Energy Expenditure of Resistance Training Activities

in Young Men

by

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A Thesis Presented in Partial Fulfillment
of the Requirements for the Degree
Master of Science

Approved April 2011 by the
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ARIZONA STATE UNIVERSITY

May 2011

ABSTRACT

The purpose of this study was to determine the energy cost of four modes of resistance training (push-ups, pull-ups, curl-ups, lunges). Twelve well trained men aged 23.6 (SD=2.84) years were recruited to participate in the study. Each of the 12 men completed three trials of each of the four exercises on one visit to the laboratory lasting slightly over one hour (M=72 min, SD=5.9 min). The oxygen consumption of the men was monitored constantly throughout the trial and data was recorded every five seconds. Mean VO2 values were calculated for each exercise. The values for push-ups (M=11.57 ml/kg/min, SD=1.99), curl-ups (M=10.99 ml/kg/min, SD=1.48), pull-ups (M=10.87 ml/kg/min, SD=2.51), and lunges (M=14.18 ml/kg/min, SD=1.78) were converted to METs (Metabolic Equivalents). The MET values (3.31, 3.14, 3.11, and 4.05 respectively) all fall within the range of moderate intensity activity. The findings of this study show that a single set of any of the above exercises will qualify as a moderate intensity activity and can be used to meet recommendations on daily physical activity.

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INTRODUCTION

Overview

As of 2004, physical inactivity and poor dietary habits accounted for 16.6% (~400,000) of all deaths in the United States (Mokdad, Marks, Stroup, & Gerberding, 2004). Physical activity has a profound impact on a variety of chronic diseases and conditions that plague the world's population. A direct inverse relationship exists between physical activity and occurrences of diseases such as cardiovascular disease, coronary heart disease, hypertension, obesity, type II diabetes, colon cancer, and depression. Regular physical activity is also associated with a lowered risk of low back pain, osteoporosis and osteoarthritis, and provides an improved quality of life in the elderly (American College of Sports Medicine [ACSM], 2010).

The US Department of Health and Human Services, the ACSM, and the American Heart Association, have released recommendations for the amount of physical activity needed by adults to experience and maintain health benefits (Department of Health and Human Services [DHHS], 2008; Haskell et al., 2007). These recommendations specify that resistance training should be performed at least twice a week in addition to cardiovascular exercise to promote health and reduce the risks for disability. The recommendation for weight training was made because resistance training has a direct, beneficial impact on diseases such as hypertension, type II diabetes, cardiovascular disease and rheumatoid and osteoarthritis. Resistance training also aids in the prevention of sarcopenia and osteoporosis (Braith & Stewart, 2006; Maeda et al., 2006; Misra et al., 2008; Nelson et al., 1994).

The Compendium of Physical Activities (Compendium) was developed as a tool to help identify the energy expenditure of all forms of physical activity, including strength training (Ainsworth et al., 1993; Ainsworth et al., 2000). Because some physical activity recommendations have called for a specific amount of energy expenditure every week (e.g., the 1996 Surgeon General's Recommendation for 1,000 metabolic equivalent (MET) minutes/week) or called for a defined number of minutes every week in moderate and/or vigorous physical activity (e.g., US Physical Activity Guidelines for 150 minutes of moderate intensity physical activity per week), the Compendium has become invaluable as a tool to help classify the intensity of various physical activities (DHHS, 2008; Haskell et al., 2007).

The Compendium has compiled an extensive list of measured and estimated MET values for a variety of activities; however, it is optimal to have measured activities for every activity within the Compendium. As resistance training is included as a popular activity in the Conditioning Activities category within the Compendium, it is important to add as many accurately measured resistance training activities to the Compendium as possible.

Purpose of Study

The purpose of this study was to accurately measure and record the energy expenditure for four modes of resistance training; the push-up, the curl-up, the pull-up, and single leg alternating lunges. The recorded values were added to the existing resistance training activities currently listed in the Compendium.

Research Aim

The aim of this study was to contribute to the literature by further enhancing the validity of the MET levels for activities presented in the Compendium. The MET intensities for activities measured in this study were added to the already extensive list of activities found within the Compendium, and served to augment the Conditioning Activities section.

