditure was associated with free weight circuit weight training at light and moderate resistance in apparently healthy adults. 18 females, age 18-45 and 12 males, age 19-41 years volunteered to participate in the quasi experimental study. All of the participants participated in both the low intensity and moderate intensity condition first, and then completed the other condition 48 hours later to ensure adequate recovery. The light resistance condition was a 1.4 kg bar for both males and females. The moderate resistance condition used a 5.9 kg load for females and 10.5 kg for males as a result of their greater strength capacity. When the females completed the light resistance condition, their resting energy expenditure was 3.62 ± 0.45 kcals/min compared to the moderate resistance condition where it was 4.04 ± 0.45 kcals/min. In males, the light resistance condition elicited a 4.99 ± 0.83 kcal/min expenditure and a 6.21 ± 1.01 kcal/min expenditure in moderate resistance (Beckham & Earnest, 2000). Results from both of these studies suggests that even an acute bout of resistance training can have an effect on resting metabolic rate for up to 24 hours post exercise.

The Effects of High Intensity Resistance Training on Resting Metabolic Rate

High intensity resistance exercise is achieved by lifting 80% or greater of one's one repetition maximum (1RM). High intensity exercise of long duration can result in a prolonged recovery period, contributing to substantial post-exercise energy expenditure above resting values. An experimental study by Melby, Scholl, Edwards, and Bullough (1993) was conducted to examine the effects of an acute high intensity bout of resistance exercise on resting metabolic rate and post-exercise energy expenditure. Study participants included a total of seven males. The participants were between the ages of 20 and 40, were apparently healthy, and participated in regular weight lifting exercises three to four times a week for at least one hour a session. On day one at 7:00 a.m., resting metabolic rate was measured for one hour via indirect calorimetry while the participants were in a 12 hour fasted state. The subjects were fed a standardized breakfast and went home having been instructed to remain sedentary. At 2:00 p.m. the participants returned to the lab and completed a 90 minute bout of high intensity weight lifting. The next morning the participants returned at 7:00 a.m., approximately 15.5 hours after the exercise bout and had their resting metabolic rate measured. The results showed significantly elevated resting metabolic rates the morning after the exercise bout (2,110 ± 80 kcal/day) compared with the morning before exercise (1,930 ± 70 kcal/day). The average increase was 9.4% while the range was 5.4-19.4%. This study proposes that high intensity resistance training prolongs the increase in energy expenditure above baseline longer than moderate intensity (Melby, Scholl, Edwards, & Bullough, 1993).

Post-exercise energy expenditure in response to acute high intensity resistance exercise was studied by Gillette, Bullough, and Melby (1994). Ten apparently healthy males, ages 22-35 years completed three conditions including a 100 minute bout of strenuous weight lifting, a bout of cycling, and a control condition of sitting. Separating each condition was seven days. The strenuous weight lifting condition consisted of ten upper and lower body lifts, five sets of each exercise at 70% of each participant's one repetition maximum. Resting energy expenditure was measured the morning of the exercise and the morning following the exercise. The average resting metabolic rate the morning of the exercise bout was 1,930 kcals/day compared to 2,020 kcals/day the morning following the exercise bout. This study found that weight lifting of high intensity used in this study is capable of stimulating a higher energy expenditure following exercise than a steady-state bout of cycling (Gillette, Bullough, & Melby, 1994).

Broeder et al. (2013) identified the effects of high intensity resistance training on resting metabolic rate after a 12 week program. 47 males aged 18-35 years old were randomly assigned to either a control, resistance trained, or endurance trained group. The resistance trained group used a combination of free weights and Nautilus machines four days a week for 12 weeks. The endurance trained group walked or jogged four days a week. Resting metabolic rate was measured using a SensorMedic 2900 metabolic cart before the training program began and the day after the program ended. Resting metabolic rate values pre-treatment were 5.36 ± 0.17 kJ/min and 5.58 0.21 kJ/min post-treatment. In the resistance trained group, fat free mass increased significantly by 3.3% and fat mass decreased 11.8%, whereas the endurance trained group showed no significant changes in these variables (Broeder et al, 2013). These results suggest that resistance training can play a vital role in maintaining or increasing metabolic rate.

Campbell, Crim, Young, and Evans (1994) explored whether a 12 week high intensity resistance training program would influence resting metabolic rate. Resting metabolic rate was measured before and after the training program in 12 men and women, ages 56-80 years. The training protocol consisted of two upper body and two lower body exercises performed at 80% of the participant's one repetition maximum. The results indicated that the participants required an increase in energy intake of 15% to maintain body weight during the program. The mean resting metabolic rate increase was 8.3%. These results suggest that resting metabolic rate can increase after a high intensity resistance training program in elderly adults (Campbell, Crim, Young, & Evans, 1994). The present study will utilize high intensity resistance exercise to examine its effects on RMR.

Conclusion of Literature Review

The purpose of this literature review was to examine a variety of research articles and review articles regarding resting metabolic rate and resistance training. Included were research studies of various research designs including experimental, quasi experimental, cross sectional, and prospective studies, all of high rigor. Regardless of the design, the majority of the results were similar. Resting metabolic rate has a direct relationship to body weight management and energy balance. Secondly, resistance training can improve resting metabolic rate and other physiological components. Therefore, I proposed in this study to examine the effects of an acute bout of high intensity resistance exercise on the resting metabolic rate of middle- aged women. The following section explains the research study methods.

CHAPTER III

METHODS

The purpose of this study was to examine the effects of an acute bout of high intensity resistance exercise on resting metabolic rate in apparently healthy women. The sample population consisted of 18 women ages eighteen to forty-five years of age. These women were recruited from Indiana, Pennsylvania through the use of electronic, paper, and in person advertising. Exclusion criteria were used to ensure that the sample population was as representative of the population demographics as possible. In addition, exclusion criteria were used to eliminate possible confounders and biases that would potentially skew the results. Participants were excluded if they had known cardiovascular, pulmonary, or metabolic disease, or other chronic disease or musculoskeletal injury that would limit their ability to safely perform a resistance exercise routine. Additionally, a body mass index greater than 29.9 kg/m^2, the use of thyroid, hypertension, diet medication, and/or beta blockers, were menopausal, or smoked cigarettes were also exclusion criteria. Participants who smoked one or more cigarettes a day were excluded. Participants for this study were currently participating in resistance training at least once a week for a total of sixty minutes a week for at least three months. Volunteers who met inclusion criteria and agreed to participate were asked to come to an initial session in the Human Performance Lab in Zink Hall. During this initial session, the principle investigator obtained informed consent and assessments of body composition, resting heart rate, and resting blood pressure. Then, the participants went to the James Mill Fitness Center where the principle investigator demonstrated each of the eight exercises included in the exercise protocol to establish baseline levels of intensity. After the demonstrations, the participants performed an eight repetition maximum assessment for all of the exercises in the protocol. At least 48 hours after the initial session but no longer than one week, a second session was conducted in the fitness center to practice the eight exercises in the resistance exercise protocol. The following week, the participants were asked to return to the human performance laboratory for an assessment of resting metabolic rate. Immediately after these assessments, they went to the fitness facility to perform the acute bout of resistance exercise under supervision of the principle investigator. Immediately after the exercise bout, participants went to the human performance lab where a resting metabolic rate measurement was taken. Participants returned to the human performance lab 24 hours after the completion of the exercise bout, for a final assessment of resting metabolic rate. The results of this study were intended to examine if an acute bout of high intensity resistance exercise would increase the resting metabolic rate in apparently healthy adult women, immediately and 24 hours after the bout of resistance exercise. This design of this study was quasi-experimental. Prior to the beginning of data collection, the research team was informed about the procedures for the 8RM assessment and resting metabolic rate measurement. The research team practiced both the 8RM assessment and resting metabolic rate measurement with the principle investigator prior to data collection. Intensity and safety guidelines were thoroughly reviewed with the research team prior to data collection.

Participants and Recruitment

Apparently healthy adult women between the ages of eighteen and forty five were invited to participate in the study. Participants for this study must have participated in moderate resistance training for at least once a week or for a total of sixty minutes a week for at least three months prior to the start of the study. There were no exclusion criteria regarding participating in regular aerobic exercise. Body mass index (BMI) was used to classify participants as either normal weight (18.5-24.9 kg/m^2), overweight (25-29.9 kg/m^2), or obese (30-39.9 kg/m^2). No woman with a BMI greater than 29.9 kg/m^2 was included in the study. The women were apparently healthy and free of cardiovascular, pulmonary, and metabolic diseases including cardiac, peripheral vascular, or cerebrovascular disease, COPD, asthma, interstitial lung disease, cystic fibrosis, renal disease, and diabetes mellitus (type 1 and 2). The use of beta-blockers, thyroid, hypertension, or diet medication excluded participation in this study. The consumption of dietary supplements including vitamins and minerals did not exclude participation. Women with a resting blood pressure of greater than or equal to 140 mmHg systolic and/or greater than or equal to 90 mmHg diastolic or previously diagnosed with hypertension by a medical professional, were excluded from participation. Participants who currently or previously smoked cigarettes within six months prior to the start of the study were excluded. Participants who consumed any amount of energy drinks were excluded from participation. The participants were free of any chronic disease or orthopedic issue that prohibited or limited their ability to participate in high intensity resistance exercise. The participants were premenopausal and indicated no signs of menopause. Pregnant women and women that were pregnant six months prior to the start of the study were excluded. Participants meeting all of the criteria were invited to participate.

Participation in this study was strictly on a voluntary basis. Adult women were recruited from Indiana, PA, as well as the surrounding geographical area through the use of paper, electronic, and in person advertising. Paper advertisements including flyers were developed to provide information regarding the study design, participation requirements, and inclusion criteria. The flyers were distributed to several buildings on the Indiana University of Pennsylvania's (IUP) campus and surrounding local businesses. Print advertisements were given to female employees of Indiana Regional Medical Center.

Internet based advertising was also implemented. A generalized email was sent to IUP female students, faculty, and staff. These emails consisted of the same information that was provided on the print advertisements.

After the participants were screened, met initial entry criteria, and agreed to participate, they signed the informed consent form during the initial session in the human performance lab. They were given information regarding the testing schedule and testing requirements. The informed consent provided participants with a brief description of the study including the purpose, participant expectations and requirements, risks and benefits of participation, and withdrawal information. The informed consent reminded the participant that participation was strictly on a voluntary basis and no compensation would be given for participation.

Instrumentation

In this study, a variety of assessment tools were used to evaluate resting metabolic rate, body weight, body mass index, heart rate, blood pressure, and ratings of perceived exertion (RPE). The following tools were used in these assessments.

ParvoMedics True One 2400 Metabolic Measuring System™

This tool is used to measure resting metabolic rate and metabolic responses to exercise. This is an indirect calorimetry method that utilizes open circuit spirometry to measure the volume of oxygen and carbon dioxide expelled by an individual. It measures these expired gases relative to the atmospheric gas content. This measurement provides a volume of oxygen consumed by the body (VO_2), which is then used in calculations to estimate caloric expenditure at a given point in time.

Physician's Scale

This is a tool used to measure an individual's height and weight. The scaled used in this study is located in the Center for Health Promotion and Cardiac Disease at IUP. The measurements of height and weight were used to calculate each participant's body mass index.

BodPod™

The BodPod is a machine that measures body density by using air displacement plethysmography. Body density is used to estimate body fat percentage. In order to use this machine, participants were instructed to wear form-fitting Lycra or a spandex swim suit along with a skullcap. At the completion of the test, a detailed print out was created by the machine in which percent body fat was given.

Polar Heart Rate Monitor™

Polar FT1 heart rate monitors are used to measure heart rate at rest and during exercise. This monitor consists of a transmitter that is fastened to an elastic strap worn below the chest muscles and a watch worn around the wrist. There are two grooved electrodes on the back of the transmitter that transmits the heart rate signal to the watch where the heart rate is displayed.

Aneroid Sphygmomanometer

Aneroid Sphygmomanometers are used to assess systolic and diastolic blood pressure. It is commonly referred to as a blood pressure cuff. The model used in this study was a Prestige Medical sphygmomanometer.

Borg's Rating of Perceived Exertion (RPE) Scale

An RPE scale is used to determine how a subject "perceives" their level of exertion to be on a scale of 6 to 20. The scale was designed theoretically to correlate to the individual's heart rate ranging from 60bpm (RPE of 6) to 200bpm (RPE of 20). The value indicated by the subject should be indicative of the level of fatigue they are feeling accounting for total body fatigue, shortness of breath, and muscle pain.

Testing and Measurement Procedures

Prior to measurement and testing, all participants were screened for eligibility and provided informed consent. The participant's first meeting was in the Human Performance Lab in Zink Hall for assessments of body composition, resting heart rate, resting blood pressure, height, and weight. Participants then went to the James Mill Fitness Center located in Zink Hall. During this session, the principle investigator demonstrated each of the eight exercises that were performed during the single bout of resistance exercise. The exercises included a loaded squat, bent over barbell row, leg curl, biceps curl, leg extensions, triceps extensions, standing twist with a plated weight, and lateral shoulder raise. Proper form and safety guidelines were provided to the participants. After the demonstrations of all eight required exercises, the participants had an assessment of their eight repetition maximum for each of the exercises included in the protocol. The eight repetition maximum assessments were performed in order to determine the appropriate loads that were used for the single bout of high intensity resistance exercise. The eight repetition maximum assessment was done by having the participants select a weight they thought they could lift 10-14 times. The weight was then increased by 5-10% for upper body and 10-20% for lower body until the participants could only perform eight repetitions. After the initial session, the participants then came at least 48 hours, but not more than one week, after this initial session for additional practice for all eight exercises at the determined intensity. At least 48 hours, but not more than one week, after the practice session, the participants came to the Human Performance Lab for the third session. This session included the initial measurement of resting metabolic rate. Immediately following the measurement of resting metabolic rate, the participants went to the James Mill fitness center to perform the single bout of the eight resistance exercises at 80% of their pre-determined repetition maximums. Immediately following the last set of exercises, participants returned to the human performance lab for a post exercise resting metabolic rate measurement. 24 hours after the completion of the exercise bout, the participants returned for a final measurement of RMR. The total number of participant sessions was four, for a total time commitment five and a half hours.

