How is Energy Expenditure Different 2 and 24 Hours After Near Maximal Resistive Exercise in Trained vs. Untrained College-Aged Males?

Andrew Newton

Indiana University of Pennsylvania

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HOW IS ENERGY EXPENDITURE DIFFERENT 2 AND 24 HOURS AFTER NEAR MAXIMAL RESISTIVE EXERCISE IN TRAINED VS. UNTRAINED COLLEGE-AGED MALES?

A Thesis
Submitted to the School of Graduate Studies and Research
in Partial Fulfillment of the Requirements for the Degree
Master of Science

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August 2012
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Introduction: In general, however, the public is not well-versed in the concept of energy expenditure. It is important to understand energy expenditure to reduce obesity. Methods: Twenty two males aged 18-24 completed a four session protocol to measure energy expenditure. The participants were stratified into either a “trained” or “untrained” group. Participants were then randomized into a resistance exercise group or quiet rest group. Energy expenditure was measured at four periods. Results: Significant differences were seen when comparing the pre-intervention measure to the post-intervention measure (P < .000), and when comparing the pre-intervention measure to the two-hour post-intervention measure (P < .005), but not when comparing the pre-intervention measure to the 24-hour post-intervention measure (P < .432). Discussion: There was an increase in metabolic rate following the resistance training protocol, but not following the quiet rest. This increase remained significant at the two-hour post-intervention measure, but not 24-hour post-intervention measure.
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CHAPTER I

INTRODUCTION

The health and fitness benefits of regular exercise are well-established and well-known (Mayo Clinic Staff, 2011). In general, however, the public is not as well-versed in the concept of energy expenditure. For example, individuals know they are exercising to burn calories, but are not aware of the mechanism responsible for the expenditure of these calories.

Energy expenditure is measured in kilocalories (kcal), and includes four entities to accumulate total energy expenditure. Resting metabolic rate, the thermogenic effect of food digestion, energy excreted in waste, and daily physical activity all consume a certain amount of energy. Total energy expenditure gives the total expenditure of energy, measured in kcal, in one day. The energy taken in comes from food ingested.

Resting metabolic rate is defined as the “energy expended while an individual is resting quietly in a supine position” (Plowman, 2008, p. 231). This does not include activities of daily living or physical activity. The thermogenic effect of food digestion is the measure of energy required for the processing and storage of food. The caloric balance equation is the mathematical summation of all calorie intake and energy expenditure from all sources (Plowman, 2008, p. 229). As energy expenditure increases, more energy is burned and less energy is stored. Reducing energy storage has implications on the likelihood of extra body weight and obesity.

Of the four ways to expend energy, daily physical activity is the most controllable form. “Physical activity can account for a large amount of the variability in energy expenditure” (Rehrer, 2009, p. 610). Resting metabolic rate typically accounts for the bulk of energy expenditure. However, elite athletes may expend most of their energy through physical activity.
Energy expenditure during daily physical activity is directly related to the mode, duration, and intensity of the activity. If the exercise is resistance training, the intensity is sometimes measured as a percentage of the participant’s one-repetition maximum. This will be utilized in this study as the form of measurement.

This study explores the difference in post-exercise energy expenditure between trained and untrained college-aged males. Understanding the relationship between exercise and energy expenditure is important and useful in the future prevention of obesity. In essence, this study will investigate energy expenditure to determine if there is a difference in having higher energy expenditure two and twenty-four hours post-exercise in a trained athlete as opposed to an untrained individual.
Research Question

How is energy expenditure different 2 and 24 hours after near maximal resistive exercise in trained vs. untrained college-aged males?

Hypotheses

- Energy Expenditure will be greater in the trained group of males as compared to the untrained group of males at the pre-bout measure, the post-treatment measure, the 2-hour post-treatment measure, and the 24-hour post-treatment measure.

- The magnitude of increase in resting metabolic rate will be greater in the group of trained participants vs. the untrained participants at both the 2 hour-post exercise measure and the 24-hour post-exercise measure.

- The exercise group will see a greater increase in resting metabolic rate than the quiet rest group at both the 2-hour post-bout measure and the 24-hour post-bout measure.

Design

This study has an experimental design that includes 4 groups. Once level of exercise condition was determined (trained vs. untrained), participants were randomized into an exercise group or quiet rest group. Placement into exercise level group was based on self-reported minutes of aerobic and resistance exercise per week. The untrained group included individuals who currently participated in 30 minutes or less per week of aerobic and resistance exercise. The trained group included individuals who participate in 150 minutes of aerobic and resistance exercise or more per week. Placement into the exercise group or quiet rest group was randomized based upon order of entry into the study. The first participant was placed into the
exercise group, the second participant was placed into the quiet rest group, and so on. Measurements of metabolic rate were taken through the use of a metabolic cart.

The quiet rest group had a total of three sessions and controlled for contact. The group had energy expenditure taken at rest, post-intervention, 2 hours post-intervention, and 24 hours post-intervention.

The exercise group had total of four sessions. A one-repetition maximum was measured in all participants in the group that performed the resistive exercise at least seven days prior to their pre-bout resting energy expenditure at the first session by following National Strength and Condition Association guidelines for measuring a one-repetition maximum. The second session included resting energy expenditure measurement. Then, the trained or untrained individual performed a bout of resistive exercise at 70% of their measured one-repetition maximum. The bout included a minimum of three sets of 12 repetitions of a dead-lift, a box-squat, and a bench press. These were performed at 70% of the one-repetition maximum.

Resting energy expenditure measurements was taken after the exercise, 2 hours after the exercise, and 24 hours after the conclusion of the exercise in both groups. These will be considered the third and fourth sessions.

**Limitations**

1. Time between measurements was not exactly 2 and 24 hours after the conclusion of the exercise, possibly slightly skewing the data.
2. A convenience sample was used to recruit college-aged males, both trained and untrained, so the data may not be fully applicable to other ages included in the general population.
Assumptions

1. Participants understood and followed directions to refrain from an exercise session between the near-maximal lift and the 2-hour, as well as the 24-hour post metabolic rate test.
2. The metabolic cart is a valid and reliable measure of resting metabolic rate.
3. The research participants are representative of college-aged males.
4. Participants did not ingest any food, drink, or supplements that will effect RMR measurement.
5. Participants properly executed and followed directions for a 12-hour fast.
6. Participants were truthful about the amount of time they spend exercising within a typical week.

Significance

This study examined the difference in energy expenditure between trained and untrained college aged males. Currently, there is a lack of research involving this comparison. The study contributes to the research regarding health and fitness of young adults, and provides measures of energy expenditure in individuals regardless of the individual having trained or untrained status. In addition, we were able to see the impact of resistance exercise on metabolic rate and varying time periods after the exercise.

Definition of Terms

One-Repetition Maximum - maximum amount of weight one can lift in a single repetition for a given exercise.
**Resting metabolic rate** - energy expended while an individual is resting quietly in a supine position.

**Basal Metabolic Rate** – energy expended in one day in an individual at rest; more accurate than RMR, but more restrictive and more difficult to measure.

**Energy Expenditure** - the amount of energy (calories), that a person uses to breathe, circulate blood, digest food, and be physically active.

**Total Daily Energy Expenditure** – The amount of energy used by an individual in a 24-hour time period.

**Physical Activity Energy Expenditure** – The cost to an individual, in energy, devoted to physical activity

**Caloric Balance Equation** – The equation that determines total daily energy expenditure. The four components are Basal Metabolic Rate, the thermogenic effect of food, physical activity, and the energy used to excrete waste.

**Trained Individual** – An individual who participates in an accumulative 150 minutes or more per week of aerobic and resistance exercise.

**Untrained individual** – An individual who participates in less than 2 days a week of physical activity, each day totaling less than 30 minutes of aerobic and resistance exercise.

**Metabolic Cart** – A computerized Apparatus, manufactured by ParvoMedics, used for metabolic measurement in the laboratory at Indiana University of Pennsylvania.
**Box-squat** – A weight training exercise. A variation on the parallel squat performed with a box under the lifter that stops descent at the bottom for the purpose of consistency and safety.

**Dead-lift** – A weight training exercise where one lifts a loaded barbell off the ground from a bent-over, stabilized position to a standing position, followed by a small pause.

**Bench Press** – A weight training exercise in which one lies on a bench with feet on the floor and raises a loaded barbell in a linear motion away from the chest.

**Fat Free Mass** – Lean mass, refers to muscles, water, bones, and other non-fat tissues in the body.

**Excess Post-exercise Oxygen Consumption** – A measured, increased rate of oxygen intake following physical activity.
CHAPTER II
REVIEW OF LITERATURE

Energy Expenditure

Energy expenditure is most simply defined through the negative energy components associated with the caloric balance equation. Energy is expended in three ways. The first is resting metabolic rate, the second is thermogenesis, and the third is work or exercise. (Plowman, 2008, p.229). Measurement of energy expenditure in humans is required to assess metabolic needs, fuel utilization, and the relative thermic effect of different food, drink, drug and emotional components. (Levine, 2005)

“Basal Metabolic Rate is the energy expended when an individual is lying at complete rest, in the morning after sleep in the post-absorptive state. Resting energy expenditure, in general, is within 10% of the BMR and is measured in subjects at complete rest in the post-absorptive state,” (Levine, 2005).

Energy expenditure is standardized by reporting it as a metabolic equivalent (MET). (Murray, 2009) Thus, reported figures will be expressed with a MET value. A MET is defined as the ratio of the work metabolic rate to the resting metabolic rate. “One MET is defined as 1 kcal/kg/hour and is roughly equivalent to the energy cost of sitting quietly. A MET also is defined as oxygen uptake in ml/kg/min with one MET equal to the oxygen cost of sitting quietly, equivalent to 3.5 ml/kg/min.” (The Compendium of Physical Activity, n.d.).

Regarding measurement of basal metabolic rate, Levine (2005) noted that, “The instruments are often configured as a ‘metabolic cart’ and therefore are transportable although often not portable. Measurements to within 1% of chemical standards can be obtained using
these instruments, which can be used for measurements of basal metabolic rate and resting energy expenditure.”

In the past, it has been documented that both aerobic and resistance training increase the resting metabolic rate over the baseline of the participant for a varying amount of time after the exercise. “It is well established that energy expenditure following exercise remains elevated above resting values for a period of time. Studies of aerobic exercise performed in men suggest that the magnitude and duration of this elevation appears to be primarily dependent on exercise intensity, with exercise duration having a small influence.” (Phelain, 1994, p. 140). It is important to note that energy expenditure associated with exercise includes energy expended both during exercise and during recovery. (Binzen, 2001).