Definition of Terms

Resistance Training: A form of physical activity in which a person moves a given weight, either an external weight or the individual's body weight, through a full range of motion. This form of training usually targets a specific muscle group and is used to strengthen this muscle group.

MET: Metabolic Equivalent. A standard unit used to represent energy cost. Equal to 3.5 Kilocalories/min.

Oxygen uptake: The amount of oxygen a body uses in a given amount of time.

Lunge: An exercise performed by taking a large step forward then lowering oneself down so that the rear knee lightly contacts the ground.

Curl-up: An exercise performed by lying on one's back, and raising one's upper body off the ground to a predetermined position.

Push-up: An exercise performed by lying on one's stomach on the floor, and fully extending the arms while maintaining a straight body from head to toe, such that only the hands and toes remain in contact with the floor.

Pull-Up: An exercise performed by initially hanging from an overhead bar with arms fully extended and feet suspended in air. The individual then flexes the arms, pulling himself upward until the chin is above the bar.

Chapter 2

REVIEW OF LITERATURE

Importance of Physical Activity and Resistance Training

For the past several decades, researchers have been examining the relationship between physical activity and the prevalence of diseases. There is a direct inverse relationship between physical activity and a variety of chronic diseases and conditions. Cardiovascular disease (CVD), coronary heart disease (CHD), hypertension, obesity, type II diabetes, colon cancer, and depression have an inverse relationship with regular physical activity. In addition, regular physical activity provides a lowered risk of low back pain, osteoporosis and osteoarthritis and provides an improved quality of life in the elderly (ACSM, 2010).

Physical Activity and Resistance Training Guidelines

In 2007, Haskell et al. described the ACSM-American Heart Association (AHA) recommendation for healthful physical activity that updated and clarified the 1995 Centers for Disease Control and Prevention (CDC)-ACSM recommendations for physical activity. The recommendation described the dose of activity required by adults to maintain and/or improve their level of health (Pate et al., 1995). The revision rose out of a need to update the literature summarized in the 1995 recommendation regarding moderate intensity physical activity and clarified misinterpretations of the original recommendations. The updated recommendation called for adults between the ages of 18 and 65 to accumulate 30 minutes of moderate intensity activity for at least five days a week, or 20 minutes of vigorous intensity activity at least three days a week. This activity should be acquired in addition to the activities of daily living (showering, shopping, doing laundry, etc) and should be undertaken in bouts lasting at least 10 minutes. These recommendations also suggest that resistance training should be performed with 8 to 10 exercises on two non-consecutive days every week with 8 to 12 repetitions of each exercise. The resistance exercises should focus on major muscle groups with a weight great enough to cause volitional fatigue within that range of repetitions.

In 2008 the federal government released the Physical Activity Guidelines for Americans (DHHS, 2008). The government's guidelines were similar to the ACSM-AHA recommendation; however there were some subtle differences. The national guidelines call for 150 minutes of moderate intensity activity to be performed throughout the week, or 75 minutes of vigorous activity to be performed throughout the week. Although similar to the ACSM-AHA recommendation, the guidelines do not specify that the activity needs to take place five days a week for moderate physical activity or three days a week for vigorous physical activity. In addition, the national guidelines recommend moderate or high intensity muscle strengthening activities be performed two or more days a week and include seven major muscle groups.

In 2009 the ACSM developed a position stand on the progression of resistance training for healthy adults (Ratamess et al., 2009). Developed as an update of the original position stand published in 2002 (Kraemer et al., 2002), the updated position stand reviewed all facets of resistance training including load, volume, periodization, specificity, and recovery times between sets. The position stand concluded that adaptation to, and results from, resistance training is highly individualized. Thus, resistance training programs should be designed specifically for each individual to match his/her goals and abilities.