Initial Laboratory Session

Participants came to the human performance lab for assessments of height, weight, resting heart rate, resting blood pressure, and body composition. Participants were oriented to all of the equipment. The first test performed was height and weight, which required the participants to stand on a physician's scale while the principle investigator performed the measurements. The participants then put the Polar heart rate monitor™ equipment on. The watch was fastened around their wrist and the transmitter was fastened to the elastic band and placed under their shirt directly below their bra. They then quietly sat in a chair with their feet flat on the floor for three minutes. After three minutes, a resting heart rate was read from the Polar heart rate monitor™. After the resting heart rate was assessed, resting blood pressure was measured while the participant remained seated in the chair with her feet flat on the floor. They then were asked to change into the proper clothing for the BodPod™ which included Lycra or spandex material shorts and a sports bra. The principle investigator assisted the participant in putting on the skullcap that was placed over the top of the head in the same manner a swimming cap would be placed. Participants were instructed on the procedure of the BodPod™. They were instructed to sit quietly in the machine for approximately two minutes while the measurement was taken.

After the measurement was completed, the participant was instructed to change back into their initial clothing. This concluded the initial laboratory session.

Exercise Demonstrations and Assessment of 8RM

During the initial session after the assessments in the human performance lab, the participants went to the James Mill Fitness Center for the assessments of the 8RM. Participants were asked to dress ready to participate in physical activity and to wear tennis shoes. Participants were first introduced to the fitness center. The principle investigator informed the participants of the names of the machines that they would be using along with an orientation to each piece of equipment. Next, the investigator demonstrated the exercise and proper breathing techniques for all eight of the exercises. Throughout the demonstrations, the investigator answered participant questions. After the demonstrations, the participants had their eight repetition maximum measured for each of the eight exercises. The research team supervised this session and assisted when necessary. Measurement of 8 RM followed the National Strength and Conditioning Associations protocol as described in the *Essentials of Strength Training and Conditioning* (2008) textbook.

The participant began the session with a warm-up. The warm up included walking on a treadmill at 0% grade at 3.0 mph for three minutes. The participant then performed medicine ball passes for thirty seconds with the principle investigator. She rested for thirty seconds and then performed a medicine ball press for thirty seconds. She then rested for thirty seconds. The next exercise was thirty seconds of body weight squats. At the conclusion of the warm up, the participant rested for three minutes.

An 8RM assessment was performed for each of the eight exercises included in the exercise protocol including a loaded squat, bent over barbell row, leg curl, seated triceps extension, leg extension, bicep curl, trunk twist, and lateral raise. To begin, the participant selected a weight that she felt comfortable lifting 10-14 repetitions for the given exercise. She completed the set by performing 10-14 repetitions. She then rested for two minutes. If the participant was able to lift more weight, a 5-10% load increase for upper body exercises and a 10-20% load increase for lower body exercises was applied. The participant then performed 10-14 repetitions of this weight. After this second set, she rested for three minutes. This load increase procedure was repeated until the participant could only perform eight repetitions. This procedure was repeated for each exercise.

Participant Practice Session

At least 48 hours after, but no longer than one week after the initial session, the participants returned to the James Mill Fitness Center and practiced each of the exercises included in the protocol at the intensity determined during the 8RM assessments for an hour. The participants were guided through this protocol by the research team. This session mimicked the single bout of resistance exercise that would be performed for the actual data collection.

Initial Resting Metabolic Rate Measurement

At least 48 hours, and no longer than a week after the second session of the exercise protocol practice, the participants attended the initial resting metabolic rate measurement. All the participants attended the initial resting metabolic rate measurement session in private at the Human Performance Lab. Participants were asked to fast for twelve hours and refrain from physical activity for 24 hours prior to this session. During the twelve hour fast, the participants were allowed to consume water. They were also asked to get at least eight hours of sleep the night before the measurement. They were instructed not to consume any medications for 24 hours prior to the measurement. Next, the participants were asked to lie on a comfortable cot in the supine position. A plastic dome was placed over her head and top of shoulders, with the plastic skirt tucked behind her back. The cot was located in a semi-darkened private room. The resting metabolic rate measurement then began using the ParvoMedics 2900 Metabolic Measurement System™ and continued for 40 minutes. The first ten minutes of the measurement were discarded to allow for an adjustment period to the procedure. Only the last thirty minutes were included in the analysis. After 40 minutes, the plastic dome was removed and the participant was asked to stand-up.

Immediate Post Exercise Bout Resting Metabolic Rate Measurement

Immediately following the completion of the resistance exercise protocol, the participants returned to the Human Performance Lab for a measurement of resting metabolic rate. The participant was asked to lay on a cot in the supine position. A plastic dome was placed over her head and top of shoulders, with the plastic skirt tucked behind her backside. The resting metabolic rate measurement began using the ParvoMedics 2400 Metabolic Measuring System™ and continue for 40 minutes. The first ten minutes of the measurement were discarded so a true resting state could be achieved. After 40 minutes, the plastic dome was removed and the participant was asked to stand-up.

24 Hours Post Exercise Bout Resting Metabolic Rate Measurement

The final testing day occurred 24 hours after the completion of the exercise bout. Participants came no earlier than 22 hours and no longer than 24 hours after the completion of the exercise bout. All participants attended the final session in private at the Human Performance Lab. Participants were asked to fast for twelve hours and refrain from physical activity besides the exercise bout prior to their measurement. They were asked to sleep for a minimum of eight hours the night before the measurement. The participant laid on a cot in the supine position. A large plastic dome was placed over her head and top of shoulders, with the plastic skirt tucked behind her backside. The resting metabolic rate measurement began using the ParvoMedics 2400 Metabolic Measuring System™ and continued for 40 minutes. The first ten minutes of the measurement were discarded in order to achieve a true resting state. After 40 minutes, the plastic dome was removed and the participant was asked to stand-up. After all the measurements were taken, the data was reviewed with each participant. The participants had an opportunity to ask questions regarding the research study. After questions were answered and data was reviewed, the data collection phase of the study was concluded. This session lasted fifty minutes.

Body Weight Measurement

Body weight and height were assessed during the initial session in the Human Performance Lab after informed consent was obtained. The physician's scale was used for these measurements. The height and weight were then used in the ACSM body mass index equation (mass in kilograms/height in meters^2) to determine body mass index that was used to classify participants as either normal weight or overweight.

Heart Rate Measurement

Heart rate was measured at the initial session in the Human Performance Lab as well as monitored continuously throughout the exercise session. The participants were instructed to place the Polar heart rate elastic strap with the fastened transmitter under their chest muscles and place the watch on their wrist. After sitting quietly with their feet flat on the floor for three minutes, resting heart rate was read from the watch during the initial and final lab sessions. During the exercise session, heart rate was assessed immediately after each set for each of the eight exercises and documented on each participants exercise log.

Blood Pressure Measurement

A blood pressure reading occurred after the resting heart rate measurement during the initial session in the laboratory. Participants sat for three minutes in a resting state, with feet flat on the floor before the resting measurement was taken. Blood pressure was measured once by the principle investigator or research team during the exercise bout, immediately following the completion of the fourth exercise. The aneroid sphygmomanometer was placed over the upper arm, with the artery mark, indicating proper alignment, positioned over the brachial artery. The investigator supported the participants arm as the cuff was inflated to 220 mmHg. The cuff was slowly deflated as the first and fourth Korotkoff sounds were noted as the systolic and diastolic blood pressure readings. Blood pressures were documented on each participant's data sheet.

Body Composition Measurement

Body composition was assessed using the BodPod™ located in the laboratory during the initial testing day before the participants went to the fitness center for testing. This measurement was taken after the resting blood pressure measurement once the participants changed into the appropriate clothing. The participants were required to wear form fitting spandex clothing along with a tight "skull" cap. The participants were in this machine for approximately two minutes while the data was collected.

Resting Metabolic Rate Measurement

Resting metabolic rate was measured during the initial and final resting metabolic rate laboratory sessions. This test required participants to fast for twelve hours prior to the initiation of the test. Participants were instructed to refrain from low, moderate, and high intensity exercise for at least 24 hours prior to the test. Participants were instructed to not consume alcohol or energy drinks or ingest drugs within 24 hours of the test. Prior to the initiation of the measurement, the ParvoMedics TrueOne 2400 Metabolic Measuring System™ was calibrated for air flow and gas flow analysis. The calibration was in adherence to the systems guidelines and instructions. Participants remained in the supine position for a 40 minute period while the data was collected. The first 10 minutes of data collection were excluded from data analysis to account for the participants adaptation phase to the measurement process. Prior to the test, participants were told that if at any time during the test they wanted to end the test, they had to raise their arm and the investigator would remove the dome.

Single Bout of High Intensity Resistance Training

Participants participated in one bout of high intensity resistance exercise. This session lasted one hour and was supervised by the research team. All exercise sessions took place in the James Mill Fitness Center in Zink Hall on the campus of Indiana University of Pennsylvania. The single bout consisted of eight exercises. Once the participant arrived at the fitness center, she placed the Polar heart rate monitor and watch around her chest and wrist. She then sat in a chair for three minutes with their feet flat on the floor. After the three minutes, resting heart rate and resting blood pressure were measured and recorded on the participant's data sheet. Ratings of perceived exertion (RPE) were assessed during the second set of each exercise.

Before the bout of exercise began, each participant performed a five minute warm up. The warm up included walking on a treadmill at 0% grade at 3.0mph for three minutes. The participant performed medicine ball passes for thirty seconds with the principle investigator. She then rested for thirty seconds and then performed a medicine ball press for thirty seconds. She then rested for thirty seconds. The next exercise was thirty seconds of body weight squats. After the conclusion of the warm up, the participant rested for three minutes.

Immediately after the warm up, participants began the exercise session with the loaded squat. Each exercise was performed for three sets of eight repetitions. Immediately after each set, there was a 60 second rest period before the participant began the next set. After each set, heart rate was immediately read from the Polar heart rate monitor and recorded on the data sheet. After the fourth exercise, blood pressure was assessed within one minute and then exercise resumed immediately.

Exercises:

The first exercise was a loaded squat. This was done while the participant held a weighted bar behind their back so the bar rested on her shoulders. She performed a squatting motion so there was 90 degree flexion in the knees. The second exercise was a bent-over barbell row. The participant stood with her knees slightly bent as she bent over as the back remained straight. The participant held the dumbbells towards the ground. She then adducted, flexed, and extended the shoulders while the elbow joint was flexed. This motion resulted in a pulling motion of the weight towards her sternum. The next exercise was a leg curl on the Nautilus machine. The fourth exercise was a seated triceps extension using a dumbbell. To begin, the elbows were behind the head at a 90^{o} angle. The dumbbell was raised as the elbows extended. The fifth exercise was a leg extension using the leg extension machine. The legs were fully extended and then the weight was slowly lowered as flexion of the knees occurred. The sixth exercise was a bilateral bicep curl performed using dumbbells. Feet were shoulder width apart with the knees slightly bent. A full repetition was defined as flexing the elbows and then slowly lowering the weight back to a resting position as the elbows were extended. The seventh exercise was a trunk twist holding a plated weight. The participant held the weight extended out in front of her and slowly rotated her body from left to right as her hips remained straight. The last exercise was a lateral raise using dumbbells. The participant stood with feet shoulders width apart. The palms faced in towards the participant. The shoulders were abducted to shoulder level and then slowly adducted back to the starting position.

Intensity Monitoring

The intensity for each exercise was determined by the participant's 8RM assessments prior to the exercise session. During the exercise session, the participants wore a Polar heart rate monitor™. Heart rate during exercise did not exceed 80% of the participants calculated age predicted heart rate maximum (220-age). During each set of each exercise, heart rate was assessed from the Polar heart rate monitor. RPE was assessed during the second set of each exercise. The desired RPE of each exercise was between 14 (somewhat hard) and 17 (very hard). Blood pressure was measured once after the completion of the fourth exercise.

Safety Monitoring

During participation in this study, safety of the participants was of the utmost importance. Safety precautions were followed in order to best prevent the occurrence of accidents and injuries. Each participant was encouraged to ask questions and voice concerns throughout the entire study, especially involving exercise intensity and proper from. No participant was asked to perform beyond her ability and safety. Each participant was closely monitored by the principle investigator or the research team. The principle investigator selected exercises that were within the populations' functional abilities. If any participant was unable to safely perform any of the exercises for any reason, the principle investigator adapted the exercise to allow for safe participation. One participant could not perform the loaded squat because of a previous knee injury. In this instance, the participant performed the leg press machine instead of the loaded squat. All of the locations used throughout the study were equipped with appropriate fire, biohazard, and AED equipment. There was a phone in each location in the case of a 9-1-1 emergency.

Data Collection

The initial laboratory session was the first collection of weight and height, body composition, resting heart rate, and resting blood pressure. The second session in the laboratory included the initial resting metabolic rate measurement. During the acute bout of resistance exercise, RPE, heart rate, blood pressure, loads, sets, and repetitions were recorded. Immediately after completion of the exercise bout, resting metabolic rate was measured. 24 hours after the exercise bout, the final session of data collection of resting metabolic rate occurred in the lab. This concluded the data collection within the study. One participant did not complete the study, withdrawing after the first session. 22 were screened for participation, but 18 participants were included in data analysis.

Statistical Analysis

To describe the characteristics of the group at baseline, measures of central tendency and independent t tests were used to detect differences between the groups. Independent samples t-tests and Tukey's post hoc pairwise comparisons were used to describe the differences within and between each group from baseline to the post exercise session measurements. This test provided information on how much and how significantly resting metabolic rate changed from pre to post testing. Univariate analyses of variance were used to determine if any significant differences existed between baseline, immediately post exercise, and 24 hours post exercise resting metabolic rates.

Confidentiality

Every participant was provided a copy of the informed consent with a description of the study requirements, benefits, and risk of participation. The confidentiality of all the data collected throughout the study was kept in an off-site locked filing cabinet in a location only accessible to the principle investigator. All paper-based data collection and participant information was kept in this location. Only upon request of a specified participant was information disclosed to that individual.

CHAPTER IV

RESULTS

Baseline Results

This section reviews statistical analyses that describe the sample of 18 participants as one group, compare means of covariates by age (18-30 years and 31-45 years) and BMI category (normal weight and over weight) at baseline, and describe the distribution of the sample and the covariates. In addition, this section reviews statistical analyses that test the assumptions of normality needed to conduct an analysis of variance (ANOVA) and t-tests to compare the sample in terms of age and BMI categories (normal weight and over weight).

Demographics

19 women were initially recruited for this study; however, 18 completed the entire protocol including baseline resting metabolic rate measurement, exercise bout, immediately post exercise resting metabolic rate, and 24 hour post exercise resting metabolic rate. Recruitment in this study was not targeted at one specific race or ethnicity; however, all participants in this study were Caucasian. The average age of all participants was 28.11 (±1.70) years. 19 (100%) of the participants were recruited from Indiana University of Pennsylvania. All of the participants lived in Indiana County. Descriptive statistics of the sample and covariates can be seen in Table 1.