Resting energy expenditure has been shown to be lower in older adults, partly because of the reduction of fat-free mass associated with sarcopenia. (Hunter, 2000, p. 977) However, a study with Olympic weight lifters (Scala, 1987) found that during the preparatory phase, energy expenditure was measured at 392 kcal or 11 kcal.min-1. “These values were much higher than those reported for non-athletic samples of resistance training experienced subjects (approximately 6 kcal.min-1).” (Meirelles, 2004, p.131)

Exercise increases energy expenditure during exercise, and may be able to create an increase in metabolic rate, and in turn energy expenditure, for as long as up to 48 hours post-exercise (Williamson, 1997).

Following a bout of exercise, many studies in humans have shown a short-term elevation in resting metabolic rate, mostly due to Excess Post-exercise Oxygen Consumption. “EPOC appears to have two phases, one lasting less than two hours and a smaller much more prolonged
effect lasting up to 48 h.” (Speakman, 2003, 621). Many other studies have failed to validate the short-term elevation of resting metabolic rate.

Research has shown that long-term elevations in resting metabolic rate can be made through an extended exercise programs. Reasons for this are outlined in Speakman (2003).

First, long-term exercise programs are able to change body composition, usually an increase in fat-free body mass. With this increase in lean tissue, resting metabolic rate will increase as the body supplies energy for this added, energy demanding tissue. Second, elevations may occur as a result of various physiological processes within the body, some of these including genetic factors. (Speakman, 2003.)

Physical activity is an important part of weight maintenance. It represents a way for the body to expend energy and have a negative caloric balance. A negative caloric balance is creates weight loss. A constant caloric balance maintains the weight of an individual, and a positive caloric balance creates weight gain. The expected daily caloric requirement of a college-aged, active male is 3,000 calories (Zelman, 2008). That requirement is very different than the estimated 2,400 calories required for a college-aged, sedentary male.

**Energy Expenditure and Level of Fitness**

A study completed by Broeder (1992), examined the effects of aerobic fitness on resting metabolic rate. This study was unique, because it was able to look at the effect of fitness level on resting metabolic rate as opposed to a specific mode of exercise. 69 male volunteers were recruited from the University of Texas at Austin student pool. Subjects were divided into one of three groups, based on VO2 max, to create tiers of fitness level. Low fitness participants had a
measured VO2 max of less than 45 ml/kg/min, moderate fitness participants had a VO2 max of 45 to 60 ml/kg/min, and high fitness participants had a VO2 max at or above 60 ml/kg/min.

Resting metabolic rate was measured once each day for two days after a 12-hour fast. It is also important to note that participants did not participate in any exercise for at least 48 hours leading up to the measurement.

Results of this study indicated that a significant, positive correlation was found between VO2 max and resting metabolic rate. However, when expressed as either absolute or relative to FFW, no differences were observed between fitness level groups. Researchers concluded that resting metabolic rate is independent of a person’s current aerobic level, as well as a person’s training status.

**Energy Expenditure Specific to Aerobic Exercise**

Previous studies have documented the relationship between energy expenditure or resting metabolic rate and exercise. Aerobic and Resistance exercise are normally studied independently in terms of their effect on energy expenditure or resting metabolic rate.

Bingham (1989), investigated the effect of exercise and an improved fitness level on basal metabolic rate. Participants were monitored at baseline for a three to five week control period to measure basal metabolic rate. Participants then completed a nine week training program. The program gradually increased the intensity and duration of physical activity, keeping the duration constant at five days per week. By the end of the nine weeks, participants were jogging 60 minutes per day, five days per week. Basal metabolic rate was then measured one-hour post exercise and 13-hours post-exercise.

Results showed that energy expenditure increased an average of 28% total during two weeks of a high-activity period as opposed to the last two weeks of the control period. Energy
expenditure was expressed in megajoules throughout this study. At the end of the 9-week training program, participants saw an average increase in basal metabolic rate of 18 MJ/24h. These results were deemed not significant at a confidence level of .95. The researchers deemed that exercise did not have a significant effect on basal metabolic rate. It is important to note that this study was completed and published in 1989. (Bingham, 1989).

The Bingham study gave useable results in terms of the long-term effect of aerobic exercise on basal metabolic rate. For the purposes of understanding the effects of exercise on resting metabolic rate, it is also important to investigate the acute effect exercise has on resting metabolic rate.

Researchers examined obese women for a total of six weeks to see the effect of food restriction and aerobic exercise on resting metabolic rate. Eight women with 37-50% body fat participated in the six-week, inpatient study and were placed on a one week maintenance diet followed by a five-week caloric restriction diet that reduced their caloric intake 800 kcal per day.

During the five weeks of the caloric restriction diet, five subjects also participated in a daily, supervised aerobic exercise program that consisted of strictly a progressive walking program. It is important to note that intensity and duration of walking was individualized based on the specific capabilities of each subject individually. The other 3 subjects remained sedentary for the duration of the data collection. (Hill, 1987.)

Resting metabolic rate was measured weekly by indirect calorimetry. At the end of the study, researchers found that resting metabolic rate decreased substantially due to the decrease in caloric intake. However, RMR actually decreased to a greater degree in the exercising subjects. Researchers figured that the progressive increases in energy expenditure associated to the physical activity program led to the caloric deficit being greater in the exercise group.
Single bouts of aerobic exercise effect metabolic rate, while those participating in aerobic conditioning over a period of time may not see the same benefit.

**Energy Expenditure and Aerobic vs. Resistive Exercise**

Gillette (1994), examined the effect of exercise on metabolic rate when research was still in its early stages on the topic. This study was unique because it compared a group of participants in an aerobic exercise group, a resistive exercise group, and a control group.

The study asked participants for essentially, a full day of their time. A meal, consistent in caloric and nutrient value, was provided to all participants the night before the treatments. In the morning, resting metabolic rate was measured by indirect calorimetry with the use of a metabolic cart. After breakfast and lunch, “pre-exercise metabolic rate” was measured, and was followed by the treatment. The treatment was either aerobic exercise, resistive exercise, or a non-exercise treatment.

After the treatment, Excess Post-exercise Oxygen Consumption was measured and followed by another meal, after which EPOC was measured once more. Resting metabolic rate was again measured the morning following the treatment.

A study found that the 5-hour EPOC of the resistive exercise group was significantly greater than the aerobic group. Perhaps more importantly, results showed that the elevation of post-exercise metabolic rate accounted for an additional mean of 51 kcal expended for the resistive exercise group, as compared to an additional 27 kcal expended for the aerobic group. Both of these cite the additional kcal expended above the mean of the individuals in the control group. (Gillette, 1994).

Looking at the effects of chronic exercise and its effect on energy expenditure, researchers also completed a study comparing the effects of endurance and resistance training on
total daily energy expenditure, specifically resting metabolic rate. The study looked at specifically young, non-obese women. Participants were randomized into either a 24 week aerobic exercise program or a 24-week resistance training program.

Although significant changes were seen in body composition and measureable fitness variables, no significant changes were seen in any groups in total energy expenditure following the physical activity intervention in either group. Although resting metabolic rate did increase in resistance-trained women, it was not significant when researchers adjusted for fat-free body mass. (Poehlman, 2002).

Researchers attempted to compare the effects of endurance training and resistance training to a control group in terms of their ability to change resting metabolic rate and energy expenditure. Sixty-four male volunteers were recruited from the University of Texas at Austin.

Participants were assigned to either a resistance training group, an endurance training group, or a control group. Body composition, VO2 max, and resting metabolic rate were measured pre-treatment and post-treatment. It is important to note that subjects did not perform any exercise training for at least 48 hours leading up to the pre-treatment and post-treatment measures of resting metabolic rate. (Broeder, 1992).

Results showed a significant decrease in relative body fat, fat weight, and waist-hip ratio at the post-treatment measurement as compared to the pre-treatment measurement in both exercise groups.

However, the study found no significant differences between the pre-training and post-training measurements in regards to resting metabolic rate in either the endurance training group or the resistance training group. Researchers did find a small decline in energy intake and a
significant increase in energy expenditure, however, due to the increased energy use associated with the training programs. (Broeder, 1992.)

It is also important to compare weight training with aerobic training. Researchers completed a study in an attempt to compare the effect of weight training and aerobic, treadmill exercise training on post-exercise oxygen consumption. (Burleson, 1998). Although this does not specifically speak to changes in energy expenditure, a greater EPOC has a known association with greater energy expenditure. The point of this is to examine differences between aerobic training and resistance training.

Researchers recruited 15 males between the ages of 20 and 26. A minimum of six months of weight training experience prior to the study was required. The subjects were randomized into either a treadmill group or a weight training group. Both groups had exercise protocols to complete in a 27-minute timeframe. Physiological responses were measured before, during, and after the treatments. VO2 was measured through a calibrated metabolic cart. (Burleson, 1998).

After analyzing data, researchers came to the conclusion that greater energy can be required for recovery from weight training exercise as compared to steady state, aerobic exercise, if the protocols are matched for duration. Total oxygen consumption in the first 30 minutes of recovery was significantly greater in the weight training group as compared to the treadmill group. Researchers hypothesized that the higher intensity of the resistance training was probably the source of this elevation, in addition to the physiological responses specifically resulting from weight training. (Burleson, 1998).

Researchers investigated the effects of a single bout of both aerobic and resistive exercise on resting energy expenditure and substrate utilization. A key component of this study was the
attempts were made by researchers to maintain a relatively constant intensity and duration between the aerobic bout of exercise and the resistive bout of exercise. (Jamurtas, 2004).

The unique feature of this study was that, in addition to being able to see the effect of a bout of exercise on energy expenditure, researchers were able to see the differences in the resistance group as compared to the aerobic group. Seeing these combined effects, as well, is unique in this area of research.

Ten young males were recruited to participate through Thessaly University in Larisa, Greece. Subjects had pre-measurements taken and were placed into one of three groups: A weight lifting group, a running group, or a control group.

Post-data collection results showed that together, sixty minutes of weight lifting and aerobic training resulted in significantly greater resting energy expenditure 10 hours following the bout of exercise. In addition, resistance exercise caused a greater elevation, and resting energy expenditure remained elevated at both the 24 hours post bout and 48 hours post bout measurements.