Resistance Training, Health Promotion, and Disease Prevention

Resistance training has a positive influence on disease risks. In a review of the literature, Phillips and Winett (2010) demonstrated that resistance training may be as effective, if not more so, than aerobic training for the prevention and maintenance of many chronic diseases. Resistance training has beneficial effects on hypertension, type II diabetes, cardiovascular disease, both rheumatoid and osteoarthritis, the prevention of sarcopenia and osteoporosis, and enhanced quality of life in older and disabled adults (Braith & Stewart, 2006; Maeda et al., 2006; Misra et al., 2008; Nelson et al. 1994). A brief summary of the health benefits of resistance training is provided for several health conditions.

Resistance training, arterial function and hypertension. It is well known that arterial function has a direct impact on hypertension. The artery's ability to expand allows for more blood to pass through and less pressure to build in the artery. Despite years of research, the role of resistance training on arterial function still is highly debated. Rakobowchuk et al. (2005) examined the effects of resistance training on central arterial compliance. Twenty eight healthy males with an average age of 23 years (*SD* = 3.9) years participated in this study. All men were physically active but had not performed regular resistance training for a minimum of six months prior to beginning the study. Participants completed a 12 week resistance training program designed to develop hypertrophy. A three day split routine (e.g. alternate muscle groups on subsequent days) was used to ensure that the participants would be able to lift weights each day. The split routines were scheduled into a day of pulling exercises (pull-down, wide-grip row, narrow-grip row, reverse fly, bicep curl), a day of pushing exercises (shoulder press, bench press, vertical bench press, tricep extensions, chest fly), and a day of lower body exercises (leg extensions, leg curls, incline leg press, seated calf raise). The participants were randomly assigned to one of the three split routines to begin training. Sessions took place five days per week, with participants limiting the exercise sessions to twice a week. To assure that the participants continued to progress throughout the program, a one rep max (1RM) was recorded for each participant four times throughout the trial, once at baseline, and again at the fourth, eighth and twelfth week. Measurements included blood pressure, arterial compliance, and body composition taken at baseline and again at the middle and end of the study. The researchers found that 12 weeks of resistance training had no effect on central arterial compliance as had been previously reported (Bertovic et al., 1999). The researchers also noticed a drop in both brachial pulse pressure (M = 61.1, SD = 1.4 mmHg to M = 57.6, SD = 1.2 mmHg) and carotid pulse pressure (M = 52.2, SD = 1.9 mmHg to M = 46.8, SD = 2.0 mmHg) throughout the study. The results were found to be significant ($p < 0.01$) in each study.

Maeda et al. (2006) examined the effect of a specific type of resistance training on arterial function in older adult men. Eleven healthy men between the ages of 60 and 67 years participated in the trial. Inclusion criteria were being sedentary, non-smokers, drug free, and with no signs of chronic disease prior to participation. Participants completed a training program consisting of 12 weeks of lower body resistance training. The program consisted of three sets each of isokinetic knee extension and knee flexion exercises. For each set, the participants completed 10 repetitions at 60% of their one repetition maximum

(RM). Before any measurements were taken, participants rested for two days after completing an exercise session. In addition, participants fasted for 12 hours prior to returning for testing. These steps were taken to ensure that there was no residual effect from the training and that nitric oxide (NOx, a known vasodilator) levels were not altered by dietary consumption. Much like Rakobowchuk et al. (2005), the researchers found no change in central arterial stiffness. Further, an increase in plasma NOx was observed, indicative of enhanced arterial function. Contrary to an earlier study (e.g. Bertovic et al. 1999) that showed an increase in arterial stiffening in young men following resistance training, these results indicate that resistance training may be beneficial to older men.