Baseline Characteristics

The results of this study were evaluated by the sample and then stratified by age group (18-30 and 31-45 years old), and by BMI category (normal weight and overweight). 10 were included in the 31-45 years old group and 8 were included in the 31-45 years old age group. When separated by BMI groups, 10 were included in the normal weight group, and 8 were included in the over weight group. The mean age of all participants (n=18) was 28.11 ± 7.22 years. The mode was 21 years. The mean weight was 63.92 ± 12.15 kilograms (kg). The mean

BMI was 23.81 ± 3.17 kg/m^2. The mean absolute initial resting metabolic rate was 1807.5 ± 281.46 kcal/day. The mean relative initial resting metabolic rate was 29.04 kcal/kg/day ± 4.12.

The following baseline characteristics were evaluated by stratifying the participants as covariates by age group (18-30 and 31-45 years old) and BMI category (normal weight and overweight). The average age of participants in the 18-30 year old, normal weight subgroup was 23 ± 3.03 years. The mean body mass was 55.24 ± 3.42 kg. The mean BMI was 21.61 ± 0.58 kg/m^2. The mean initial absolute resting metabolic rate was 1588.83 ± 142.38 kcal/day. The mean initial relative resting metabolic rate was 38.68 ± 3.94 kcal/kg/day.

The following baseline characteristics represent the participants in the 18-30 years, overweight subgroup. The average age of participants in this subgroup was 21.50 ± 0.58 years. The mean weight was 68.40 ± 9.74 kg. The mean BMI was 26.07 ± 2.48 kg/m^2. The mean initial resting metabolic rate was 2060.75 ± 220.51 kcal/day. The mean initial relative resting metabolic rate was 34.97 ± 4.47 kcal/kg/day.

The following baseline characteristics represent the participants in the 31-45 years normal weight subgroup. The average age of participants in this subgroup was 34.75 ± 2.87 years. The mean weight was 57.38 ± 2.45 kg. The mean BMI was 21.35 ± 1.51 kg/m^2. The mean initial absolute resting metabolic rate was 1784.25 ± 179.12 kcal/day. The mean initial relative resting metabolic rate was 33.26 ± 2.89 kcal/kg/day.

The following baseline characteristics represent the participants in the 31-45 years, over weight subgroup. The average age of participants in this subgroup was 35.75 ± 4.92 years. The mean weight was 78.98 ± 13.40 kg. The mean BMI was 27.32 ± 2.64 kg/m^2. The mean absolute initial resting metabolic rate was 1905.5 ± 373.82 kcal/day. The mean initial relative resting metabolic rate was 28.21 ± 6.17 kcal/kg/day.

Table 1

Demographics of Sample and Covariates

	Sample (n=18)	18-30 years Normal Weight (n=6)	18-30 years Overweight (n=4)	31-45 years Normal Weight (n=4)	31-45 years Overweight (n=4)
	Mean(SD)*	Mean(SD)*	Mean(SD)*	Mean(SD)*	Mean(SD)*
Age (years)	28.11(±7.22)	23.00(±3.03)	21.50(±0.58)	34.75(±2.87)	35.75(±4.92)
Weight (kg)	63.92(±12.15)	55.24(±3.42)	68.40(±9.74)	57.38(±2.45)	78.98(±13.40)
BMI (kg/m^2)	23.81(±3.17)	21.61(±0.58)	26.07(±2.48)	21.35(±1.51)	27.32(±2.64)
Fat Mass (kg)	16.10(±8.03)	14.04(±8.59)	17.65 (±7.81)	11.93(±2.53)	21.78(±9.84)
Fat Free Mass (kg)	47.91(±7.84)	41.20(±7.27)	50.76(±4.44)	45.84(±1.72)	57.20(±3.99)
Initial RMR (kcal/day)	1807.5(±281.46)	1588.83(±142.38)	2060.75(±220.51)	1784.25(±179.12)	1905.5(±373.82)
Initial RMR (kcal/kg/day)	29.04(±4.12)	34.97(±4.47)	38.68(±3.94)	33.26(±2.89)	28.21(±6.17)

SD for standard deviation

A Shapiro-Wilk test for normality was used to validate the assumptions of normality within the group. Results indicated age, weight, BMI, fat mass, and fat free mass were not normally distributed. Baseline absolute and relative resting metabolic rate were normally distributed. This test showed statistically significant effects within the sample (alpha set at p=0.05) (Table 2).

Table 2

Shapiro-Wilk Test for Normality

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	Df	Sig.	Statistic	df	Sig.
Age (years)	.261	18	.002	.848	18	.008*
Weight (kg)	.195	18	.067	.889	18	.010*
BMI	.195	18	.070	.874	18	.020*
Initial RMR (kcal/day)	.126	18	.200	.944	18	.338
Initial RMR (kcal/kg/day)	.122	18	.200	.942	18	.318
Fat Mass (kg)						
Fat Free Mass (kg)	.117	18	.200	.963	18	.658
Fat Mass (kg)	.172	18	.171	.907	18	.004*

*Statistical significance (p<.05)

Histograms were used to examine the distribution and test the assumptions of normality. Histograms and expected values plots (Q-Q plots) were used to analyze the distribution of each variable (age, weight, BMI, and initial RMR) among the sample (n=18). These histograms showed that age, weight, BMI, fat mass, and fat free mass were not normally distributed, whereas baseline absolute resting metabolic rate and baseline relative resting metabolic rate were normally distributed . Histograms and Q plots can be seen for age, weight, BMI, baseline absolute resting metabolic rate, fat mass, fat free mass, and baseline relative resting metabolic rate.

A histogram was used to visually see the distribution of age among the sample (Figure 1). The histogram shows that age was not normally distributed in the sample.

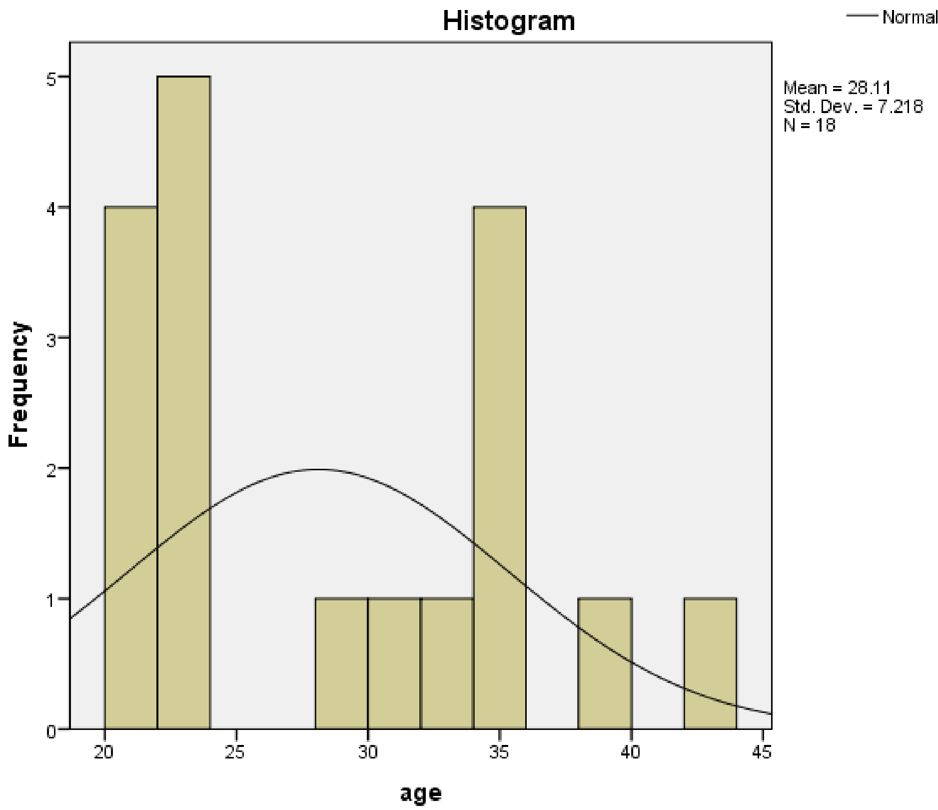

Figure 1. Frequency of ages of participants.

A Q-Q plot was used to visually see the distribution of age among the sample (Figure 2) The Q-Q plot shows that age trended from expected values in the sample.

Figure 2. Observed values vs. expected values of participant age.

A histogram was used to visually see the distribution of age among the sample (Figure 3). The histogram shows that weight (kg) was not normally distributed in the sample.

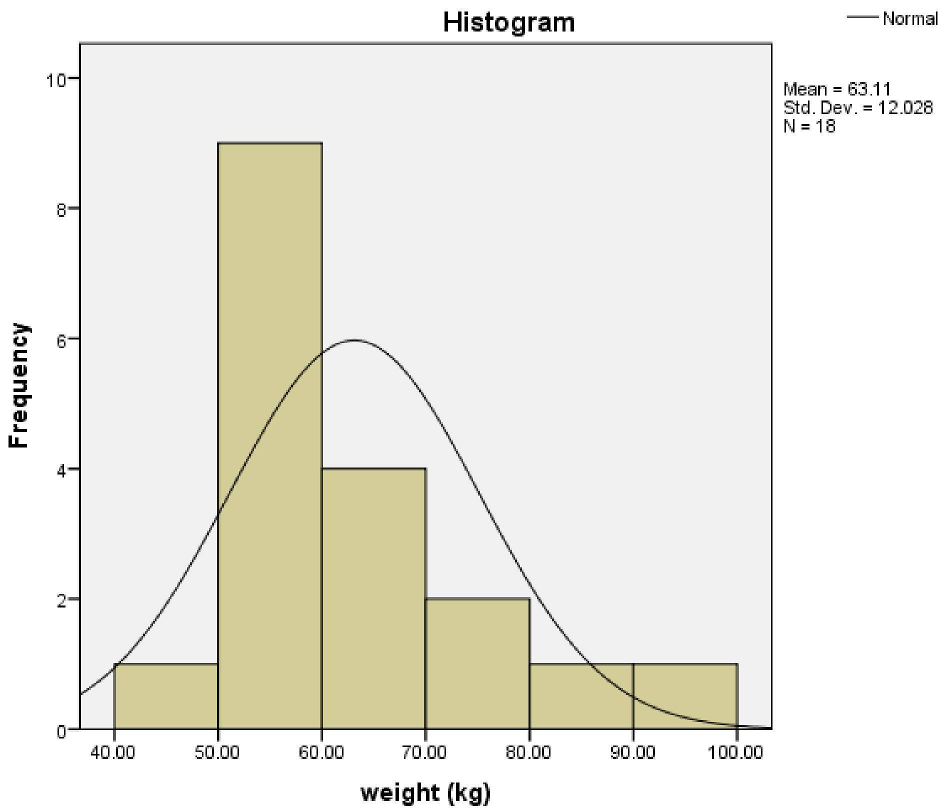

Figure 3. Frequency of weight for participants.

A Q-Q plot was used to visually see the distribution of weight among the sample (Figure 4) The Q-Q plot shows that weight trended from expected values in the sample.

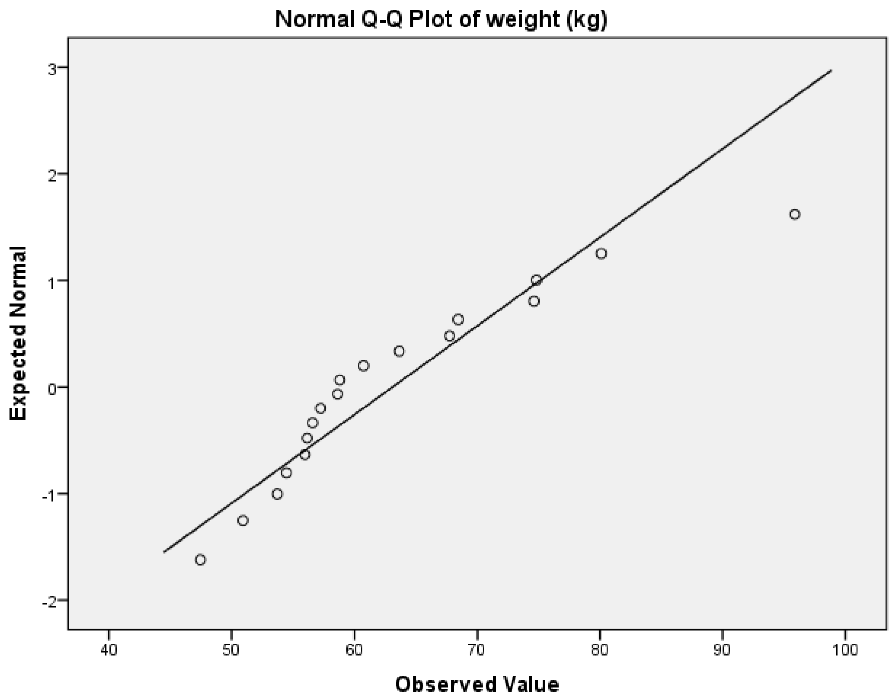

Figure 4. Observed values vs. expected values of participant weight.

A histogram was used to visually see the distribution of BMI among the sample (Figure 5). The histogram shows that BMI was not normally distributed in the sample.

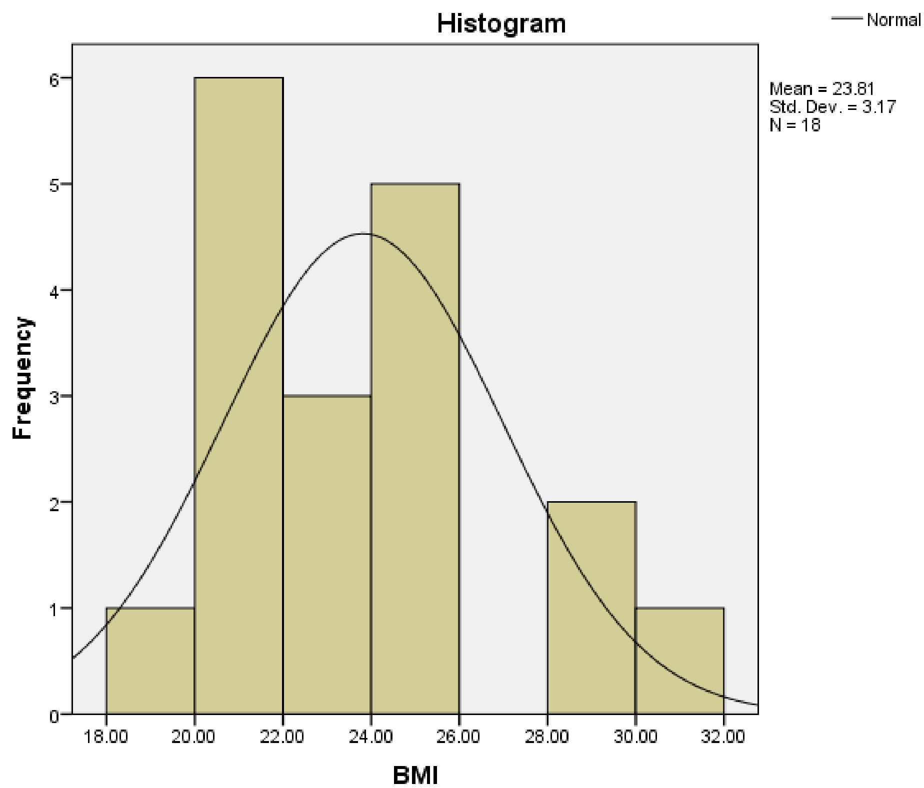

Figure 5. Frequency of BMI of participants.