Researchers also provided insight into the differences between studies that have found that resting energy expenditure can remain elevated up to 48 hours after a bout of exercise and studies that found no significant elevation in resting energy expenditure beyond one hour following exercise. Researchers (Jamurtas, 2004) observed that studies finding no significant elevations beyond the 1 hour post-bout measure generally used protocols much lower in intensity as compared to studies that found an elevation lasting 48 hours.

Another study investigated the effects of strength training, and also strength training combined with aerobic exercise in resting metabolic rate and fat free mass in previously, moderately obese women (Byrne, 2001).
Thirty-six sedentary women between the ages of 18 and 45 years old were recruited from the University of Texas at Austin and the surrounding communities. Fifteen participants were placed into a training group and eleven participants were placed into a control group. In the group of 25 participants training, some were placed into a resistance training only group, and others were placed into a resistance training plus walking group. Resting metabolic rate was measured through indirect calorimetry at baseline, once between 36-48 hours following the exercise bout, and one taken between 48-60 hours following the exercise bout. This was done to insure that researchers avoided measuring the acute response to an exercise bout, and were measuring the intended variables of the effects of the 20-week training program.

Following a 20-week training program of either resistance exercise or resistance exercise combined with aerobic training, the resistance trained group showed a significant increase in resting metabolic rate following the exercise treatment. However, increases were not significant when fat free mass was taken into account. The resistance trained and aerobic trained group actually showed a decrease in resting metabolic rate following the single session of exercise. These results apply to both post-exercise timeframes. The control group showed no changes.

Results of the previously mentioned studies regarding a comparison of aerobic and resistance training, or a combination of the two, and their effects on resting metabolic rate and energy expenditure are somewhat inconclusive. Most of the results are in agreement that resistance training seems to have a greater effect on energy expenditure at about the 2 hour post-bout measure or earlier. Beyond that, results are somewhat inconclusive.

Energy Expenditure Specific To Resistive Exercise

“Some resistance training studies have found a 6-8% increase in RMR post-exercise, while others found no difference in RMR among young men after 16 weeks of training.”
(Williamson, 1997, p.M353). Generally, there is some disparity in terms of the short-term and long-term effects of resistive exercise on metabolic rate. However, a large number of studies that did find an elevation in metabolic rate due to resistance training protocols have seen that increase disappear in the 60 to 120 minute timeframe. (Williamson, 1997).

A study conducted at Pennsylvania State University to measure basal metabolic rate 48 hours after a single bout of concentric exercise in healthy 59-77-year-old men. 12 men, free of chronic disease, performed 16 sets of 10 repetitions at 75% of their individual 1-repetition maximum. The test used a single-leg knee extension and a bench press. The unique feature of this study was that a time-frame of 48 hours was used. Thus, basal metabolic rate was measured 48 hours after the conclusion of the bout of concentric exercise. This was a way of obtaining more practically applicable data. (Williamson, 1997).

In the Williamson study, a 3% increase in basal metabolic rate was reported 48 hours after an acute bout of concentric resistance exercise. Researchers explained that protein flux, glycogen repletion, increased cytokine activity, elevated sympathetic activity, and increased substrate cycling all could have played a role in the increase in basal metabolic rate following exercise. A key observation of this study was an increase in BMR 48 hours after an acute bout of exercise. The researchers theorized that elevations in plasma catecholamines, cortisol, growth hormone, and testosterone in response to the resistive activity may have all had a role in the increase in post-exercise energy expenditure. An attempt was made to match the caloric expenditure between the aerobic exercise and the resistive exercise match, but researchers found that to be a limitation of the study.

Researchers examined the effects of resistance training on total daily energy expenditure, physical activity related energy expenditure, and fitness among women with coronary heart
The physical activity intervention in the study consisted of a six month resistance program group and a 6-month control group. All subjects measured a one-repetition maximum for bench press and leg extension. The exercise program group consisted of participants training at 50% of their one-repetition maximum initially, and being gradually moved toward the goal of training at 80% of the one-repetition maximum as time went on. Researchers attempted to keep participants at a rating of perceived exertion of 14 or higher. (Ades, 2005).

Doubly-labeled water and indirect calorimetry were used to measure free-living physical activity related energy expenditure and total energy expenditure. After the intervention, the resistance trained group experienced significant increases in leg strength and arm strength.

Most importantly, increases were found in both physical activity related energy expenditure and resting metabolic rate, leading to a substantial increase in total energy expenditure. These were determined by a 10-day doubly-labeled water collection period and indirect calorimetry. After the resistance training intervention, total daily energy expenditure increased by an average of 177 kcal per day over the control group. It is important to note that these changes were observed even though there were no significant changes in body composition as measured by dual x-ray absorptiometry.

Researchers came to this measurement through the measurement of resting metabolic rate and physical activity related energy expenditure. Resting metabolic rate increased an average of 51 kcal/day in the resistance trained group as compared to the control group, and physical activity related energy expenditure increased an average of 123 kcal/day in the resistance trained group as compared to the control group. (Ades, 2005.)

Researchers studied the effects of a resistance training program on metabolic rate, post-exercise oxygen consumption, and substrate usage. Twelve women ages 24 to 34 were recruited
from Arizona State University. Participants were measured for energy expenditure at pretrial, trial, and post-trial. The post-trial measurement was taken 2 hours following the conclusion of the exercise session to assess EPOC. The exercise session began immediately at the conclusion of the pre-trial energy expenditure measurement for those in the exercise session. For participants in the control group, controlled sitting was used in place of the exercise session. (Binzen, 2001.)

Three sets of 9 different exercises were completed in a timeframe of 45 minutes. Protocol dictated that intensity would be 70% of the individual’s one-repetition maximum for each exercise.

Following the data collection, researchers found that energy expenditure (resting metabolic rate) was significantly elevated for at least one hour following the resistance exercise treatment as compared to the controlled sitting treatment. No significant differences were seen in EPOC or energy expenditure in minutes 90-120 of recovery. Additionally, respiratory exchange ratio was significantly lower in the exercise group as compared to the controlled sitting group at the 120 minute mark of recovery. (Binzen, 2001.)

Researchers attempted to compare age and gender effects of strength training on resting metabolic rate, energy expenditure cost of physical activity, and body composition.

Forty-six participants volunteered for the study through a phone interview. Subjects all fell into one of four age and gender categories. Males, 20 to 30 years of age were placed into the “young men” group. Females, 20 to 30 years of age were placed into the “young women” group. Males, 65-75 years of age were placed into the “older men” group. Females, 65-75 years of aged were placed into the “older women” group. (Lemmer, 2001.)
A metabolic cart with attachable hood was used to measure resting metabolic rate. A dual energy x-ray absorptiometer was used to measure fat free mass and fat mass. Energy expenditure of physical activity and total energy expenditure were estimated through the use of a physical activity monitor. The treatment of strength training was a 3 day per week program for an average of 24 weeks. Training included exercises that trained all of the major muscle groups of the body.

When all of the participants were pooled into one group, the participants had shown an increase of 7% in resting metabolic rate in terms of their absolute, acute response to strength training as compared to their pre-program measurement. Both the young men and older men groups showed this 7% increase, and there were no significant difference between age or gender groups. However, there was a 9% increase in absolute resting metabolic rate following training for the men, as compared to no significant differences in women.

When resting metabolic rate was corrected for fat free mass, there was still a significant increase in resting metabolic rate after the strength training intervention for all groups, with no significant interactions between groups.

Researchers concluded that this study was the first to be able to show that changes in resting metabolic rate in response to a strength training program are affected by gender, but not by age. As the researchers outlined, resting metabolic rate increase significantly after the training program in males, but not in females. Researchers hypothesized that differences in sympathetic nervous system activity responses to strength training between genders may be partially responsible for the different responses. (Lemmer, 2001).

The above research studies offer conflicting results. Common themes include the idea that acutely, resistance exercise has the ability to increase resting energy expenditure. In some studies, multi-week resistance training programs have shown the ability to create a sustained
increase in energy expenditure, specifically resting metabolic rate. In other studies, long-term resistance training programs have shown no ability to create a sustained increase in resting metabolic rate.
CHAPTER III

METHODS

Purpose

This study will investigate the effect of resistance exercise on resting metabolic rate. The purpose is three-fold:

1) To measure and compare energy expenditure of college-aged males following a treatment of resistive exercise at 70% of the one-repetition maximum compared to quiet rest.

2) To measure and compare the energy expenditure of trained vs. untrained college-aged males.

3) To examine the effect of exercise on energy expenditure 2 and 24-hours post-exercise.

Subjects

A total of 22 males between the ages of 18 and 24 participated in the study. Recruitment will come from courses taught at Indiana University of Pennsylvania in the spring 2012 semester. Courses include Health and Wellness courses, as well as Health and Physical Education courses. Recruitment was based on a personal visit and distribution of follow-up contact information, as well as a flyer posted in Zink Hall.

Participants were assigned to one of two groups, “trained,” or “untrained.” Trained participants will be individuals who regularly complete 150 minutes of total exercise per week. Untrained participants were individuals who regularly complete less than 30 minutes of total exercise per week.
Once level of exercise condition was determined (trained vs. untrained), participants were randomized into either an exercise group or a quiet rest group. Participants were randomized based on entry into the study. The first participant was placed into the exercise group; the second participant was placed into the quiet rest group, and so on. Participant 22 was the only exception, as he was placed into the exercise condition.

Originally, we had planned for this participant to be the 23rd participant. Because of the time schedule, he had almost simultaneously started with another participant. As he was in the middle of his resistance training protocol, we found that the body fat percentage of the original participant number 22 would rule him ineligible. The principal investigator made the decision to finish the resistance training protocol for this participant rather than create unnecessary stress on the participant.

Participants qualified for participation only if their measured body fat was between 16% and 26%. This placed all participants into either “Average” or “Above Average” fitness level as determined by the American College of Sports Medicine. In addition, participants were taught by the principal investigator how to properly perform the exercise protocol through verbal instruction, and given an exercise information sheet packet (Appendix A).

**Instruments**

Instruments used in this study were the Parvomedics metabolic cart with attachable dilution option and attachable hood, a Continental Health-o-Meter Medical Scale, a BODPOD, and a hydrostatic weighing tank that includes a scale.