Carter, Ray, Downs, and Cooke (2003) examined the effects of strength training on arterial blood pressure. The purpose of the study was to determine if strength training lowered arterial blood pressure. Twenty two men and 3 women, all healthy, average age of 21 years, participated in the trial. Participants were assigned to an exercise or a control group. The groups were matched for age and recreational activity based on a questionnaire. The exercise group participants completed an eight week strength training program consisting of three sessions per week. The sessions included three sets of ten repetitions on each of seven exercises; leg press, leg curls, chest press, lateral row, shoulder press, bicep curl, and triceps extensions. When the participant could successfully complete three sets of 10 repetitions, the weight was increased. Blood pressure levels were measured at the start of the study. Before blood pressures were taken, participants refrained from performing physical activity and drinking or eating meals with caffeine for 12 hours. Following the study, systolic, diastolic, and mean arterial blood pressures decreased significantly in the exercise group, with no change in the control group. The exercise group's systolic blood pressure was reduced from 130 mmHg (*SD* = 3) to 121 mmHg (*SD* = 2). This was found to be significant (p = 0.01). Additionally, diastolic blood pressure was reduced from 69 mmHg (*SD* = 3) to 61 mmHg (*SD* = 2). This value was also found to be significant (p = 0.04). The control group showed no significant difference in either systolic blood pressure (*M* = 119, *SD* = 3 mmHg to *M* = 120, *SD* = 3 mmHg) or diastolic blood pressure (*M* = 64, *SD* = 2 mmHg to *M* = 62, *SD* = 2 mmHg). The results indicated that resistance training is effective in reducing blood pressure.

Type II diabetes mellitus. Human muscle uses glucose to fuel movement. Exercise programs designed to enhance muscular performance have beneficial effects on type 2 diabetes mellitus (T2DM). T2DM is characterized by the body's inability to remove glucose from circulating blood.

Misra et al. (2008) examined the effects of resistance training on insulin sensitivity, glycemia, lipids, and body composition in Asian Indians with T2DM. Thirty patients with T2DM participated in the study. Each participant completed 12 weeks of progressive resistance training. The training program consisted of three resistance training sessions each week, with two sets of ten repetitions performed on each of six exercises. The exercises included biceps flexion, shoulder flexion, finger grip, hip flexion, knee extension, and heel rise. If the participant was successfully able to complete all 10 repetitions of both sets, the weight was subsequently raised by 0.5 kg during the next session. Measurements of all variables were taken at baseline and again following the 12 week program. Measures of insulin sensitivity, glycemia and blood lipids improved significantly following the resistance training program. Fasting blood glucose decreased by

2.7 mmol/l (*SD* = 2.2, $p < 0.001$), total cholesterol decreased by 0.39 mmol/l (*SD* = 0.7, $p = 0.003$), and total serum triglycerides decreased by 0.39 mmol/l (*SD* = 0.5, $p < 0.001$) as compared with baseline levels. Although no significant change in total body fat was observed ($p > 0.05$), there was a significant reduction in truncal (*M* = 5.2 mm, *SD* = 3.5, $p < 0.001$) and peripheral (*M* = 4.5 mm, *SD* = 3.1, $p = 0.001$) subcutaneous adipose tissue compartments. The results showed that resistance training was effective in reducing diabetic health indicators of Asian Indians with T2DM.

Bweir et al. (2009) examined the effects of resistance training and aerobic training on HbA1c and blood glucose levels in adults with T2DM. Seventeen male and three female participants with a mean age of 53.4 years (45-65 years), participated in the study. All participants were sedentary with T2DM. Participants were matched for age, waist circumference, and gender, and were assigned to one of two groups. One group participated in 10 weeks of resistance training while the other participated in 10 weeks of aerobic training. Blood glucose and HbA1c levels were measured 12 weeks prior to beginning each protocol and immediately upon beginning the exercise regime. These pre-exercised values were used as baseline control levels. Both groups met three days per week for exercise training. Participants in the aerobic group exercised on a treadmill for 50 minutes per session with the intensity set at 60% of their estimated maximal heart rate for 20 minutes. They gradually progressed to 75% of their estimated maximal heart rate for the remaining 30 minutes. The resistance training group completed seven weight lifting exercises chosen to incorporate a variety of movement patterns, including knee and hip flexion/extension, shoulder flexion/extension and adduction/abduction, elbow flexion/extension, and a chest press. Participants performed three sets of eight to ten repetitions on each of the exercises and were given a two minute rest period between sets. The weight resistances were designed to elicit a similar exercise heart rate response as the aerobic training group. Both the aerobic and resistance training group showed significant decreases in HbA1c levels ($p < 0.001$). However, the resistance training group had a significantly lower HbA1c level (M = 8.8%, SD = 1.1) than did the aerobic training group (M = 8.7%, SD = 0.7) at the end of the 10 week period. The results were found to be significant (p = 0.006). The researchers concluded that resistance training was more effective than aerobic training at lowering HbA1c levels in type II diabetics.