A Q-Q plot was used to visually see the distribution of BMI among the sample (Figure 6) The Q-Q plot shows that BMI trended from expected values in the sample.

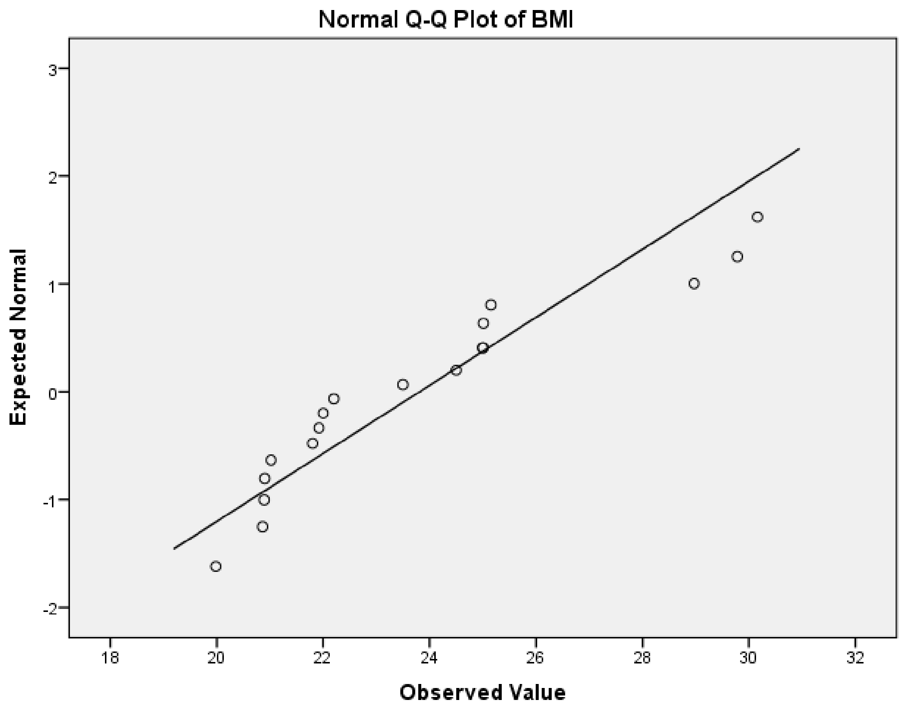

Figure 6. Observed values vs. expected values of participant BMI.

A histogram was used to visually see the distribution of baseline absolute resting metabolic rate among the sample (Figure 7). The histogram shows that baseline absolute resting metabolic rate was normally distributed in the sample.

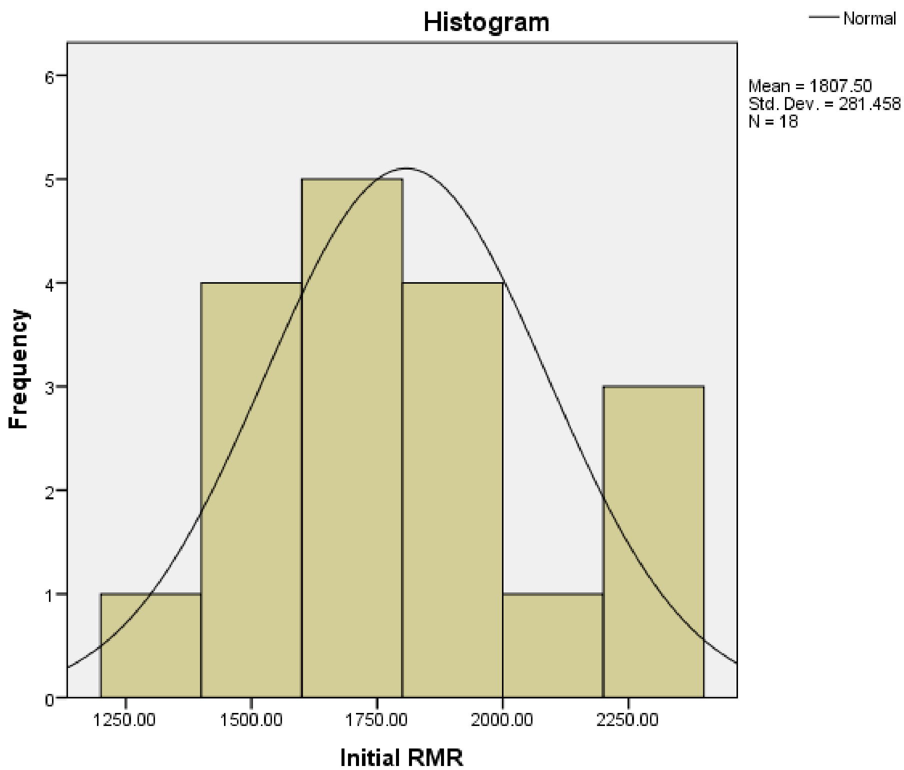

Figure 7. Frequency of baseline absolute resting metabolic rate of participants.

A Q-Q plot was used to visually see the distribution of baseline absolute resting metabolic rate among the sample (Figure 8) The Q-Q plot shows that baseline absolute resting metabolic rate did not trend from expected values in the sample.

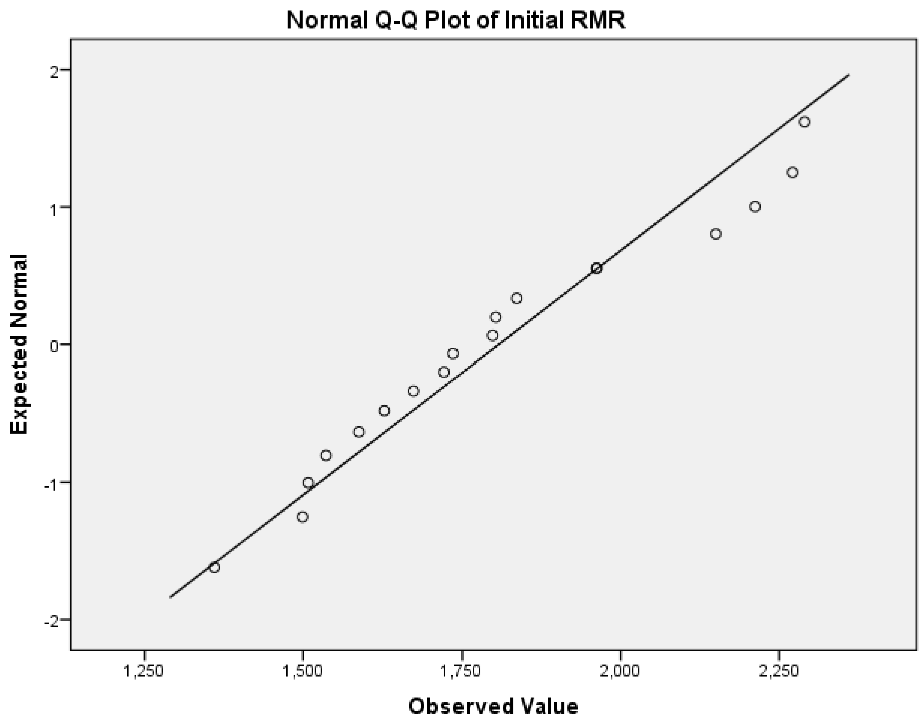

Figure 8. Observed vs. expected values of participant absolute resting metabolic rate.

A histogram was used to visually see the distribution of fat mass among the sample (Figure 9). The histogram shows that fat mass was not normally distributed in the sample.

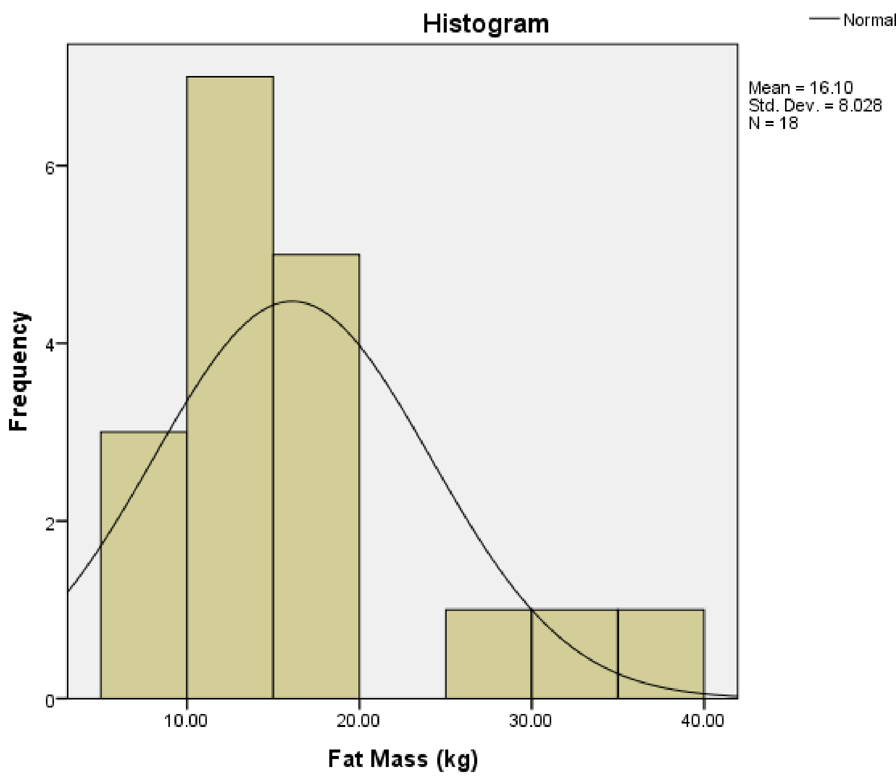

Figure 9. Frequency of fat mass of participants.

A Q-Q plot was used to visually see the distribution of fat mass among the sample (Figure 10) The Q-Q plot shows that fat mass did trend from expected values in the sample.

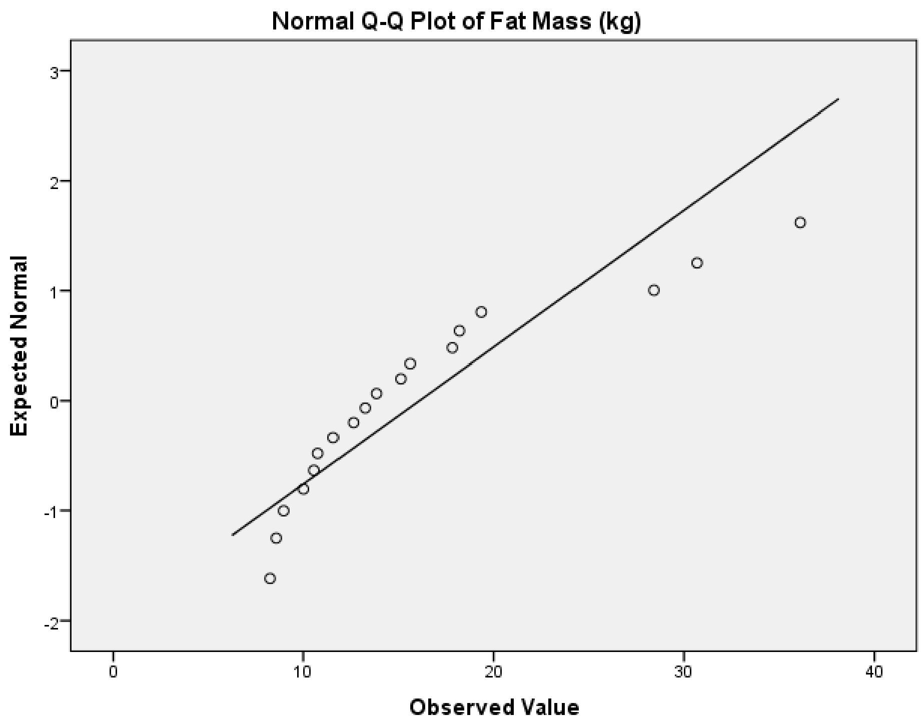

Figure 10. Observed vs. expected values of participant fat mass.

A histogram was used to visually see the distribution of fat free mass among the sample (Figure 11). The histogram shows that fat free mass was not normally distributed in the sample.

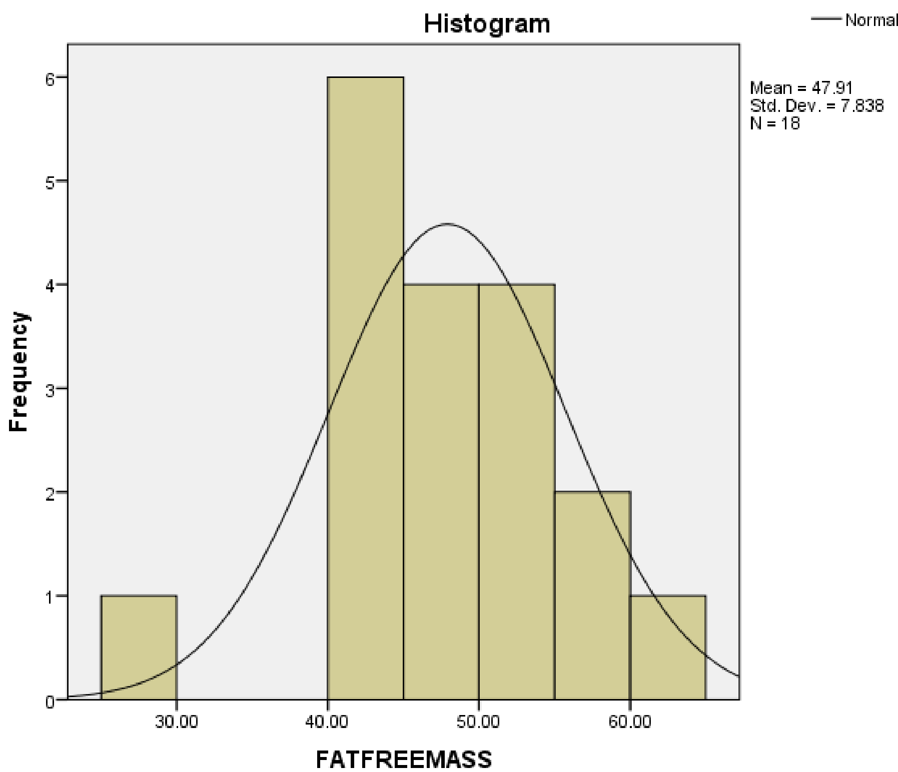

Figure 11. Frequency of fat free mass of participants.