A Parvomedics metabolic cart with attachable dilution option and attachable hood were used to measure resting metabolic rate. Each participant was instructed to lie flat with the attachable hood encased around their upper body. Expired air was collected and analyzed in the
metabolic system, while room air enters the attachable hood at its top. Although data was collected for 30 minutes for each metabolic measurement, only the last 25 minutes of data was used in calculating and measuring resting metabolic rate for each of the participants. This was to ensure that the subject had reached a true resting state.

The Continental Health-o-Meter Scale measured height and weight of the participants. To calculate body fat percentage for each of the participants, a BODPOD and a hydrostatic weighing tank were used. Hydrostatic weighing is “generally regarded” as the gold-standard of accuracy for body fat percentage measurements (Ohio State University Department of Health and Exercise Science, 2011). Participants were measured using an average of 5 trials of the hydrostatic weighing procedure. The closest 3 were used to determine body fat percentage. The BODPOD uses a method of air displacement plethysmography and provides validated body composition measures. Each participant underwent both methods of body fat analysis and an average of the two was taken and used as the body fat percentage for each participant.

**Procedures**

This study was an experimental, cross-sectional study examining the effect of exercise on resting metabolic rate. The entire data collection procedure for a participant required the participant to report to the Human Performance Laboratory in Zink Hall a total of 4 times.

Before sessions began, all participants were contacted by e-mail, and sometimes by phone to set up an appointment to discuss the study overall and the appropriate clothing for the first session. Participants were given a sheet that described the proper clothing which included a reminder of the time of their first session (APPENDIX F).

Session 1 started with signing of informed consent. Informed consent was approved by the Indiana University of Pennsylvania Institutional Review Board for the Protection of Human
Subjects (APPENDIX G). Next, analysis of possible inclusion criteria took place. First, the participant completed a form detailing their self-reported exercise habits. Only participants who complete above 150 minutes or below 30 minutes of total exercise per week, on average, were included. If the participant completed 150 minutes or more of total exercise per week, the participant was placed into the trained group. If total exercise per week was 30 minutes or less, the participant was placed into the untrained group. Participants filled out a form measuring their total number of minutes of physical activity (APPENDIX E).

Next, body fat percentage was calculated. The participant was measured for height and weight first. The BODPOD and underwater weighing methods were both used, and an average of the two was taken and used as the body fat percentage for the participant. The BODPOD and measurements were taken by either the principal investigator, or a trained member of the exercise science program at Indiana University of Pennsylvania. The trained assistants were senior to sophomore level students in the exercise science undergraduate program. The principal investigator measured the body composition of all 22 participants using hydrostatic weighing. Only participants with a body fat percentage between 16% and 26% were included.

Following that, the participant went through an exercise teaching session. This session prepared the participant to perform the resistance exercise protocol. The protocol included a barbell bench-press, a barbell dead-lift, and a barbell box-squat and will take place in Zink Hall, in the James G. Mill fitness center. A barbell will be used for all 3 lifts. The participant was given 10-minutes to read the 3-page exercise information packet (Appendix A). After that, verbal instructions were given on proper execution of the resistance exercise protocol.

The principal investigator, a certified American College of Sports Medicine Health Fitness Specialist, then oversaw the measurement of a one-repetition maximum for each of the
three exercises in the protocol. The one-repetition maximum was measured according to National Strength and Conditioning Association guidelines as outlined in Baechle (2008). First, a low weight was selected and performed. From that, based on the difficulty of the performance and other factors, the principal investigator increased the load appropriately. This process continued until failure.

Two spotters were required for the execution of both the barbell dead-lift and the barbell box-squat. These positions were filled by the principal investigator, trained senior to sophomore level assistants from Indiana University of Pennsylvania Exercise Science program, or a combination.

Finally, before the participants left the first visit, participants were given verbal instructions and a copy of instructions on how to properly execute a 12-hour fast (Appendix b). This included 12 hours of refraining from all food, beverages, or supplements except water. This also included any caffeine products as well as smoking, smokeless tobacco use, and chewing gum. Also, directions for the next visit were given, including appropriate clothing to perform the exercise protocol. Quiet rest group participants were given the same clothing instructions. The entire visit took an about 2.5 hours.

Session 2 took place no less than 7 days after session 1. This was done, in part, to insure that any after-effects of the one-repetition maximum measurement, in regards to physiology of the body, were completed. Participants returned to the Human Performance Lab in a fasted state and were again measured for height and weight to insure accuracy of tests. Participants were then placed under the attachable hood and connected to the metabolic cart. Participants were asked to lie quietly and still for a total of 30 minutes. Data was be collected during the last 25 minutes. Once resting metabolic rate is measured, exercise group participants went to the fitness center
and performed the resistance exercise protocol under the supervision of the project director. Spotters were the project director, trained members of the IUP exercise science program, or a combination. Exercise sessions must have been completed in 90 minutes. At the conclusion of the exercise session, a metabolic rate measurement was taken.

During this time, participants placed into the quiet rest group remained lying or sitting comfortably, and the metabolic cart apparatus will be removed. The room was dimly lit or lit, based on the choice of the participant. The priority was to create a stress-free, comfortable environment. The participant rested for 45 minutes, at the end of which time a metabolic rate measurement was taken.

At the conclusion of this measurement, participants were be given a meal replacement bar made by nature valley and a Gatorade. Participants remained in the Human Performance Laboratory in Zink Hall, and were seated comfortably.

Another measurement took place 2 hours following the exit of the quiet rest participant, or 2-hours following the conclusion of the exercise protocol by the resistance exercise group participant. The participant was connected to the metabolic cart through the attachable hood and asked to lie quietly in the same location as visit 2 for 30 minutes. The metabolic cart was used to collect data the last 25 minutes.

Session 3 took place either 24-hours after the exit of the quiet rest participant, or 24-hours after the conclusion of the resistance protocol by the resistance exercise group participant. In addition, participants were thanked for their time, efforts, and contributions to their peers and community, and given a contact-information sheet (Appendix C) if they would like to be sent a detailed copy of their results.
In between sessions, participants were asked not to participate in any planned exercise. Also, participants were asked to refrain from any smoking, smokeless tobacco, or alcohol use between session 2 and session 3. All data was recorded on a data collection sheet (APPENDIX D).
CHAPTER IV
RESULTS

Data are reported for a total of twenty two participants. Participants ten and eighteen did not return for the third session, leaving us with no data for the 24-hour post-exercise metabolic rate measurement. Twelve of these participants were trained and ten of them were untrained. Twelve of these participants were placed into the exercise group, and 10 of the participants were placed into the quiet rest group.

Participant nineteen felt dizzy during the workouts, and took frequent, extended breaks during the resistance exercise. Participant seventeen felt very lightheaded after the resistance exercise, and was given approximately 4 ounces of lemon-lime Gatorade. The drink helped, and he was able to resume activities following a 5 minute break. During this break, his heart rate and blood pressure were monitored several times by the principal investigator and the heart rate and blood pressure were within normal parameters. Based on his heart rate and blood pressure being within normal parameters and his wish to continue, he finished the exercise protocol.

Participant twenty two was included in the exercise condition. The reason for this was that he and another potential participant came in on the same day, at about the same time. The potential participant was eventually found to be ineligible due to an inappropriate body fat percentage.

The participants were placed into a category of being “trained” or “untrained” based on their total number of minutes of planned physical exercise per week. Participants who participated in 150 minutes or more of aerobic plus resistance exercise were placed into the trained group. Participants who participated in 30 minutes or less of planned physical exercise
per week were placed into the untrained group. Participants were then randomized to either a resistance exercise protocol, or quiet rest protocol. Randomization was based on number of entry into the study. In the following text, the resistance exercise and quiet rest protocol will collectively be referred to as intervention.

The mean age of all participants was 21 years ± 1.45. The mean age of the trained group was 20.91, and the mean age of the untrained group was 21.1. The average body weight for the trained group was 192.33 pounds ± 22.28. The average body weight for the untrained group was 193 pounds. The average fat-free mass for the trained group was 158.12 pounds. The average fat-free mass for the untrained group was 153.47 pounds. The average body fat percentage of the 22 participants measured by the BODPOD was 19.90%. The average body fat percentage of the 22 participants measured by hydrostatic weighing was 18.95%.

The average resting metabolic rate measurement for the trained group at baseline was 2,255 kcal/day ± 180.42 kcal. The average resting metabolic rate measurement for the untrained group at baseline was 2,148 kcal/day ± 306.24 kcal. There were no significant differences between these the trained and untrained groups in any of these parameters.

An independent samples t-test was performed to compare resting metabolic rate at baseline between the trained group and the untrained group. Levene’s Test for Equality of Variances revealed that equal variances would be assumed (P < .017). There were no significant differences between the trained and untrained groups when comparing baseline resting metabolic rates (P < .367).

In regards to hypothesis number 1, we found no significant differences in the pre-intervention resting metabolic rate measurement. Hypothesis 1 was not supported.
Table 1

*Trained vs. Untrained Resting Metabolic Rate*

<table>
<thead>
<tr>
<th>Training</th>
<th>N</th>
<th>Mean</th>
<th>Std. Deviation</th>
<th>Std. Error Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trained</td>
<td>12</td>
<td>2255.00</td>
<td>180.427</td>
<td>52.085</td>
</tr>
<tr>
<td>Untrained</td>
<td>9</td>
<td>2147.67</td>
<td>306.243</td>
<td>102.081</td>
</tr>
</tbody>
</table>

Table 2

*Trained vs. Untrained Resting Metabolic Rate – Independent Samples Test*

<table>
<thead>
<tr>
<th>Levene's Test for Equality of Variances</th>
<th>t-test for Equality of Means</th>
<th>95% Confidence Interval of the Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>F</td>
<td>Sig.</td>
</tr>
<tr>
<td>Equal variances not assumed</td>
<td></td>
<td>.937</td>
</tr>
</tbody>
</table>

An independent samples t-test was also run to compare resting metabolic rate at baseline between the resistance exercise group and the quiet rest group. Levene’s Test for Equality of Variances revealed that equal variances will be assumed (P < .488). No significant differences between the exercise group and the quiet rest group when comparing baseline resting metabolic rate (P < .211).
Table 3