A Q-Q plot was used to visually see the distribution of fat free mass among the sample (Figure 12) The Q-Q plot shows that fat free mass did trend from expected values in the sample.

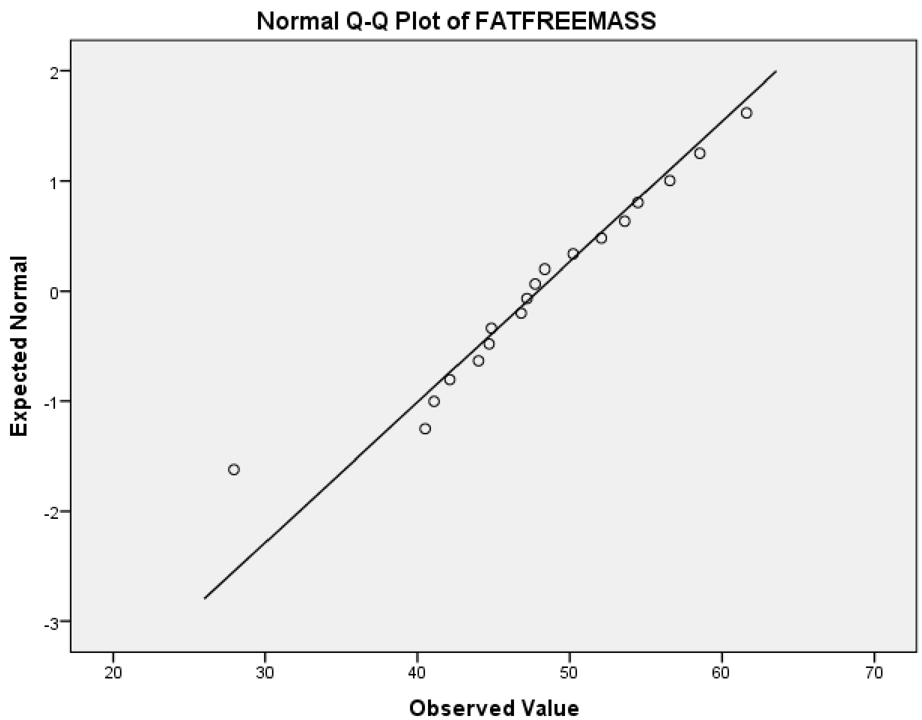

Figure 12. Observed vs. expected values of participant fat free mass.

A histogram was used to visually see the distribution of relative baseline resting metabolic rate among the sample (Figure 13). The histogram shows that relative baseline resting metabolic rate was normally distributed in the sample.

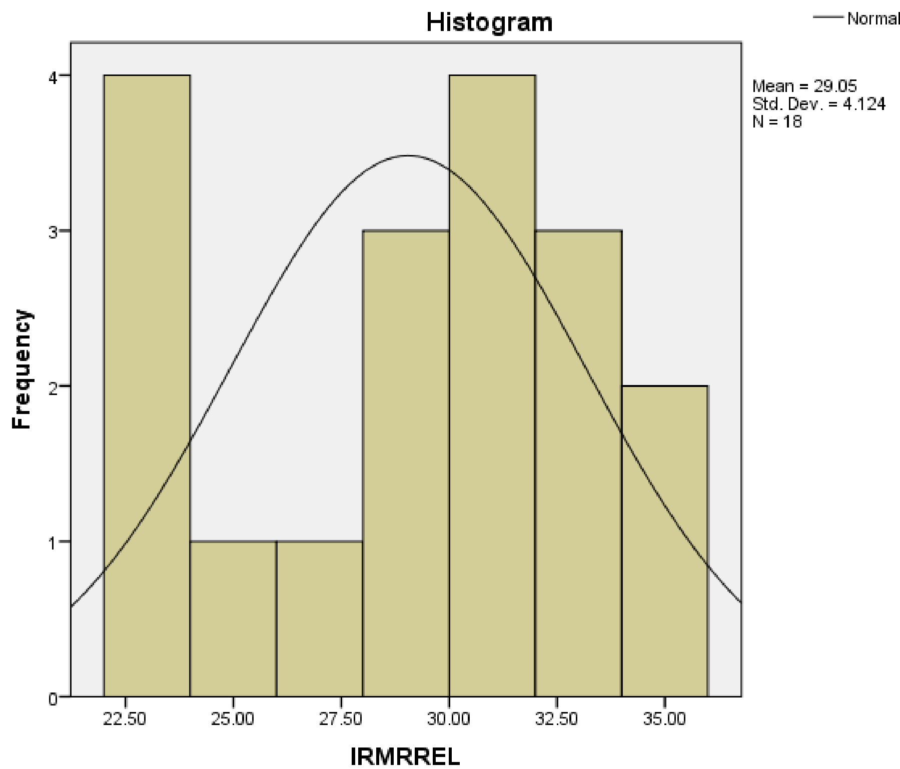

Figure 13. Frequency of relative baseline resting metabolic rate of participants.

A Q-Q plot was used to visually see the distribution of baseline relative resting metabolic rate among the sample (Figure 14) The Q-Q plot shows that baseline absolute resting metabolic rate did not trend from expected values in the sample.

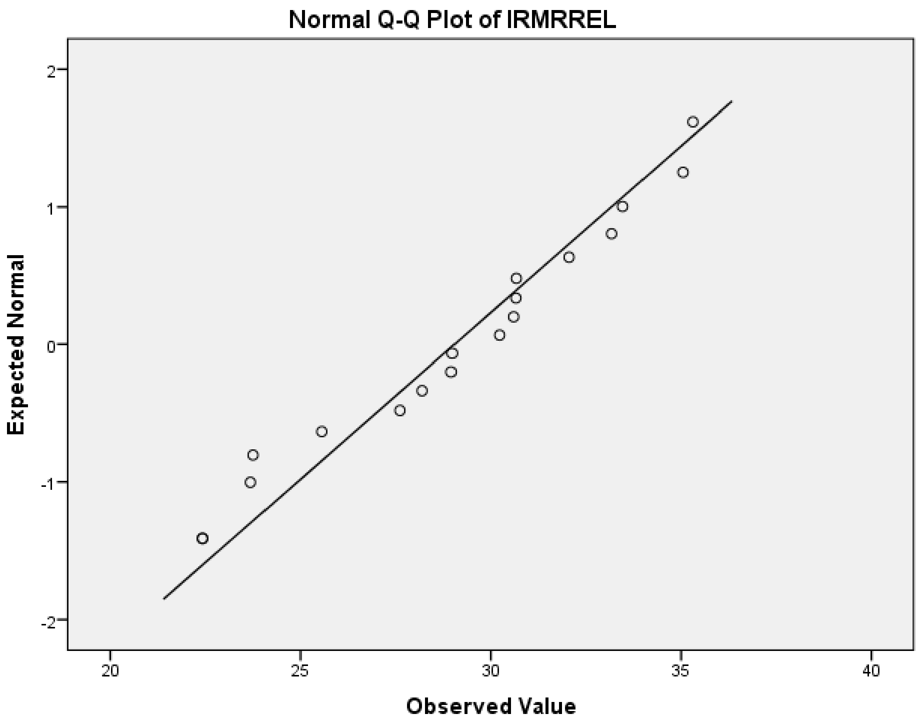

Figure 14. Observed vs. expected values of participant relative baseline resting metabolic rate.

Effects of the Exercise Bout

Participants participated in a single bout of high intensity resistance exercise consisting of eight exercises. Before the participants completed this single exercise bout, a baseline resting metabolic rate was measured. In addition, immediately after the exercise bout and 24 hours after the exercise bout, resting metabolic rate was measured. The effects of the exercise bout were examined in the entire sample and then separately by BMI category. The variables examined included baseline, immediate post exercise, and 24 hours post exercise resting metabolic rates (absolute and relative). In order to test for **hypothesis #1** that states resting metabolic rate will increase immediately and remain elevated above baseline 24 hours after an acute bout of high intensity resistance exercise, a repeated measures of variance test was performed. The average baseline absolute resting metabolic rate for the sample (n=18) was 1807.50 kcal/day ±281.45 (29.04 kcal/kg/day). The average absolute resting metabolic rate immediate post exercise was 2103.77 kcal/day ± 339.31 (33.91 kcal/kg/day). The average resting metabolic rate 24 hours post exercise was 1765.22 kcal/day ± 248.66 (28.46 kcal/kg/day) (Table 3). The Greenhouse-Geisser test of within subjects effects showed that absolute resting metabolic rate increased significantly for the entire sample from baseline (1807.50 kcal/day) to immediate post exercise (2103.77 kcal/day) (p=.000, alpha, p=.0001) (Table 4).

Table 3

Descriptive Statistics for the Initial, Immediate Post, and 24 Hours Post RMR for the Sample

n=18	Absolute RMR (kcal/day)	Relative RMR (kcal/kg/day)
Baseline RMR	1807.50 ± 281.45	29.04 ± 6.89
Immediately Post Exercise	2103.77 ± 339.31	33.91 ± 5.51
24 Hours Post Exercise	1765.22 ± 248.66	28.46 ± 4.13

Table 4

Tests of Within Subjects Effects

Source		Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Time	Sphericity Assumed	1225126.778	2	612563.389	27.213	.000	.615
	Greenhouse-Geisser	1225126.778	1.598	766883.580	27.213	.000	.615
	Huynh-Feldt	1225126.778	1.737	705268.770	27.213	.000	.615
	Lower-bound	1225126.778	1.000	1225126.778	27.213	.000	.615
Error(time)	Sphericity Assumed	765350.556	34	22510.310			
	Greenhouse-Geisser	765350.556	27.158	28181.226			
	Huynh-Feldt	765350.556	29.531	25917.022			
	Lower-bound	765350.556	17.000	45020.621			

Tukey's post hoc pairwise comparisons were used to determine whether there was significance between baseline and immediate post exercise resting metabolic rates, baseline and 24 hours post resting metabolic rates, and immediate post exercise and 24 hours post exercise for the sample. The within subjects factors that were used in the pairwise comparisons can be seen in Table 5.

Table 5

Within Subjects Factors

Time	Dependent Variable
1	Baseline RMR
2	Immediate Post Exercise RMR
3	24 Hours Post Exercise RMR

Tukey's post hoc pairwise comparisons (Table 6) show the significance between each of the within subjects factors for the sample (n=18). The post hoc pairwise comparisons were not used to show the significance between each of the within subjects factors for the covariates age and BMI (18-30 normal weight, 18-30 overweight, 31-45 normal weight, 31-45 overweight) because the sample size within each covariate (n=6,4,4,4 respectively) was too small to detect any statistical differences. The results of this test indicate that from baseline (1807.50 kcal/day ±281.45) to immediate post exercise (2103.77 kcal/day ± 339.31), absolute resting metabolic rate for the sample significantly increased by an average of 296.27 kcal/day (p=.000). From baseline (1807.50 kcal/day ±281.45) to 24 hour post exercise (1765.22 kcal/day ± 248.66) absolute resting metabolic rate, the results show no significant difference (p=.789). The increase in absolute resting metabolic rate from immediate post exercise (2103.77 kcal/day ± 339.31) to 24 hour post exercise (1765.22 kcal/day ± 248.66) was statistically significant (p=.000). The mean increase in resting metabolic rate from immediately post exercise to 24 hours post exercise was 338.55 kcal/day.

Table 6

Tukey's Post Hoc Pairwise Comparisons

(I) time	(J) time	Mean Difference (I-J)	Std. Error	Sig.[b]	95% Confidence Interval for Difference[b] Lower Bound	Upper Bound
1	2	-296.278*	51.823	.000*	-433.868	-158.687
	3	42.278	36.517	.789	-54.675	139.231
2	1	296.278*	51.823	.000*	158.687	433.868
	3	338.556*	59.028	.000*	181.837	495.274
3	1	-42.278	36.517	.789	-139.231	54.675
	2	-338.556*	59.028	.000	-495.274	-181.837

Based on estimated marginal means
* The mean difference is significant at the .05 level

Table 7

Repeated Measures ANOVA

	Value	F	Hypothesis df	Error df	Sig.	Partial Eta Squared
Pillai's trace	.683	17.237[a]	2.000	16.000	.000	.683
Wilks' lambda	.317	17.237[a]	2.000	16.000	.000	.683
Hotelling's trace	2.155	17.237[a]	2.000	16.000	.000	.683
Roy's largest root	2.155	17.237[a]	2.000	16.000	.000	.683

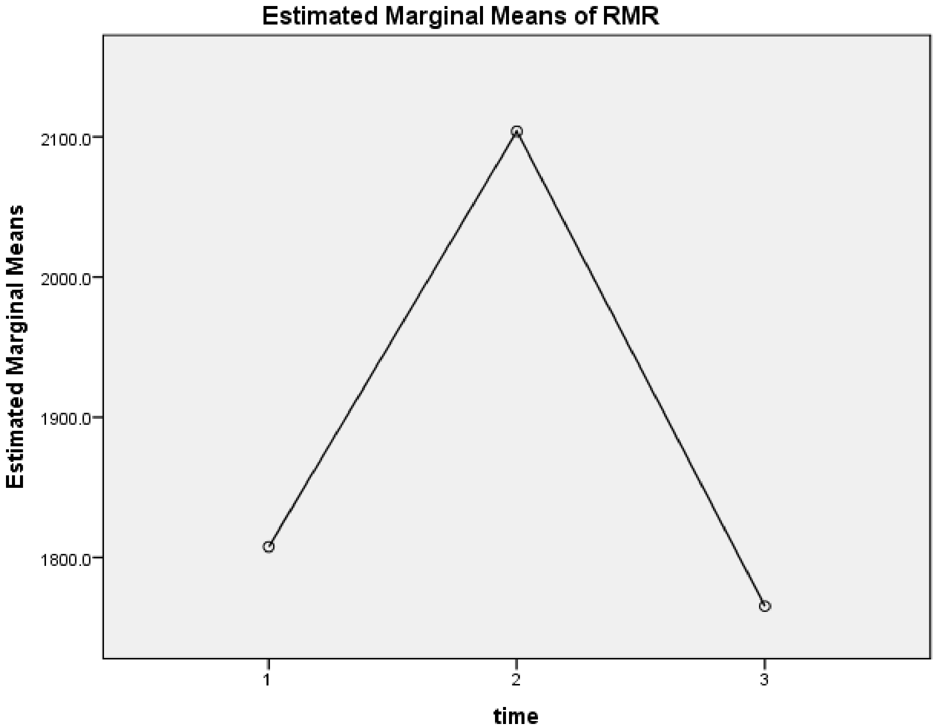

Figure 15. Estimated Marginal Means of RMR.