*Exercise vs. Quiet Rest Resting Metabolic Rate*

<table>
<thead>
<tr>
<th>Group</th>
<th>N</th>
<th>Mean</th>
<th>Std. Deviation</th>
<th>Std. Error Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>Exercise</td>
<td>12</td>
<td>2267.08</td>
<td>265.797</td>
<td>76.729</td>
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<tr>
<td>Non-exercise</td>
<td>9</td>
<td>2131.56</td>
<td>192.364</td>
<td>64.121</td>
</tr>
</tbody>
</table>

Table 4

*Exercise vs. Quiet Rest Resting Metabolic Rate - Independent Samples Test*

<table>
<thead>
<tr>
<th></th>
<th>Levene's Test for Equality of Variances</th>
<th>t-test for Equality of Means</th>
<th>95% Confidence Interval of the Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>F</td>
<td>Sig.</td>
<td>t</td>
</tr>
<tr>
<td>Equal variances assumed</td>
<td>.501</td>
<td>.488</td>
<td>1.293</td>
</tr>
<tr>
<td>Equal variances not assumed</td>
<td>1.355</td>
<td>18.992</td>
<td>.191</td>
</tr>
</tbody>
</table>

Independent samples t-tests were run to compare the change in metabolic rate between resistance exercise and quiet rest. These tests compared the pre-intervention measure to the post-intervention measure, the pre-intervention measure to the 2-hour post-intervention measure, and the pre-intervention measure to the 24-hour post-intervention measure.
When comparing the pre-intervention measure to the post-intervention measure, Levene’s Test for Equality of Variances revealed that equal variances will not be assumed (P < .000). Significant differences were seen (P < .000). When comparing the pre-intervention measure to the 2-hour post-intervention measure, Levene’s Test for Equality of Variances revealed that equal variances will not be assumed (P < .042). Significant differences were seen (P < .005). When comparing the pre-intervention measure to the 24-hour post-intervention measure, Levene’s Test for Equality of Variances revealed that equal variances will be assumed (P < .382). No significant differences were seen with a 2-tailed significance (P < .432).

Thus, there were significant differences between the pre-intervention measure and the post-intervention measure and the pre-intervention to 2-hour post-intervention measures, but not from the pre-intervention measure to the 24-hour post intervention measure.

Table 5

| Change in Metabolic Rate Between Exercise condition |
|---------------------------------|------------|-------------|-------------|
|                                  | Group      | N          | Mean        | Std. Deviation | Std. Error Mean |
| Pre-Post Difference             | Exercise   | 12         | 578.4167    | 326.12838     | 94.14515       |
|                                 | Quiet Rest | 9          | -11.5556    | 112.69440     | 37.56480       |
| Pre- 2Hr Post Difference        | Exercise   | 12         | 198.0000    | 210.34690     | 60.72192       |
|                                 | Quiet Rest | 9          | -17.6667    | 79.69787      | 26.56596       |
| Pre-24Hr Post Difference        | Exercise   | 12         | 8.4167      | 151.89318     | 43.84778       |
|                                 | Quiet Rest | 7          | 63.4286     | 127.31962     | 48.12229       |
Table 6

<table>
<thead>
<tr>
<th></th>
<th>Levene's Test for Equality of Variances</th>
<th>t-test for Equality of Means</th>
<th>95% Confidence Interval of the Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>F</td>
<td>Sig.</td>
<td>t</td>
</tr>
<tr>
<td>Pre-Post Difference</td>
<td>Equal variances assumed</td>
<td>20.023</td>
<td>.000</td>
</tr>
<tr>
<td></td>
<td>Equal variances not assumed</td>
<td></td>
<td>5.820</td>
</tr>
<tr>
<td>Pre-24Hr Post Difference</td>
<td>Equal variances assumed</td>
<td>4.737</td>
<td>.042</td>
</tr>
<tr>
<td></td>
<td>Equal variances not assumed</td>
<td></td>
<td>3.254</td>
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<tr>
<td>Pre-24Hr Post Difference</td>
<td>Equal variances assumed</td>
<td>.807</td>
<td>.382</td>
</tr>
<tr>
<td></td>
<td>Equal variances not assumed</td>
<td></td>
<td>-.845</td>
</tr>
</tbody>
</table>

*Significant at .05  
**Significant at .01

In regards to hypothesis number 3, a significant difference between the pre-intervention measure and the post-intervention and 2-hour post-intervention measures was observed.

However, no significant changes in the difference between the pre-intervention measure and the 24-hour post-intervention measure were observed. Hypothesis number 3 was not supported.
Independent samples t-tests were run to compare the change in metabolic rate between the trained group and the untrained group. When comparing the pre-intervention measure to the post-intervention measure, Levene’s Test for Equality of Variances revealed that equal variances would be assumed (P < .708). No significant differences were observed (P < .883). The training group possessed by the participant did not influence the change in metabolic rate between the pre-intervention to post-intervention measures. When comparing the pre-intervention measure to the post-intervention measure, Levene’s Test for Equality of Variances revealed that equal variances would not be assumed (P < .534). No significant differences were observed (P < .074). The training group possessed by the participant did not influence the change in metabolic rate between the pre-intervention measure and the 2-hour post-intervention measures. When comparing the pre-intervention measure to the 24-hour post-intervention measure, Levene’s Test for Equality of Variances revealed that equal variances would be assumed (P < .857). No significant differences were observed with a two-tailed significance (P < .276). The training group possessed by the participant did not influence the change in metabolic rate between the pre-intervention measure and the 24-hour post-intervention measure.

In regards to hypothesis number 2, no significant differences were observed in the magnitude of change between the trained and untrained conditions at the 2-hour post-intervention measure or the 24-hour post-intervention measure, as compared to the pre-intervention measure. Hypothesis number 2 was not supported.
Table 7

*Change in Metabolic Rate Between Training Status*

<table>
<thead>
<tr>
<th>Training</th>
<th>N</th>
<th>Mean</th>
<th>Std. Deviation</th>
<th>Std. Error Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-Post Difference</td>
<td>Trained</td>
<td>12</td>
<td>336.9167</td>
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</tr>
<tr>
<td></td>
<td>Untrained</td>
<td>9</td>
<td>310.4444</td>
<td>380.63864</td>
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<tr>
<td>Pre- 2Hr Post Difference</td>
<td>Trained</td>
<td>12</td>
<td>39.2500</td>
<td>165.81157</td>
</tr>
<tr>
<td></td>
<td>Untrained</td>
<td>9</td>
<td>194.0000</td>
<td>209.50418</td>
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<tr>
<td>Pre-24Hr Post Difference</td>
<td>Trained</td>
<td>11</td>
<td>59.8182</td>
<td>131.21571</td>
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<tr>
<td></td>
<td>Untrained</td>
<td>8</td>
<td>-14.1250</td>
<td>154.42468</td>
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Table 8

<table>
<thead>
<tr>
<th></th>
<th>Levene's Test for Equality of Variances</th>
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<th>95% Confidence Interval of the Difference</th>
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<td>Equal variances not assumed</td>
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</tr>
<tr>
<td>Pre2HrPostDiff</td>
<td>.401</td>
<td>.534</td>
<td>1.892</td>
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<td></td>
</tr>
<tr>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pre24HrPostDiff</td>
<td>.033</td>
<td>.857</td>
<td>1.127</td>
</tr>
<tr>
<td>Equal variances assumed</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Equal variances not assumed</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Next, the status of being trained or untrained was observed in regards to its impact on the difference in metabolic rate when undergoing the exercise intervention. An independent samples
t-test was run to compare the differences between training conditions within the exercise group.

When comparing the pre-intervention measure to the post-intervention measure (P < .152), the pre-intervention measure to the two-hour post-intervention measure (P < .831), and the pre-intervention measure to the 24-hour post-intervention measure (P < .210), Levene’s Test for Equality of Variances revealed that equal variances could not be assured for any of the three.

No significant change was observed for the pre-intervention to post-intervention measures (P < .528), the pre-intervention to two-hour post-intervention measures (P < .087), or the pre-intervention to 24-hour post-intervention measures (P < .462). Thus, being trained or untrained did not have a significant impact on metabolic rate in the resistance exercise group.

Table 9

<table>
<thead>
<tr>
<th></th>
<th>Training</th>
<th>N</th>
<th>Mean</th>
<th>Std. Deviation</th>
<th>Std. Error Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-Post Difference</td>
<td>Trained</td>
<td>7</td>
<td>621.8571</td>
<td>292.50039</td>
<td>110.55475</td>
</tr>
<tr>
<td></td>
<td>Untrained</td>
<td>5</td>
<td>517.6000</td>
<td>395.25789</td>
<td>176.76470</td>
</tr>
<tr>
<td>Pre- 2Hr Post Difference</td>
<td>Trained</td>
<td>7</td>
<td>110.4286</td>
<td>182.94431</td>
<td>69.14645</td>
</tr>
<tr>
<td></td>
<td>Untrained</td>
<td>5</td>
<td>320.6000</td>
<td>198.15221</td>
<td>88.61636</td>
</tr>
<tr>
<td>Pre-24Hr Post Difference</td>
<td>Trained</td>
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<td>37.2857</td>
<td>114.80957</td>
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<tr>
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<td>-32.0000</td>
<td>200.43578</td>
<td>89.63760</td>
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<td>t-test for Equality of Means</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>----------------------</td>
<td>---------------------------------------</td>
<td>-------------------------------</td>
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<td></td>
</tr>
<tr>
<td></td>
<td>F</td>
<td>Sig.</td>
<td>t</td>
<td>df</td>
<td>Sig. (2-tailed)</td>
</tr>
<tr>
<td>Pre-Post Difference</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Equal variances</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>assumed</td>
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<td>.152</td>
<td>.528</td>
<td>10</td>
<td>.609</td>
</tr>
<tr>
<td>Equal variances</td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>not assumed</td>
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<td>7.025</td>
<td>.632</td>
<td>10</td>
<td>104.25714</td>
</tr>
<tr>
<td>Pre-2Hr Post Difference</td>
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<td>.831</td>
<td>1.897</td>
<td>10</td>
<td>.087</td>
</tr>
<tr>
<td>Equal variances</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>assumed</td>
<td>1.870</td>
<td>8.302</td>
<td>.097</td>
<td>112.40147</td>
<td>467.73797</td>
</tr>
<tr>
<td>Equal variances</td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>not assumed</td>
<td>.696</td>
<td>5.879</td>
<td>.513</td>
<td>69.28571</td>
<td>99.58882</td>
</tr>
</tbody>
</table>

Table 10

*Difference in Metabolic Rate Change Between Training Status in Quiet Rest*
Likewise, the difference in metabolic rate between the trained and untrained groups was compared in the quiet rest condition only. Levene’s Test for Equality of Variances revealed that equal variances would be assumed for all three of our comparisons.