* Each F tests the multivariate effect of time. These tests are based on the linearly independent pairwise comparisons among the estimated marginal means.

Next, the effects of the exercise bout on resting metabolic rate were examined between the normal weight and overweight BMI categories. For the normal weight BMI group, the average baseline resting metabolic rate was 1667.00 ± 179.27 kcal/day, the immediate post exercise resting metabolic rate was 1912.30 ± 169.28 kcal/day, and the 24 hour post resting metabolic rate was 1661.10 ± 143.42 kcal/day. For the overweight BMI group, the average baseline resting metabolic rate was 1983.12 ±295.99 kcal/day, the immediate post exercise resting metabolic rate was 2343.77 ± 353.44 kcal/day, and the 24 hour post resting metabolic rate was 1895.37 ± 298.11 kcal/day. Descriptive statistics for resting metabolic rates of BMI groups can be seen in Table 8.

Table 8

Descriptive Statistics of Resting Metabolic Rate for BMI Groups

	Yes-NW No-OW	Mean	Std. Deviation	N
Baseline RMR	Yes	1667.000	179.2776	10
	No	1983.125	295.9959	8
	Total	1807.500	281.4578	18
Immediate Post Ex RMR	Yes	1912.300	169.2835	10
	No	2343.125	353.4493	8
	Total	2103.778	339.3186	18
24 Hours Post Ex RMR	Yes	1661.100	143.4259	10
	No	1895.375	298.1140	8
	Total	1765.222	248.6641	18

The average baseline resting metabolic rate for both of the BMI groups combined while controlling for age was 1825.19 ± 57.97 kcal/day. The resting metabolic rate immediate post exercise was 2128.62 kcal/day ± 56.59 kcal/day and the 24 hours post exercise resting metabolic rate was 1778.28 ± 54.99 kcal/day (Table 9).

Table 9

Descriptive Statistics for Resting Metabolic Rates While Adjusting for Age

Time	Mean	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
1	1825.199[a]	57.977	1701.624	1948.775
2	2128.625[a]	56.594	2007.997	2249.254
3	1778.282[a]	54.999	1661.055	1895.509

a. Covariates appearing in the model are evaluated at the following values: Age = 28.111.

Tukey's post hoc pairwise comparisons were used to determine whether there was significance between baseline and immediate post exercise resting metabolic rates, baseline and 24 hours post resting metabolic rates, and immediate post exercise and 24 hours post exercise between BMI categories (normal weight and overweight) while adjusting for age. The covariate of BMI was evaluated at the value of age equaling 28.11, the average age of the sample. Between baseline and immediate post exercise, absolute resting metabolic rate significantly increased by an average of 303.426 ± 45.91 with alpha set at .05 (p=.000). From baseline to 24 hours post exercise, resting metabolic rate did not significantly increase (alpha, .05, p=.691). The mean difference was 46.91 ± 37.52 kcal/day. From immediate post exercise to 24 hours post exercise, resting metabolic rate significantly increased by an average of 350.34 ± 49.09 kcal/day (alpha=.05, p=.000). The Tukey's post hoc pairwise comparisons can be seen in Table 10.

Table 10

Tukey's Post Hoc Pairwise Comparisons of RMR While Adjusting for Age

(I) time	(J) time	Mean Difference (I-J)	Std. Error	Sig.[b]	95% Confidence Interval for Difference[b]	
					Lower Bound	Upper Bound
1	2	-303.426*	45.916	.000*	-427.111	-179.741
	3	46.917	37.522	.691	-54.158	147.993
2	1	303.426*	45.916	.000*	179.741	427.111
	3	350.344*	49.089	.000*	218.110	482.577
3	1	-46.917	37.522	.691	-147.993	54.158
	2	-350.344*	49.089	.000*	-482.577	-218.110

Based on estimated marginal means

*. The mean difference is significant at the .05 level.

b. Adjustment for multiple comparisons: Bonferroni.

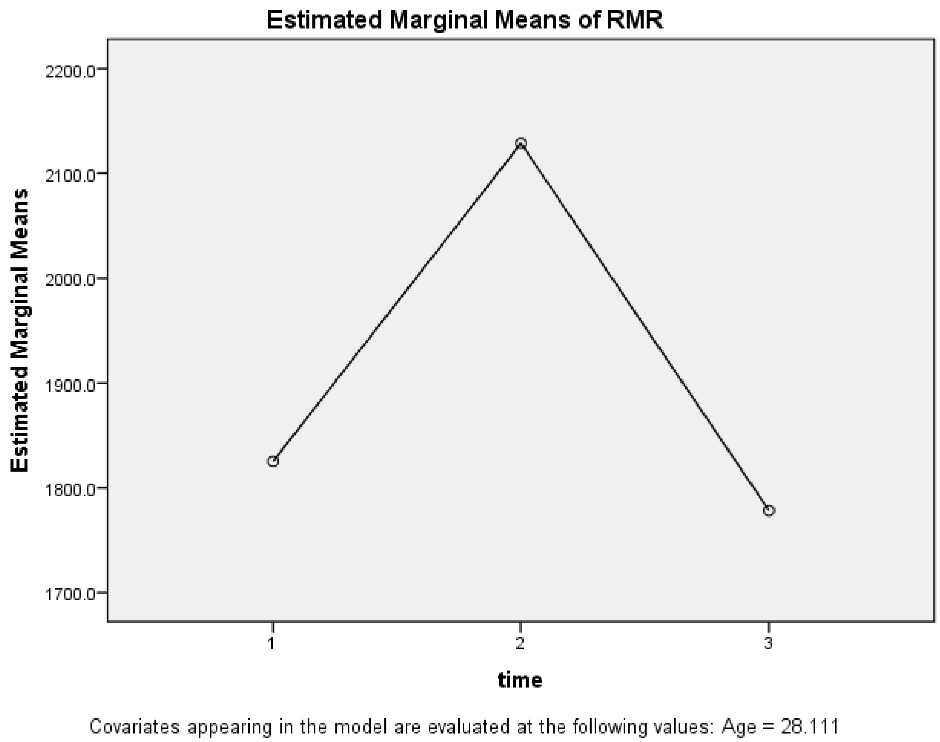

Figure 16. Estimated Marginal Means of Resting Metabolic Rate While Adjusting for Age.

The average baseline resting metabolic rate for both of the age groups combined while controlling for BMI was 1807.50 ± 60.46 kcal/day. The resting metabolic rate immediate post exercise was 2103.78 kcal/day ± 73.74 kcal/day and the 24 hours post exercise resting metabolic rate was 1765.22 ± 57.38 kcal/day (Table 11).

Table 11

Descriptive Statistics for RMR for Age Category While Controlling for BMI

Time	Mean	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
1	1807.500[a]	60.464	1679.322	1935.678
2	2103.778[a]	73.738	1947.459	2260.096
3	1765.222[a]	57.384	1643.573	1886.871

a. Covariates appearing in the model are evaluated at the following values: BMI = 23.8133.

Tukey's post hoc pairwise comparisons were used to determine whether there was significance between baseline and immediate post exercise resting metabolic rates, baseline and 24 hours post resting metabolic rates, and immediate post exercise and 24 hours post exercise between age categories (18-30 and 31-45 years old) while adjusting for BMI. The covariate of BMI was evaluated at the value of 23.81, the average BMI of the sample. Between baseline and immediate post exercise, absolute resting metabolic rate significantly increased by an average of 296.28 ± 53.91 kcal/day with alpha set at .05 (p=.000). From baseline to 24 hours post exercise, resting metabolic rate did not significantly increase (alpha, .05, p=.746). The mean difference was 42.28 ± 35.31 kcal/day. From immediate post exercise to 24 hours post exercise, resting metabolic rate significantly increased by an average of 338.556± 58.13 kcal/day (alpha=.05, p=.000). The Tukey's post hoc pairwise comparisons can be seen in Table 12.

Table 12

Tukey's Post Hoc Pairwise Comparisons of Resting Metabolic Rates for Age Categories While Controlling for BMI

Time	(J) factor1	Mean Difference (I-J)	Std. Error	Sig.[b]	95% Confidence Interval for Difference[b]	
					Lower Bound	Upper Bound
1	2	-296.278*	53.191	.000*	-438.459	-154.097
	3	42.278	35.308	.746	-52.101	136.657
2	1	296.278*	53.191	.000*	154.097	438.459
	3	338.556*	58.130	.000*	183.172	493.939
3	1	-42.278	35.308	.746	-136.657	52.101
	2	-338.556*	58.130	.000	-493.939	-183.172

Based on estimated marginal means

*. The mean difference is significant at the .05 level.

b. Adjustment for multiple comparisons: Bonferroni.

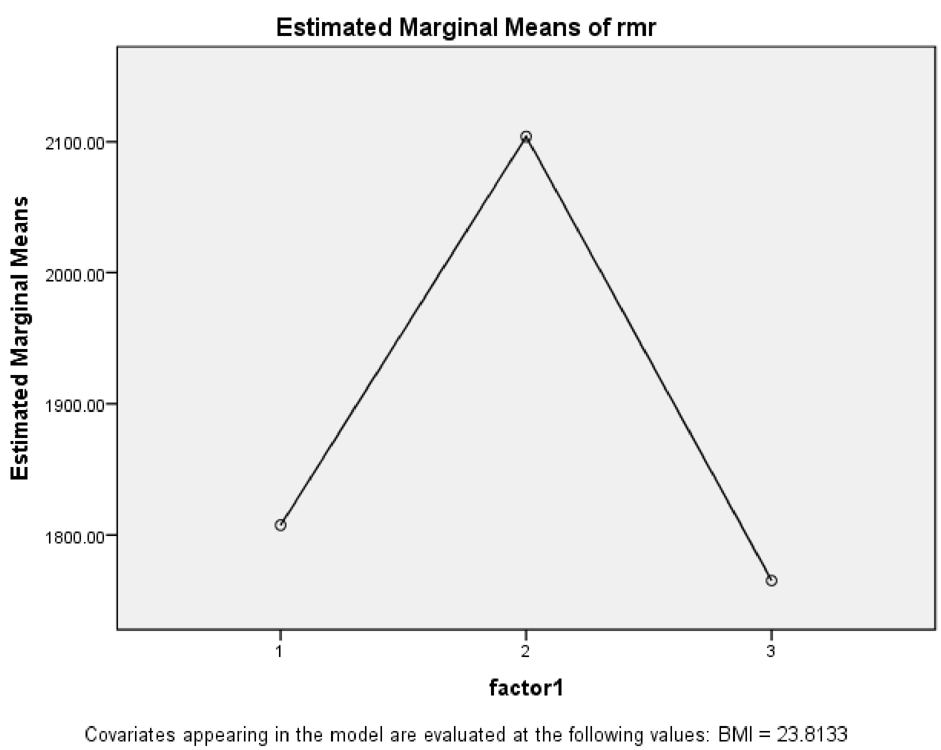

Figure 17

Estimated Marginal Means of Resting Metabolic Rate While Adjusting for BMI

One of the participants in the 31-45 overweight group had a BMI of 30.98 kg/m^2, and from the BMI histogram (Figure 5), was an outlier. Since this participant may have effected the results with a small sample size, a Tukey's post hoc pairwise comparison was re-run without the outlier (n=17). The average baseline RMR was 1787.35 ± 67.04 kcal/day. The average RMR immediate post exercise was 2100.00 ± 84.74 kcal/day. The average RMR 24 hours post exercise was 1750.41 ± 60.15 kcal/day (Table 13). Between baseline and immediate post exercise, absolute resting metabolic rate significantly increased by an average of 312.647 ± 52.15 kcal/day with alpha set at .05 (p=.000). From baseline to 24 hours post exercise, resting metabolic rate did not significantly increase (alpha, .05, p=1.00). The mean difference was 36.94 ± 38.32 kcal/day. The Tukey's post hoc pairwise comparisons can be seen in Table 14. **Therefore, for hypothesis #1, we can reject the null hypothesis and accept the hypothesis that absolute resting metabolic rate will increase immediately post exercise from baseline. Since there was no evident change between baseline resting metabolic rate and 24 hours post exercise, we accept the null hypothesis.**

Table 13

Descriptive Statistics for RMR When Removing Outlier

			95% Confidence Interval	
Time	Mean	Std. Error	Lower Bound	Upper Bound
1	1787.353	67.041	1645.232	1929.474
2	2100.000	84.735	1920.370	2279.630
3	1750.412	60.149	1622.903	1877.921

Table 14

Tukey's Post Hoc Pairwise Comparison When Removing Outlier

(I) factor1	(J) factor1	Mean Difference (I-J)	Std. Error	Sig.[b]	95% Confidence Interval for Difference[b]	
					Lower Bound	Upper Bound
1	2	-312.647*	52.153	.000*	-452.053	-173.241
	3	36.941	38.317	1.000	-65.480	139.363
2	1	312.647*	52.153	.000	173.241	452.053
	3	349.588*	61.505	.000	185.183	513.993
3	1	-36.941	38.317	1.000	-139.363	65.480
	2	-349.588*	61.505	.000	-513.993	-185.183

In order to test for **hypothesis #2**, which states that at baseline, resting metabolic rate will be higher in women 18 to 30 years of age compared to women 31 to 45 years of age, independent of body mass index, an independent samples t-test was used to determine the differences between the two age groups. 10 participants were grouped into the 18-30 age group, and 8 participates were grouped into the 31-45 age group. The 18-30 age group had a mean absolute resting metabolic rate of 1777.60 (±294.71) kcal/day. The 31-45 age group had a mean absolute resting metabolic rate of 1844.85 (±278.99) kcal/day (Table 15). Results of the independent samples t test indicated that no statistically significant differences existed between the two groups based on age for baseline absolute resting metabolic rate, with alpha set at p=.05, (p=.903) (Table 16).

Table 15

Descriptive Statistics for Baseline RMR of the 18-30 and 31-45 Age Categories

Baseline RMR	18-30 years old (n=10)	31-45 years old (n=8)
kcal/day	1777.60 (±294.71)	1844.85 (±278.99)

Table 16

Levene's Test for Equality Between Age Categories for Absolute RMR

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Baseline RMR	Equal variances assumed	.015	.903	-.493	16	.629	-67.2750	136.5844	-356.8210	222.2710
	Equal variances not assumed			-.496	15.481	.627	-67.2750	135.7046	-355.7420	221.1920

Another independent samples t test was conducted to determine whether baseline relative resting metabolic rate was different between the two age groups. The 18-30 years old age group had a mean relative RMR of 29.96 (±3.67) kcal/kg/day. The 31-45 years old age group had a mean relative RMR of 27.91 (±4.62) kcal/kg/day. Results of this test indicated that there was no statistical difference between the baseline relative resting metabolic rate of the two age groups, with alpha set at $p=.05$, ($p=.411$) (Table 17) .