The pre-intervention to post-intervention ($P < .141$), pre-intervention to 2-hour post intervention ($P < .066$), and pre-intervention to 24-hour post-intervention ($P < .440$) comparisons showed no significant differences.

Table 11

<table>
<thead>
<tr>
<th></th>
<th>Training</th>
<th>N</th>
<th>Mean</th>
<th>Std. Deviation</th>
<th>Std. Error Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-Post Difference</td>
<td>Trained</td>
<td>5</td>
<td>62.0000</td>
<td>73.44726</td>
<td>32.84661</td>
</tr>
<tr>
<td></td>
<td>Untrained</td>
<td>4</td>
<td>51.5000</td>
<td>130.88799</td>
<td>65.44400</td>
</tr>
<tr>
<td>Pre- 2Hr Post Difference</td>
<td>Trained</td>
<td>5</td>
<td>60.4000</td>
<td>64.22850</td>
<td>28.72386</td>
</tr>
<tr>
<td></td>
<td>Untrained</td>
<td>4</td>
<td>35.7500</td>
<td>67.74646</td>
<td>33.87323</td>
</tr>
<tr>
<td>Pre-24Hr Post Difference</td>
<td>Trained</td>
<td>4</td>
<td>99.2500</td>
<td>166.64808</td>
<td>83.32404</td>
</tr>
<tr>
<td></td>
<td>Untrained</td>
<td>3</td>
<td>15.6667</td>
<td>31.39002</td>
<td>18.12304</td>
</tr>
</tbody>
</table>
Table 12

<p>| Difference in Metabolic Rate Change Between Training Status in Quiet Rest Condition |
|-----------------------------------------------|------------------|---------------|-----------------|-----------------|-----------------|
| Levene's Test for Equality of Variances | t-test for Equality of Means | 95% Confidence Interval of the Difference |</p>
<table>
<thead>
<tr>
<th>F</th>
<th>Sig.</th>
<th>t</th>
<th>df</th>
<th>Sig. (2-tailed)</th>
<th>Mean Difference</th>
<th>Std. Error Difference</th>
<th>Lower</th>
<th>Upper</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-Post Difference</td>
<td>Equal variances assumed</td>
<td>.761</td>
<td>.412</td>
<td>1.657</td>
<td>7</td>
<td>.141</td>
<td>113.50000</td>
<td>68.49176</td>
</tr>
<tr>
<td></td>
<td>Equal variances not assumed</td>
<td>1.550</td>
<td>4.488</td>
<td>.188</td>
<td>113.50000</td>
<td>73.22443</td>
<td>308.37210</td>
<td>81.37210</td>
</tr>
<tr>
<td>Pre- 2Hr Post Difference</td>
<td>Equal variances assumed</td>
<td>.012</td>
<td>.917</td>
<td>2.180</td>
<td>7</td>
<td>.066</td>
<td>96.15000</td>
<td>44.11264</td>
</tr>
<tr>
<td></td>
<td>Equal variances not assumed</td>
<td>2.165</td>
<td>6.388</td>
<td>.071</td>
<td>96.15000</td>
<td>44.41234</td>
<td>203.24193</td>
<td>10.94193</td>
</tr>
<tr>
<td>Pre-24Hr Post Difference</td>
<td>Equal variances assumed</td>
<td>3.879</td>
<td>.106</td>
<td>.838</td>
<td>5</td>
<td>.440</td>
<td>83.58333</td>
<td>99.74951</td>
</tr>
<tr>
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<td>Equal variances not assumed</td>
<td>.980</td>
<td>3.280</td>
<td>.394</td>
<td>83.58333</td>
<td>85.27215</td>
<td>175.16265</td>
<td>342.32932</td>
</tr>
</tbody>
</table>

Next, a repeated measures ANOVA with Wilks’ Lambda distribution was run to assess the change of metabolic rate over time, as well as the interaction effect between training status and the change over time. The change over time was significant (P < .015). The change over time was influenced by the training status that participants possessed (P < .035). The change over time
is analyzed in the “Metabolic Rate” row, and the interaction effect between training status and the time periods is analyzed in the “MR * Training” row.

Table 13

<table>
<thead>
<tr>
<th>Effect</th>
<th>Value</th>
<th>F</th>
<th>Hypothesis df</th>
<th>Error df</th>
<th>Sig.</th>
<th>Partial Eta Squared</th>
</tr>
</thead>
<tbody>
<tr>
<td>MR</td>
<td>Pillai's Trace</td>
<td>.493</td>
<td>4.871&lt;sup&gt;a&lt;/sup&gt;</td>
<td>3.000</td>
<td>15.000</td>
<td>.015*</td>
</tr>
<tr>
<td></td>
<td>Wilks' Lambda</td>
<td>.507</td>
<td>4.871&lt;sup&gt;a&lt;/sup&gt;</td>
<td>3.000</td>
<td>15.000</td>
<td>.015*</td>
</tr>
<tr>
<td></td>
<td>Hotelling's Trace</td>
<td>.974</td>
<td>4.871&lt;sup&gt;a&lt;/sup&gt;</td>
<td>3.000</td>
<td>15.000</td>
<td>.015*</td>
</tr>
<tr>
<td></td>
<td>Roy's Largest Root</td>
<td>.974</td>
<td>4.871&lt;sup&gt;a&lt;/sup&gt;</td>
<td>3.000</td>
<td>15.000</td>
<td>.015*</td>
</tr>
<tr>
<td>MR * Training</td>
<td>Pillai's Trace</td>
<td>.426</td>
<td>3.711&lt;sup&gt;a&lt;/sup&gt;</td>
<td>3.000</td>
<td>15.000</td>
<td>.035*</td>
</tr>
<tr>
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<td>Wilks' Lambda</td>
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<td>3.711&lt;sup&gt;a&lt;/sup&gt;</td>
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<td>15.000</td>
<td>.035*</td>
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<tr>
<td></td>
<td>Hotelling's Trace</td>
<td>.742</td>
<td>3.711&lt;sup&gt;a&lt;/sup&gt;</td>
<td>3.000</td>
<td>15.000</td>
<td>.035*</td>
</tr>
<tr>
<td></td>
<td>Roy's Largest Root</td>
<td>.742</td>
<td>3.711&lt;sup&gt;a&lt;/sup&gt;</td>
<td>3.000</td>
<td>15.000</td>
<td>.035*</td>
</tr>
</tbody>
</table>

*Significant at .05

The same repeated measures ANOVA with Wilks’ Lambda distribution was run to consider the interaction effect of resistance exercise vs. quiet rest and the time periods. The change over time was influenced by whether participants were placed into the exercise group or quiet rest group (P < .005).
Table 14
Multivariate Tests – For Exercise vs. Quiet Rest

<table>
<thead>
<tr>
<th>Effect</th>
<th>Value</th>
<th>F</th>
<th>Hypothesis df</th>
<th>Error df</th>
<th>Sig.</th>
<th>Partial Eta Squared</th>
</tr>
</thead>
<tbody>
<tr>
<td>MR</td>
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<td>6.070&lt;sup&gt;a&lt;/sup&gt;</td>
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<td>15.000</td>
<td>.006</td>
<td>.548</td>
</tr>
<tr>
<td></td>
<td>.548</td>
<td>6.070&lt;sup&gt;a&lt;/sup&gt;</td>
<td>3.000</td>
<td>15.000</td>
<td>.006</td>
<td>.548</td>
</tr>
<tr>
<td></td>
<td>1.214</td>
<td>6.070&lt;sup&gt;a&lt;/sup&gt;</td>
<td>3.000</td>
<td>15.000</td>
<td>.006</td>
<td>.548</td>
</tr>
<tr>
<td></td>
<td>1.214</td>
<td>6.070&lt;sup&gt;a&lt;/sup&gt;</td>
<td>3.000</td>
<td>15.000</td>
<td>.006</td>
<td>.548</td>
</tr>
</tbody>
</table>

| MR * Group      | .563   | 6.433<sup>a</sup> | 3.000       | 15.000   | .005 | .563                |
|                 | .437   | 6.433<sup>a</sup> | 3.000       | 15.000   | .005** | .563               |
|                 | 1.287  | 6.433<sup>a</sup> | 3.000       | 15.000   | .005 | .563                |
|                 | 1.287  | 6.433<sup>a</sup> | 3.000       | 15.000   | .005 | .563                |

*Significant at .05
**Significant at .01

Next, a between-subjects ANOVA was run to measure the differences at each measurement, rather than the measurements over time as we reported previously. There were no significant differences observed between measures when considering trained vs. untrained participants (P < .710).

Table 15
Tests of Between-Subjects Effects

<table>
<thead>
<tr>
<th>Source</th>
<th>Type III Sum of Squares</th>
<th>df</th>
<th>Mean Square</th>
<th>F</th>
<th>Sig.</th>
<th>Partial Eta Squared</th>
</tr>
</thead>
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<tr>
<td>Intercept</td>
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<td>4.051E8</td>
<td>944.781</td>
<td>.000</td>
<td>.982</td>
</tr>
<tr>
<td>Training Status</td>
<td>61307.117</td>
<td>1</td>
<td>61307.117</td>
<td>.143</td>
<td>.710</td>
<td>.008</td>
</tr>
<tr>
<td>Error</td>
<td>7289848.514</td>
<td>17</td>
<td>428814.618</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Finally, a repeated measures ANOVA pair wise comparison with Bonferroni post-hoc was run to compare each metabolic rate measurement with other metabolic rate measurements. For purposes of this report, “1” will denote the Pre-intervention measure, “2” will denote the post-intervention measure, “3” will denote the 2-hour post-intervention measure, and “4” will denote the 24-hour post-intervention measure.

Significant differences were observed between the pre-intervention measure and post-intervention measure, the post-intervention measure and the 2-hour post-intervention measure, and the post-intervention measure and the 24-hour post-intervention measure. No other significant differences were observed. Significance values are displayed in the chart below.
Table 16
Pairwise Comparisons
1= Pre-Intervention, 2=Post-Intervention, 3=2-hour post-intervention, 4=24-hour post-intervention

<table>
<thead>
<tr>
<th>(I) RMR Mean Difference (I-J)</th>
<th>Std. Error</th>
<th>Sig. a</th>
<th>95% Confidence Interval for Difference a</th>
<th>Lower Bound</th>
<th>Upper Bound</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2</td>
<td>-356.684*</td>
<td>91.537</td>
<td>.006**</td>
<td>-627.883</td>
</tr>
<tr>
<td>3</td>
<td>125.684</td>
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<td>.072</td>
<td>-259.099</td>
<td>7.730</td>
</tr>
<tr>
<td>4</td>
<td>-28.684</td>
<td>32.643</td>
<td>1.000</td>
<td>-125.397</td>
<td>68.029</td>
</tr>
<tr>
<td>2</td>
<td>1</td>
<td>356.684*</td>
<td>91.537</td>
<td>.006**</td>
<td>85.485</td>
</tr>
<tr>
<td>3</td>
<td>231.000*</td>
<td>72.815</td>
<td>.032*</td>
<td>15.268</td>
<td>446.732</td>
</tr>
<tr>
<td>4</td>
<td>328.000*</td>
<td>103.042</td>
<td>.031*</td>
<td>22.714</td>
<td>633.286</td>
</tr>
<tr>
<td>3</td>
<td>1</td>
<td>125.684</td>
<td>45.031</td>
<td>.072</td>
<td>-7.730</td>
</tr>
<tr>
<td>2</td>
<td>-231.000*</td>
<td>72.815</td>
<td>.032*</td>
<td>-446.732</td>
<td>-15.268</td>
</tr>
<tr>
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<td>97.000</td>
<td>58.661</td>
<td>.693</td>
<td>-76.796</td>
<td>270.796</td>
</tr>
<tr>
<td>4</td>
<td>1</td>
<td>28.684</td>
<td>32.643</td>
<td>1.000</td>
<td>-68.029</td>
</tr>
<tr>
<td>2</td>
<td>-328.000*</td>
<td>103.042</td>
<td>.031*</td>
<td>-633.286</td>
<td>-22.714</td>
</tr>
<tr>
<td>3</td>
<td>-97.000</td>
<td>58.661</td>
<td>.693</td>
<td>-270.796</td>
<td>76.796</td>
</tr>
</tbody>
</table>

*Significant at .05  **Significant at .01  
a. Adjustment for multiple comparisons: Bonferroni.

Below are graphs of the mean metabolic rate measurements. The first shows the trained groups vs. the untrained group, and the second shows resistance exercise vs. quiet rest. Again, “1” will denote the Pre-intervention measure, “2” will denote the post-intervention measure, “3” will denote the 2-hour post-intervention measure, and “4” will denote the 24-hour post-intervention measure. Estimated marginal means denotes the metabolic rate value. In the bottom graph, “Non-exercise” denotes the quiet rest group.
Figure 1

Trained vs. Untrained Metabolic Rate
Figure 2
*Exercise vs. Quiet Rest Metabolic Rate*
CHAPTER V
DISCUSSION

A total of twenty two college-aged males were reported in the study. Twelve of these participants were trained and ten of them were untrained. Twelve of the participants were placed into the exercise group, and ten of them were placed into the quiet rest group. The breakdown includes a total of seven participants that were trained and placed into the exercise group; five participants that were trained and placed into the quiet rest group; five participants that were untrained and placed into the exercise group; and five participants that were untrained and placed into the quiet rest group.

The average age of the participants was 21. The mean age of all participants was 21 years. The mean age of the trained group was 20.91, and the mean age of the untrained group was 21.1. The average body weight for the trained group was 192.33 pounds. The average body weight for the untrained group was 193 pounds. The average fat-free mass for the trained group was 158.12 pounds. The average fat-free mass for the untrained group was 153.47 pounds. The average resting metabolic rate measurement for the trained group at baseline was 2,255 kcal/day. The average resting metabolic rate measurement for the untrained group at baseline was 2,148 kcal/day.

The average body fat percentage of the 22 participants measured by the BODPOD was 19.90%. The average body fat percentage of the 22 participants measured by hydrostatic weighing was 18.95%. For some participants, there were moderate differences in body composition between the two measures. Both methods, although very accurate, have error
associated. Overall, the body composition measures were very close when comparing the two methods in the participant group as a whole.

Hypothesis number 1 was not supported through an independent samples t-test that compared the resting metabolic rate between the group of trained and untrained participants. No significant differences were found.

Hypothesis number 2 was not supported through an independent samples t-test that compared the difference between metabolic rates between training statuses. We saw no significant differences in the magnitude of change between the trained and untrained conditions at the 2-hour post-intervention measure or the 24-hour post-intervention measure, as compared to the pre-intervention measure.

Hypothesis number 3 was not supported through an independent samples t-test that was performed to compare the change in metabolic rate between resistance exercise and quiet rest. We saw a significant difference between the pre-intervention measure and the post-intervention and 2-hour post-intervention measures. However, we did not see significant changes in the difference between the pre-intervention measure and the 24-hour post-intervention measure.

SPSS version 19 computer software was used to analyze the data. We performed a series of independent t-tests, followed by a series of repeated measure ANOVA tests. First, we performed an independent t-test to compare resting metabolic rate at baseline between the trained group and the untrained group and the exercise and quiet rest groups. We found no significant differences at baseline between the trained and untrained groups or between the exercise and quiet rest groups.

Next, we performed an independent samples t-tests were run to compare the change in
metabolic rate between resistance exercise and quiet rest. These tests compared the pre-intervention measure to the post-intervention measure, the pre-intervention measure to the 2-hour post-intervention measure, and the pre-intervention measure to the 24-hour post-intervention measure. We found significant differences between the pre-intervention measure and the post-intervention and 2-hour post-intervention measures, but not the 24-hour post-intervention measure.

This result was consistent with some of the previous literature (Gillette, 2004,) (Burleson, 1998.) However, this was in conflict with a group of other studies, (Broeder, 1992,) (Williamson, 1997,) (Jamurtas, 2004.)

The last test, pair wise comparisons repeated measures ANOVA allowed us to compare the differences between each one of the metabolic rate measurements and any of the other metabolic rate measurements. We found significant differences between the pre-intervention measure and post-intervention measure, the post-intervention measure and the 2-hour post-intervention measure, and the post-intervention measure and the 24-hour post-intervention measure.

This was to be expected, as the fairly difficult resistance exercise protocol increased the post-intervention measurement of metabolic rate significantly. Since the post-intervention measurement and the 2-hour post-intervention measurement were significantly different, we can see that the metabolic rate is quickly returning toward a baseline level. However, participants were not yet returned to baseline, as there was a still mean of an additional 198 kcal/day for the exercise group in the 2-hour post-intervention measure as compared to the baseline measure.

Overall, we saw results that are consistent with the literature. We did see some significant differences, as mentioned above, while some of the tests revealed no significant differences. The
main limiting factor was probably sample size being that we had a total of 22 participants. We feel that with a great number of participants, we may have seen a greater significance in many of the tests, as several of the tests were leaning toward significance.

There was moderate variation between resting metabolic rate in the individuals. This classification of individuals was selected because they are the same gender, fall into a specific age group, and were similarly active. Simply, these participants were either very active (150 minutes of total activity per week or more), or almost sedentary (30 minutes of total activity per week or less).

There was, however, variation even within groups. These variations could be attributed to various environmental conditions. All data was collected somewhere in the Human Performance Laboratory in Zink Hall. Temperature and humidity variation from day to day may have played a role, however.

In addition, the Human Performance Laboratory is located underneath a fitness center that is upstairs. Although this was not normally an issue, there were instances where a loud noise from the ceiling above was heard by the participants. There is no reason to think, however, that this would cause a significant change in the measurement of metabolic rate.

Other controllable variables were successfully accounted for. Lighting was an option to each participant, because we wanted to create a comfortable environment. The room was either dimly lit or lit. We did not offer the lights being off as an option, because participants were not permitted to sleep during this time. Sleeping would have impact the measurement of resting metabolic rate, and professionals and literature on the topic generally advises against sleeping during a measurement.
Future Recommendations

Future recommendations would be to investigate the relationship between intensity and duration of the elevation in metabolic rate, after an exercise session.

One study, in particular, found an increased energy expenditure at a 24-hour post-exercise measure and a 48-hour post-exercise measure. (Jamurtas, 2004.) It is also notable that while not statistically significant; a study at Pennsylvania State University found that there was a 3% increase in metabolic rate 48 hours after a bout of exercise (Williamson, 1997). In fact, researchers studied the previous literature and came to the conclusion that studies finding no significant elevations beyond the 1 hour post-bout measure generally used protocols much lower in intensity as compared to studies that found an elevation lasting 48 hours. (Jamurtas, 2004).

Future recommendations would ideally look to find a link between intensity and the lasting elevation of metabolic rate following exercise. Perhaps, the magnitude of elevation and the lasting effect of the elevation are directly related to exercise intensity, specifically in regards to resistance training. Future studies should involve multiple groups of like individuals, with each following similar resistance training protocols that differ only in intensity.