Table 17

Levene's Test for Equality Between Age Categories for Relative RMR

		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference Lower	Upper
Baseline Relative RMR	Equal variances assumed	.712	.411	1.049	16	.310	2.04675	1.95056	-2.08825	6.18175
	Equal variances not assumed			1.022	13.246	.325	2.04675	2.00302	-2.27235	6.36585

In order to further examine the hypothesis, a univariate analysis of variance was run to determine if there was a difference in resting metabolic rate for the two age categories when adjusting for BMI. The results indicated no significant difference (p=.15) with alpha set at .05 (Table 18). These results suggest that age does not have an impact on baseline absolute resting metabolic rate and relative resting metabolic rate, opposite of what was hypothesized. **Therefore, we accepted the null hypothesis for hypothesis #2.**

Table 18

Univariate Analysis of Variance Adjusting for BMI

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	297484.849[a]	2	148742.424	2.126	.154*
Intercept	202761.027	1	202761.027	2.899	.109
BMI	277369.624	1	277369.624	3.965	.065
AgeCat1830	3676.161	1	3676.161	.053	.822
Error	1049229.651	15	69948.643		
Total	60153727.000	18			
Corrected Total	1346714.500	17			

a. R Squared = .221 (Adjusted R Squared = .117)

In order to test for **hypothesis #3** which states that women with a body mass index of 18.5-24.9 kg/m^2 (normal weight) will have a higher resting metabolic rate compared to women with a BMI of 25-29.9 kg/m^2 (overweight) independent of age, an independent samples t-test was performed using these BMI covariates. The average absolute resting metabolic rate for normal weight participants was 1667.00 ± 179.28 kcal/day. The average absolute resting metabolic rate for overweight participants was 1983.13 ± 295.99 kcal/day (Table 17). The results indicate no statistical significance and that no difference exists between the absolute resting metabolic rates between normal weight and overweight participants (p=.072) (Table 18).

Table 17

Descriptive Statistics for Baseline RMR of the Normal Weight and Overweight BMI Categories

		N	Mean	Std. Deviation	Std. Error Mean
Baseline RMR (kcal/day)	Normal	10	1667.0000	179.27756	56.69254
	Overwt	8	1983.1250	295.99587	104.65034

Table 18

Levene's Test for Equality Between BMI Categories for Absolute RMR

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	Df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Baseline RMR	Equal variances assumed	3.716	.072	-2.806	16	.013	-316.12500	112.65982	-554.95314	-77.29686
	Equal variances not assumed			-2.656	10.976	.022	-316.12500	119.01991	-578.15520	-54.09480

Since the independent samples t test showed borderline significance (p=.072), a non parametric test was used to determine whether there was statistical significance between the fat free mass in the normal weight and overweight BMI categories. A non parametric test was used to examine fat free mass since fat free mass was not normally distributed for the entire sample. The average fat free mass for the normal weight BMI category was 43.06 kg. The average fat free mass for the overweight BMI category was 53.98 kg (Table 19). The non parametric Mann-Whitney test showed that the difference in fat free mass between the BMI groups was significant (.001) (Table 20).

Table 19

Descriptive Statistics for Fat Free Mass of Normal Weight and Overweight BMI Categories

		N	Mean	Std. Deviation	Std. Error Mean
Fat Free Mass (kg)	Normal	10	43.0560	6.00358	1.89850
	Overwt	8	53.9750	5.21011	1.84205

Table 20

Non Parametric Mann-Whitney Test for Fat Free Mass

	Fat Free Mass
Mann-Whitney U	5.000
Wilcoxon W	60.000
Z	-3.110
Asymp. Sig. (2-tailed)	.002
Exact Sig. [2*(1-tailed Sig.)]	.001*

a. Grouping Variable: BMI

A non parametric Mann-Whitney test was also used to determine whether fat mass was significant between the BMI groups. The Mann Whitney test showed that fat mass was significantly different between the normal weight and overweight BMI groups (p=.027) (Table 21).

Table 21

Non Parametric Mann Whitney Test for Fat Mass

	Fat Mass
Mann-Whitney U	15.000
Wilcoxon W	70.000
Z	-2.221
Asymp. Sig. (2-tailed)	.026
Exact Sig. [2*(1-tailed Sig.)]	.027[*]

a. Grouping Variable: NW

Table 22

Descriptive Statistics for Body Mass of BMI Categories

		Normal Weight	Overweight
N	Valid	10	8
	Missing	11	13
Mean		13.1980	19.7188
Median		11.0650	18.0150
Mode		8.25[a]	10.76[a]
Std. Deviation		6.65916	8.51581
Percentiles	25	8.8717	13.3875
	50	11.0650	18.0150
	75	15.2425	26.1525

a. Multiple modes exist. The smallest value is shown

Since there was a participant in the 31-45 overweight group that was an outlier, a non parametric test was used to determine whether there was significance between the fat free mass of the normal weight and overweight BMI groups when the outlier was removed from analysis. The average fat free mass for the normal weight group was 43.06 ± 6.00 kcal/day. The average fat free mass for the overweight group was 52.88 ± 4.53 kcal/day (Table 23).The results of non parametric test indicate that the fat free mass between the BMI groups was significant (p=.002).

Table 23

Descriptive Statistics for the Sample After Removing the Outlier

	BMI	N	Mean	Std. Deviation	Std. Error Mean
Fat Free Mass (kg)	0	10	43.0560	6.00358	1.89850
	1	7	52.8843	4.53498	1.71406

Table 24

Mann Whitney Test for BMI Groups for Fat Free Mass After Removing the Outlier

	FFM
Mann-Whitney U	5.000
Wilcoxon W	60.000
Z	-2.928
Asymp. Sig. (2-tailed)	.003
Exact Sig. [2*(1-tailed Sig.)]	.002*

a. Grouping Variable: BMI

b. Not corrected for ties.

We ran an additional independent samples t test to determine if differences in resting metabolic rate based on BMI category were present when resting metabolic rate was expressed in relative terms. The average relative baseline resting metabolic rate was 29.88 kcal/kg/day ± 3.37 for the normal weight BMI category. The average relative baseline resting metabolic rate was 27.26 kcal/kg/day ± 4.32 for the overweight BMI category (Table 25). The results of this test indicated that no statistically significant difference exists between the BMI categories when resting metabolic rate is expressed in relative terms (p=.226) (Table 26). **These results do not coincide with the hypothesis; therefore, the hypothesis that normal weight individuals would have a higher baseline resting metabolic rate than overweight individuals was rejected.**

Table 25

Descriptive Statistics for Relative Baseline RMR for BMI Categories

		N	Mean	Std. Deviation	Std. Error Mean
Baseline RMR	Normal	10	29.8810	3.36502	1.06411
	Over	8	27.2588	4.32383	1.52870

Table 26

Levene's Test for Equality Between BMI Categories for Relative RMR

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Baseline RMR	Equal variances assumed	1.584	.226	1.449	16	.167	2.62225	1.80927	-1.21323	6.45773
	Equal variances not assumed			1.408	13.045	.183	2.62225	1.86260	-1.40024	6.64474

CHAPTER V

DISCUSSION AND CONCLUSIONS

The purpose of this study was to examine the effect of a single bout of high intensity resistance exercise on the resting metabolic rates of a sample of apparently healthy adult women, and secondarily to examine if age or body mass index had a significant impact on baseline resting metabolic rate. Results suggest that the high intensity resistance exercise significantly increased the immediate post exercise resting metabolic rate of apparently healthy adult women. This information suggests that incorporating resistance exercise to an individuals regular exercise program is beneficial. Secondary results of the study from this sample population suggest that age does not have a significant impact on baseline resting metabolic rate. BMI did have a significant impact on baseline resting metabolic rate; however, in the opposite direction than hypothesized. Therefore, women between the ages of 18 and 45 years old are suggested to have the same probability of having similar resting metabolic rates.

Hypotheses

In testing hypothesis #1 that resting metabolic rate will increase immediately after an acute bout of high intensity resistance exercise, the null hypothesis was rejected. Since there was no evident significant change between baseline and 24 hours post exercise resting metabolic rates, we accept the null hypothesis. These results are similar to the findings of Akbulut & Rakioglu (2011), which suggest that a significant increase in resting metabolic rate can be achieved through physical activity and exercise. An experimental study by Melby, Scholl, Edwards, and Bullough (1993) found similar results. The results showed significantly elevated resting metabolic rates the morning after the high intensity exercise bout (2,110 ± 80 kcal/day) compared with the morning before exercise (1,930 ± 70 kcal/day).One possible explanation for this effect is that high intensity exercise of long duration can result in a prolonged recovery period, contributing to substantial post-exercise energy expenditure above resting values. Another explanation for this effect is that during exercise, there is a recruitment of more neuromuscular junctions when compared to rest or moderate intensity exercise. The increases in the neuromuscular activity would require more energy in the form of adenosine triphosphate to meet the demands of the active tissue (Cannon & Marino, 2010). Therefore, an increase in neuromuscular recruitment and activity would cause a significant increase in resting metabolic rate post exercise. The exercise protocol was designed to engage as many large muscle groups as possible (quadriceps, hamstrings, biceps, triceps, core stabilizers, chest, and back). The increased neuromuscular recruitment results in an increased intensity of the neuromuscular response. Contrary to other research studies results, the resting metabolic rate did not remain significantly elevated 24 hours after exercise. Since the participants had already been participating in regular resistance training at least once a week for sixty minutes for at least three months prior to the start of the research study, the effects of the exercise bout were small and not statistically significant. The results were not significant as a result of improper intensity, but a result of the participants previous resistance training. During the participant practice session and the exercise bout, intensity was monitored via the RPE scale and heart rate. The desired RPE range for each exercise was between 14(somewhat hard) and 17 (very hard) . During both the participant practice session and the exercise bout, the RPE for each exercise was between 14 and 17, indicating that the exercise intensity was challenging. The participants did not exceed their age predicted maximum heart rates which were determined using the formula (220-age), a formula commonly used for apparently healthy adults. Immediately after each set of exercise, heart rate was documented. The participants heart rate remained elevated at least 20 beats above resting heart rate. Additionally, as a result of the small sample size (n=18), the statistical differences were difficult to detect. No statistical differences were detected in the effects of the exercise bout on resting metabolic rate between the BMI groups, between the age groups when controlling for BMI, or between the BMI groups when controlling for age. This could be because there was no difference in the average resistance sessions per week or the minutes per week of resistance exercise between the normal weight and overweight BMI groups. The present exercise protocol included a total of 24 sets and 192 repetitions. The exercises included in the present study were common exercises the participants performed for the three months prior to the study. Therefore, the participants could have been adapted to the exercises. Another possible explanation for the lack of significance could be attributed to a potential lack of effort of the participants during the 8RM assessments, since they were responsible for selecting the proper weight that they felt they could lift for eight repetitions. The weight for each exercise in the protocol was to be 80% of the participants one repetition maximum, determined by the 8RM assessments Additionally, the participants were not previously sedentary. On average, they participated in 3 resistance training sessions a week for a weekly total of 141 minutes. Previous research suggests that resting metabolic rate will increase more significantly and remain elevated 24 hours post exercise in individuals who are sedentary compared to individuals who are regularly active (Potteiger et al., 2008). Since there was one participant that was an outlier in the 31-45 years old overweight group that could have potentially skewed the results, a Tukey's post hoc pairwise comparison was performed without this participant (n=17). This test showed that there was significance between baseline RMR and immediate post exercise RMR but no significant difference was present between baseline and 24 hours post exercise RMR for the sample. Removing this participant did not change the significance.

In testing hypothesis #2 that at baseline, resting metabolic rate will be higher in women 18 to 30 years of age compared to women 31 to 45 years of age, independent of body mass index, the null hypothesis was accepted. Results suggested that no significant differences in baseline resting metabolic rate were present between the 18-30 and 31-45 age groups. These results are not consistent with research conducted by Frisard et al. (2007), that suggests as age increases, resting metabolic rate decreases as a result of decreased physical activity, increased fat mass, muscular atrophy, and sarcopenia. Other research by Visser, Duerenberg, Staveren, & Hautvast (1995), also suggests that age has a negative linear relationship to resting metabolic rate. A possible explanation for the lack of significance between the younger and older age groups is the similarity between the age groups, and the physically active nature of the participants. In addition, both age groups had participants of both normal weight and overweight body mass indexes. When body mass index was controlled for, the lack of significant difference between the two age groups was still present. Another possible reason for the lack of significant differences between the age groups was the small sample size, especially in the 31-45 years old age group.

In testing for hypothesis #3, that normal weight (BMI=18.9-24.9 kg/m^2) participants would have a higher resting metabolic rate than overweight (BMI=25-29.9 kg/m^2) participants independent of age, the null hypothesis was accepted. In the present study, the overweight body mass index group had a greater RMR than those in the normal weight group. These results are contrary to what research by Miller et al. (2006) suggests, that those with a high body mass index indicating he or she is overweight, may have a lower resting metabolic rate compared to an individual with a normal body mass index because of the decreased muscle mass which is highly metabolically active and increased adipose tissue which is not metabolically active. One possible explanation for the overweight BMI group having higher baseline resting metabolic rates than the normal weight BMI group is that the overweight BMI group had greater fat free mass compared to the normal weight group, resulting in higher resting metabolic rates than those in the normal weight group. When the participant that was an outlier in the 31-45 overweight group was removed and data was re-analyzed, the fat free mass between the BMI groups was still present. Research conducted by Miller et al. (2006) states that fat free mass is directly related to resting metabolic rate. Individuals with greater fat free mass will have a higher resting metabolic rate. Another possible explanation for the lack of significance of the results is that there was a similarity of physically active lifestyles between each group. Both BMI groups resistance trained on average three times a week for the three months prior to the study.

Limitations and Assumptions

The sample population represents a convenience sample, which may have influenced the lack of significance in some of the results of the study (that age and BMI would impact resting metabolic rate at baseline). There was one outlier in the overweight BMI group that could have skewed the results. In addition, an increase in the number of exercises in the resistance exercise protocol may have had a larger variation of resting metabolic rate changes between the sub-groups. Each participant in the sample had participated in resistance training on average 3 times a week for 51 minutes a session for at least the three months prior to the start of the study. Therefore, the resistance exercise protocol may not have had a significant effect on the resting metabolic rate since the participants were already regularly participating in resistance exercise. Aerobic exercise was not accounted for since participation in aerobic exercise was not inclusion or exclusion criteria. When the participants completed the exercise history during the inclusion process, they might have included their time performing aerobic exercise in the total time per week of resistance exercise, since the average weekly total of resistance exercise (141 minutes/week) was greater than expected. Participants did adhere to the pre resting metabolic rate measurement guidelines including fasting and refraining from physical activity for twelve hours prior to the measurement. Participants were not recruited on the basis of race or ethnicity; however, all final participants were Caucasian. As a result, the results of this study can only be applied to apparently healthy, Caucasian females.