Physiological functions that cause elevated sympathetic activity and increased substrate cycling may be partly responsible for the extended elevation in metabolic rate we see in some studies, and perhaps a greater percentage of the studies would see similar results of an increased intensity, which would in turn create more drastic sympathetic activity and substrate cycling.
References


APPENDIX A

Bench-Press

Starting Position:

- Lie on your back on the bench
- Maintain contact with bench through head, back, butt and keep both feet on the ground
- Keep eyes under bar and grasp bar with closed grip
- Signal spotter for assistance lifting off
- Position bar over chest with elbows extended
- This is the starting position for all repetitions

Downward Movement Phase:

- Keep wrists stiff and forearms perpendicular to the floor
- Maintain contact with bench as you did in the starting position
- Lower the bar one inch from chest at approximately nipple level
- Hold position briefly, preparing to explode upward

Upward Movement Phase

- Push the bar upward until elbows are fully extended
- Keep wrists stiff and forearms perpendicular to the floor
- Maintain contact with bench as you did in the starting position
- Signal spotter for help in re-racking the bar
- Keep grip on bar until bar is resting in rack

Based upon:
APPENDIX A
EXERCISE INFORMATION SHEETS

Dead-lift

Starting Position:

- Stand with feet flat and placed at shoulder-width apart with toes pointed slightly outward
- Squat down with hips lower than the shoulders and grasp bar with either a closed grip or alternated grip
- Hands must be placed wider than shoulder width apart
- Place feet flat on floor and position bar slightly in front of shins
- Position body with a flat-back, chest held out and up, heels in contact with the floor, shoulders over or in front of the bar
- **All repetitions begin from this position**

Upward Movement Phase:

- Lift bar off the floor by extending the hips and knees
- Maintain flat-back
- Keep elbows fully extended and bar close to the shins
- Keep shoulders over or slightly in front of bar
- Continue to extend hips and knees until body reaches a complete standing position

Downward Movement Phase

- Allow knees and hips to flex slowly to lower the bar to the floor
- Keep flat-back and do not flex the torso forward

Based upon:
APPENDIX A

Box-Squat

Starting Position:

- Grasp the bar with a closed, forward-facing grip
- Step under the bar and position feet parallel to each other, shoulder-width apart
- Place the bar across the posterior deltoids (across the shoulders) in a comfortable position
- Lift elbows to create a “shelf” for the bar using the upper back and shoulder muscles
- Hold chest out and up
  - Tilt head up slightly
  - Extend hips and knees to lift bar
  - Take one or two steps backward, return feet to shoulder-width.
  - This is the starting position for all repetitions

Downward Movement Phase:

- Maintain position with back flat, elbows high, and chest out.
- Allow hips and knees to flex while keeping torso-to-floor angle constant
- Keep heels on the floor and knees over feet
- Continue flexing knees and hips slowly until butt touches the box
  - Hold position briefly, putting no weight on the box – The box is simply a measure of how “far” to go and when to end flexion of knees and hips

Upward Movement Phase

- Maintain flat-back position, and “shelf”
- Extend hips and knees at the same time
- Keep heels on floor and knees aligned over feet
- Do not flex the torso
- Continue extending until you are again standing
  - At the end of the set, step forward toward the rack.
  - Squat down until the bar rests on the supports.

Based upon:
APPENDIX B

12-Hour Fast

As part of your participation, a 12-hour fast is required of you in the 12 hours leading up to your next session. A 12-hour fast requires you to take nothing by mouth, other than water, for the 12 hours leading up to your visit. This 12-hour fast includes the following:

- No Food of any kind
- No Drink of any kind including coffee, soda, tea, lemonade, sports drinks, alcoholic beverages, milk
- No Smoking cigarettes
- No Use of smokeless tobacco
- No Use of supplements or vitamins
- No Use of chewing gum
- No protein shakes
- No energy drinks

If you have questions, contact the program director:

Andrew Newton
atniup@gmail.com
724-422-7717

Thank you for your participation.
APPENDIX C

Request of Results

To receive results of your participation in the study and be entered in a chance to win a gift card, please fill out the following information:

Name: ________________________________

Date enrolled in study: ________________________________

E-mail: ________________________________

☐ Yes, I would like to be entered in a chance to win a gift card

☐ No, I would not like to be entered in a chance to win a gift card

☐ Yes, I would like to receive the results of my participation

☐ No, I would not like to receive the results of my participation

Thank you for your participation!

Date of request: ________________________________

Signature: ________________________________

Principal Investigator Signature: ________________________________

Date: ________________________________
APPENDIX D
DATA COLLECTION SHEET

How is energy expenditure different 2 and 24 hours post a near maximal bout of resistive exercise in trained vs. untrained college-aged males?

Entry into study: _________________

Participant: ____________________________________________________________________________

Participant age: _________________

Date: _________________ Location: ____________________________________________________________________________

Height: _________________ Weight: ____________________________________________________________________________

Body Fat % (Underwater weighing): ____________________________________________________________________________

  Submerge 1: _________________
  Submerge 2: _________________
  Submerge 3: _________________
  Submerge 4: _________________
  Submerge 5: _________________

Body Fat % (BODPOD): ____________________________________________________________________________

Assigned Group (exercise or control): ____________________________________________________________________________

Training Status (trained or untrained): ____________________________________________________________________________

For exercise group only:

  Measured 1-repetition maximum (Bench Press): ____________________________________________________________________________
  Measured 1-repetition maximum (Box-squat): ____________________________________________________________________________
  Measured 1-repetition maximum (Dead lift): ____________________________________________________________________________

  Sets completed (Bench Press): ____________________________________________________________________________
  Sets completed (Box-squat): ____________________________________________________________________________
  Sets completed (Dead lift): ____________________________________________________________________________
APPENDIX D

Pre-Treatment:
Record last 10 minutes of data only. This is done to achieve a true resting state.

Resting Metabolic Rate (kcal): ________________________________
Time - Total (min:sec): ______________________________________
Duration of measure data (min:sec): ____________________________
Respiratory Quotient (CO2/O2): ________________________________
% CHO (kcal/D): ____________________________________________
% FAT (kcal/D): _____________________________________________

Post-Treatment:
Record last 10 minutes of data only. This is done to achieve a true resting state.

Resting Metabolic Rate (kcal): ________________________________
Time - Total (min:sec): ______________________________________
Duration of measure data (min:sec): ____________________________
Respiratory Quotient (CO2/O2): ________________________________
% CHO (kcal/D): ____________________________________________
% FAT (kcal/D): _____________________________________________

2 Hours Post-Treatment:
Record last 10 minutes of data only. This is done to achieve a true resting state.

Resting Metabolic Rate (kcal): ________________________________
Time - Total (min:sec): ______________________________________
Duration of measure data (min:sec): ____________________________
Respiratory Quotient (CO2/O2): ________________________________
% CHO (kcal/D): ____________________________________________
% FAT (kcal/D): _____________________________________________
APPENDIX D

24 Hours Post-Treatment:
Record last 10 minutes of data only. This is done to achieve a true resting state.

Resting Metabolic Rate (kcal): ________________________________
Time - Total (min:sec): ________________________________
Duration of measure data (min:sec): ________________________________
Respiratory Quotient (CO2/O2)): ________________________________
% CHO (kcal/D): ________________________________
% FAT (kcal/D): ________________________________

Graphs and data sheets attached
APPENDIX E

Exercise Questionnaire

Name: ________________________________

As part of your participation, please answer the following questions:

How many days per week do you exercise?

How many minutes does each exercise session last, on average?

How many minutes per week do you exercise, on average?

Of your total exercise per week, how many minutes of these are resistance training?

If you have any questions or concerns, contact the project director.

Andrew Newton
E-Mail: atniup@gmail.com
Phone: 724-422-7717

Thank you for your participation.
APPENDIX F

Dress for First Session

As part of your participation, you should dress appropriately for the first session. Your first session is scheduled for _______________. You will be participating in a BODPOD measurement, a hydrostatic weighing measurement, and weight lifting during this session. To properly complete all of this, you will need the following:

- Gym shorts or track pants
- Tennis shoes or basketball shoes
- T-shirt or something similar
- Swimming trunks
- Towel

If you have any questions or concerns, contact the project director.

Andrew Newton
E-Mail: atniup@gmail.com
Phone: 724-422-7717

Thank you for your participation.
INFORMED CONSENT

You are invited to participate in this research study. The following information is provided in order to help you to make an informed decision whether or not to participate. If you have any questions please do not hesitate to ask. You are eligible to participate because you are a student in exercise science or health and wellness classes at Indiana university of Pennsylvania.

The purpose of this study is to compare the amount of energy used in a trained vs. and untrained group of subjects. Participation in this study will require about 4 hours of your time spread out over 4 separate sessions. First you will perform weight lifting exercises to measure the highest amount of weight you can lift one time. You will be asked to sit in a sealed, egg-shape container to measure body fat. You will also be asked to get in a warm water tub to measure body fat. Next you will be assigned to a control group or an exercise group. One week later, the control group will report to the second session and lie still in a bed for about 30 minutes to measure energy expenditure. After that, you will return 2 hours later to lie for another 30 minutes, and again 24 hours later for another 30 minutes. The exercise group will follow the same procedure, but the control group will be expected to not do planned exercise between the first and last sessions. The exercise group will only participate in the exercise session provided, and will be asked not to participate in addition planned exercise until the conclusion of their participation. The risks of this study are no greater than if you were to exercise on your own.

You may find that you receive valuable information during this study. You will be leaving with a measurement of your daily resting energy expenditure. Your data will be used to compare energy expenditure to being a trained or untrained athlete, and to measure changes in energy expenditure as compared to your resting value.

Your participation in this study is voluntary. You are free to decide not to participate in this study or to withdraw at any time without adversely affecting your relationship with the investigators or IUP. Your decision will not result in any loss of benefits to which you are otherwise entitled. If you choose to participate, you may withdraw at any time by notifying the Project Director or informing the person administering the test. Upon your request to withdraw, all information pertaining to you will be destroyed. If you choose to participate, all information will be held in strict confidence and will have no bearing on your academic standing or services you receive from the University. Your performance will be considered only in combination with those from other participants. The information obtained in the study may be published in scientific journals or presented at scientific meetings but your identity will be kept strictly confidential.
If you are willing to participate in this study, please sign the statement below and deposit in the designated box by the door. Take the extra unsigned copy with you. If you choose not to participate, deposit the unsigned copies in the designated box by the door.

Project Director:  
Mr. Andrew Newton  
Indiana University of Pennsylvania  
111 Zink Hall  
Indiana, PA 15705  
Phone: 724-422-7717

Co-Investigator: Madeline Paternostro Bayles  
Professor  
Indiana University of Pennsylvania  
225 Zink Hall  
1190 Maple Street  
Indiana, PA 15701

This project has been approved by the Indiana University of Pennsylvania Institutional Review Board for the Protection of Human Subjects (Phone: 724-357-7730).

Statement of Consent:

I have read and understand the information on the form and I consent to volunteer to be a subject in this study. I understand that my responses are completely confidential and that I have the right to withdraw at any time.

Name (PLEASE PRINT)  
_________________________________________________________________________

Signature  
_________________________________________________________________________

Date  
_________________________________________________________________________

Phone number or location where you can be reached  
_________________________________________________________________________

Best days and times to reach you  
_________________________________________________________________________
I certify that I have explained to the above individual the nature and purpose, the potential benefits, and possible risks associated with participating in this research study, have answered any questions that have been raised, and have witnessed the above signature.

<table>
<thead>
<tr>
<th>Date</th>
<th>Investigator's Signature</th>
</tr>
</thead>
</table>

Project Director: Mr. Andrew Newton
Indiana University of Pennsylvania, 111 Zink Hall, Indiana, PA 15705
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