Applications and Implications for Future Research

The information presented by this study can be used in support of incorporating resistance exercise to the exercise programs of adult females. The results suggest that this population may experience an increase in resting metabolic rate as a result of high intensity resistance exercise, and therefore may experience positive changes to body composition and caloric expenditure. The exercise protocol used in this study was a practical and effective tool for increasing caloric expenditure and can easily be incorporated into most exercise programs. Future research may examine the effects of resistance exercise of a longer duration and could compare the effects of resistance exercise on resting metabolic rate between sedentary and physically active individuals. Future research may also examine the effects of resistance exercise on the resting metabolic rate of males as compared to females. Previous research suggests that males have a higher resting metabolic rate as a result of higher amounts of lean body mass as compared to females. In addition, future research may examine the effect of resistance exercise on individuals with pulmonary, cardiovascular, and metabolic diseases. This can provide useful information for increasing the caloric expenditure and altering body composition of individuals with restrictions to exercise. Further research could be conducted to compare the effects of resting metabolic rates between exercise of low, moderate, and high intensities.

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Appendix A

Consent Form

INFORMED CONSENT

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mpbayles@iup.edu 724-357-7835

You are invited to participate in this research study on a voluntary basis. When reading through the below paragraphs, if you have any questions, we ask that you contact us via the contact information listed above. The purpose of this study is to determine if participating in a one-time bout of high intensity resistance exercise can increase the amount of calories expended at rest.

You have been invited because you are an apparently healthy adult woman between the ages of eighteen and forty-five, you have no chronic disease or orthopedic issues, are not pregnant, do not smoke, and are not currently taking medication for blood pressure, thyroid, heart rate, or diet. If any of these statements are not accurate, please notify the principle investigator immediately.

All potential participants who meet these criteria will be asked to come to the laboratory in Zink Hall for assessments of body composition, resting heart rate, resting blood pressure, height, and weight. Participants will then go to the fitness center in Zink Hall for demonstrations by the principle investigator of the exercises included in the exercise protocol. The participants will then have their strength assessed by performing the demonstrated exercises using various weight that the participant is comfortable lifting. This session will be approximately ninety minutes. The participants will then be asked to come for a second session at least 48 hours later which will include practice of the exercise protocol to ensure that the participant performs the exercises safely. The third session will be in the lab for a measurement of resting energy expenditure. This measurement will require you to fast for twelve hours and refrain from physical activity for 24 hours prior to the test. During the measurement, you will lay on a cot in a private room and have a large plastic dome placed over your head. This dome will be connected to a machine that measures carbon dioxide and oxygen levels. The instrument used for this measurement is approved by the FDA and there are no risks associated with the instrument or measurement. This test will last for approximately 45 minutes at which point a snack will be provided to you. After this measurement, the participant will perform the exercise bout in the fitness center and will last for approximately one hour. Immediately after, the participants will have another measurement of resting energy expenditure for forty five minutes. The next morning, the participants will be asked to come back to the lab for a final measurement of resting energy expenditure.

The total number of participant sessions is four for an approximate five hours of total participation. It is important to note that no participant will be asked or required to exercise beyond their physical ability. Muscle soreness is a possible risk, although there is the same chance of this occurring during a regular exercise session. Blood pressure and heart rate will be assessed continually throughout the exercise sessions to ensure proper safety.

Your participation is strictly on a voluntary basis and you may decide to withdrawal at any point without penalty by contacting the principle investigator or the co-investigator. Participants who remain in the study will be provided copies of their collected data and results from the resting energy measurement. All data collected during the study will be kept for three years in compliance with federal regulations in a safe locked place that will only be accessible to the principle investigator. The research team greatly thanks you for your interest and looks forward to working with you throughout the study.

THIS PROJECT HAS BEEN APPROVED BY THE INDIANA UNIVERSITY OF PENNSYLVANIAINSTITUTIONAL REVIEW BOARD FOR THE PROTECTION OF HUMAN SUBJECTS (PHONE: 724-357-7730)

Department of Kinesiology and Health and Sport Science

VOLUNTARY CONSENT FORM:

I have read and understand the information provided in the informed consent form. I volunteer to be a participant in this research study. I understand that there is no compensation for my participation. I understand that all of my data is kept confidential and is only seen by the lead researcher, and I have the right to withdrawal at any time during the study without penalty. I have received an unsigned copy of the informed consent form to keep in my possession. I understand and agree to the conditions of this study as described.

Name (please print): ____

Signature: _____________________________________ Date: _________________________

Phone number or location where you can be reached: __________________________________

Best days to reach you: ____

I certify that I have explained to the above participant the purpose and nature of this study, and potential risks and benefits associated with participating in this study. I have answered any questions the participant posed, and have witnessed the above signature.

Investigators Signature: __________________________ Date: _________________________

Appendix B

Promotional Flyer

PARTICIPANTS NEEDED

Interested in knowing your resting metabolic rate and body composition?

Study Title: *The Effects of an Acute Bout of High Intensity Resistance Exercise on Resting Metabolic Rate in Adult Women*

Women between the ages of **18 and 45** are being recruited for participation in a one time resistance exercise session and pre and post assessments of resting metabolic rate.

- Resting metabolic rate is a measure of how many calories are expended in a day under resting conditions. This is a vital factor in weight management and body composition.

If interested or with any questions, please contact the principle investigator

Principle Investigator:
Julianne Reger
dncr@iup.edu
724-357-2193

Co-Investigator:
Dr. Madeline Bayles, Ph.D.
Professor of Kinesiology, Health, and Sport Science
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THIS PROJECT HAS BEEN APPROVED BY THE INDIANA UNIVERSITY OF PENNSYLVANIA INSTITUTIONAL REVIEW BOARD FOR THE PROTECTION OF HUMAN SUBJECTS (PHONE: 724-357-7730)

Appendix C

Promotional Email

Subject: Interested in Knowing Your Resting Energy Expenditure Value?

Text: If you are a female between the ages of 18 and 45 interested in knowing how many calories you expend at rest and your body composition, you could be a participant in a research study. The research study is going to examine the effects of resistance exercise on resting energy expenditure. The total number of participant sessions is four and you will be asked to participate in a one time bout of high intensity resistance exercise along with measurements of resting metabolic rate and body composition. If you are interested in participating or have any questions, please contact the primary investigator. Thank you and I look forward to hearing from you.

Primary Investigator:
Julianne Reger
(Master of Sports Science student)
dncr@iup.edu
724-357-2193

Co-Investigator:
Dr. Madeline Bayles, Ph.D.
Professor of Kinesiology, Health, and Sport Science
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Apendix D

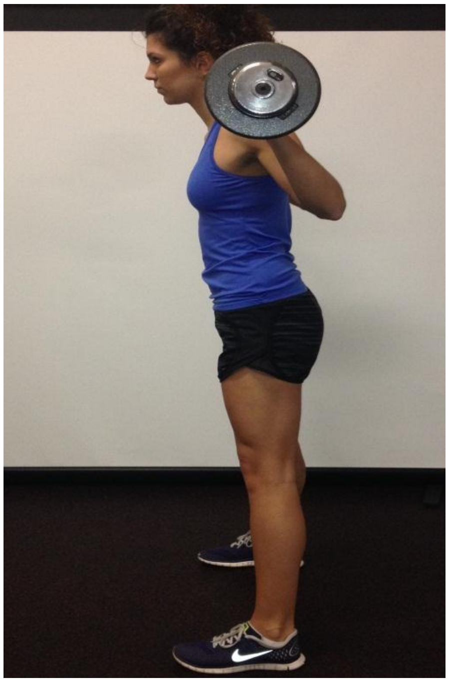
Exercise Protocol

RESISTANCE EXERCISE PROTOCOL

Warm Up:

3 minutes: Walking on a treadmill at 6% grade at 2.8-3.0mph
30 seconds: Medicine ball passes
30 seconds: Rest
30 seconds: Medicine ball press
30 seconds: Rest
30 seconds: Body weight squats.
3 minutes: Rest

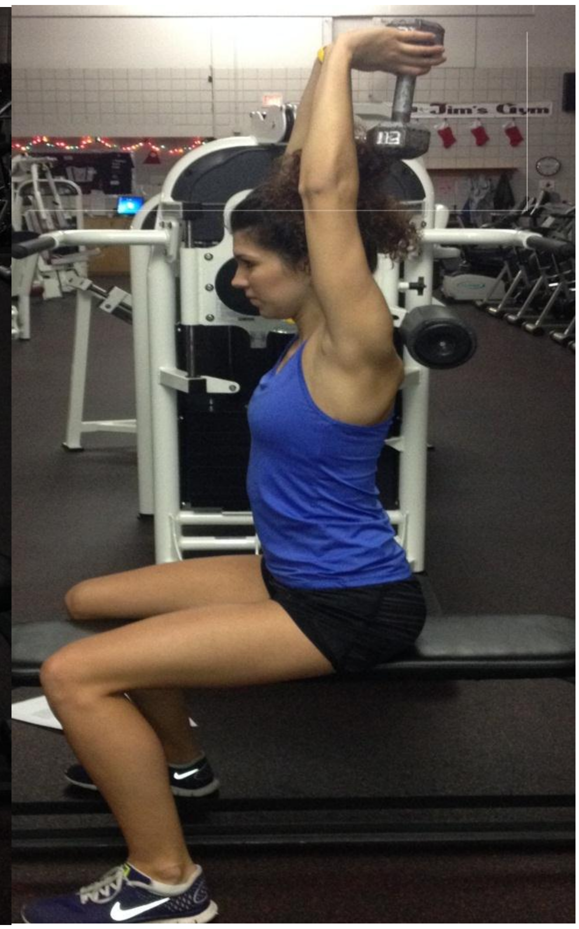
1. **Back Loaded Squat**
   Hold the weighted bar at the level of the shoulders with the bar behind your head. Stand with knees slightly bent, feet shoulder width apart, and back straight. While squatting, keep heels and balls of feet in contact with the ground. During the downward movement, bend hips and knees. Keep the head upward and keep your stomach tight. When squatting, be sure to not bend or round the back. Perform 3 sets of 8 repetitions.



2. **Standing Bent Over Barbell Row**
   Stand with knees slightly bent, and with the back straight. Bend at the hips and knees so that the back creates a 0-45^{o} angle with the ground. Hold the bar towards the ground so the arms are hanging. Pull the bar upwards towards your chest. Be sure to avoid rounding the neck or back. Perform 3 sets of 8 repetitions.

3. **Leg Extension (machine)**
   Properly set up the machine. Press the back firmly against the back pad. Place the feet behind and in contact with the roller pad. The legs should be parallel to one another. Align the knees with the axis of the machine. Keep the back straight, abs engaged, and hands lightly gripping the handles at your sides. Bend your knees towards your buttocks, pause, and then straighten knees to return to the starting position. Do not forcefully lock the knees. Perform 3 sets of 8 repetitions.

4. **Seated Dumbbell Triceps Extension**
   Sit on the bench with your back against the back pad. Grip the dumbbell with both hands. With the weight behind your head, lower the dumbbell so that the elbows are bent to 90°. Raise the dumbbell back to the starting position by straightening your elbows. Be sure to not hit the dumbbell off the back of your head by bending your wrists as your elbows bend. Perform this for 3 sets of 8 repetitions.



5. **Leg Curl (machine)**
   Properly set up the machine. Lie on the pad with your head facing the ground so your hips and torso are firmly against the pads. Place the ankles behind and in contact with the roller pad. Position the knees slightly off the bottom edge of the thigh pad. Align the knees with the axis of the machine. Grasp the handles or the sides of the chest pad. To begin, raise the roller pad by fully bending the knees. Keep the torso and hips pressed against the pads. Then, straighten the knees to return to the starting position. Do not forcefully lock the knees. Perform this for 3 sets of 8 repetitions.

6. **Bicep Curl**
   Grasp the dumbbells with a closed grip so that your palms are face out. Grip should be shoulder-width so the arms touch the side of your torso. Stand straight with the feet shoulder-width apart and the knees slightly bent. To begin, bend the elbows bringing the dumbbells upwards towards your chest. Keep the back straight and the upper arms stationary. Do not jerk or swing your body. Lower the dumbbells until the arms are completely straight. Do not swing the dumbbells off of your upper thighs. Perform this for 3 sets of 8 repetitions.

7. **Standing Trunk Twist with a Plated Weight**
   Hold the plated weight with both hands in front of your body with your arms extended. There should be a slight bend in your elbows. Stand with feet shoulder width apart and knees slightly bent. Rotate slowly from right to left while the hips stay straight. Do not rotate the hips, only the upper body.

8. Lateral Shoulder Raise (dumbbells)

Grasp two dumbbells with a closed grip. Stand with feet shoulder-width apart with the knees slightly bent, back straight, shoulders back, and head forward. Position the dumbbells so the palms face each other. To begin, raise the dumbbells up and out to the sides. The elbows and upper arms should rise together and ahead of the forearms and hands. Do not jerk or swing the dumbbells upward. Raise the dumbbells until the arms are parallel to the floor or nearly level with the shoulders. Then, slowly lower the dumbbells back to the starting position.

Appendix E

Exercise Log Sheet

Exercise Log Sheet

Participant ID: ____________________ **Date: _______________**

RBP: ____________________ mmHg RHR: ________________ bpm

Exercise	Load	Sets	Reps	RPE	HR Set 1	HR Set 2	HR Set 3
Back Loaded Squat							
Bent-Over Barbell Row							
Leg Curl							
Seated Triceps Extension							**BP:**
Leg Extension							
Bicep Curl							
Trunk Twist							
Lateral Dumbbell Raise							

Appendix F

Lab Data Collection Sheet

Lab Data Collection Sheet

Participant ID: _______________

Initial Lab Testing Day
Date: ____________

Resting Heart Rate (bpm)	
Resting Blood Pressure (mmHg)	
Height (in)	
Weight (lb)	
BMI (kg/m^2)	
Body Composition Results:	
% Fat	
% Fat Free Mass	
Fat Mass (kg)	
Fat Free Mass (kg)	
Body Mass (kg)	

Initial RMR Measurement
Date: ______________ Time: ______________

RMR	

Immediately Post Exercise RMR Measurement
Date: ______________ Time: ______________

RMR	

15 hours Post Exercise RMR Measurement
Date: ______________ Time: ______________

RMR	