Black, Swan, and Alvar (2010) evaluated the effects of varying volumes and intensities of resistance training on insulin sensitivity. Twelve men with an average age of 28 years (SD = *11*.3), and 5 women with an average age of 32.4 years (SD = 9.8) participated in a study to determine the effect of acute bouts of resistance training on insulin sensitivity. Participants were asked to maintain a similar diet for a 24 hour period prior to each test. This diet included abstaining from caffeine consumption and a 12 hour fasting period immediately prior to testing. On the day of testing, the participants had their blood drawn and were given a high glycemic meal 20 minutes prior to exercise. Exercise consisted of one of four resistance training protocols. The protocols were randomly assigned with each participant receiving a different protocol on each of the four sessions. A minimum of 72 hours was observed between sessions to ensure there were no carryover effects from previous trials. Following the session, the participants returned to the laboratory after 24 hours for a blood draw to measure glucose. The four trials were separated as follows: single set of 65% of 1RM, single set of

85% of 1RM, three sets of 65% of 1RM and three sets of 85% of 1RM. All exercise protocols significantly improved insulin sensitivity (*M* = -.62, *SD* = 1.02, *p* = 0.002) and fasting blood glucose (*M* = -4.87, *SD* = 0.14, *p* = 0.025). A significantly greater reduction in blood glucose was observed in the multiple set protocols (*M* = -3.0, *SD* = 2.2 to *M* = -1.6, *SD* = 0.6) when compared to the single set protocols (*M* = -2.7, *SD* = 1.1 to *M* = -1.6, *SD* = 2.8). These results were significant (*p* = 0.021). Also, a significantly greater improvement of insulin sensitivity was observed in higher intensity protocols (*M* = 2.5, *SD* = 0.0 to *M* = -2.8, *SD* = 1.4) than in lower intensity protocols (*M* = -1.2, *SD* = 1.2, to *M* = -2.9, *SD* = 5.3). This was found to be significant (*p* = 0.046). This study demonstrates the effects of resistance training on insulin sensitivity and blood glucose. It also shows how training intensity can alter insulin sensitivity and blood glucose.

Coronary heart disease. Smutok et al. (1993) examined the differences between aerobic and strength training on risk factors for coronary heart disease (CHD) in 37 untrained males with a average age of 50 years (*SD* = 9). The study was designed to evaluate the effectiveness of resistance and aerobic training on lipoprotein and lipid profiles, blood pressure, and glucose and insulin responses in men at risk for developing CHD. The participants were randomly assigned to one of three groups: a strength training group (*n* = 14), an aerobic training group (*n* = 13), or a control group (*n* = 10). The strength training group performed two sets of 12-15 repetitions on each of 12 different exercises that had been selected to adequately fatigue the whole body. They met three times per week on nonconsecutive days for a period of 20 weeks. The aerobic training group walked and/or jogged on a treadmill for a period of 30 minutes, on three nonconsecutive days per week. The aerobic training group exercised at a pace that kept their heart rate between 60-70% of maximum for the first two weeks, and between 75-85% for the remainder of the trial. The control group completed the same pre- and post-study measurements as did the exercise trial-groups, however the control group was instructed to refrain from resistance training or aerobic exercise. Both resistance training and aerobic exercise were effective at lowering blood glucose levels ($p < 0.05$ and $p < 0.05$) and insulin levels ($p < 0.01$ and $p < 0.01$) after glucose ingestion. The resistance training group showed a significant lowering of their fasting insulin levels ($p < 0.05$). No significant differences were observed in blood pressure or lipid levels in either training group after 20 weeks of training. This study demonstrated that both aerobic, and weight, training equally reduced risk factors for CHD.

Arthritis. Lemmey et al. (2009) conducted a randomized controlled trial to examine the effects of resistance training on participants with rheumatoid arthritis (RA). Twenty eight participants participated in this study. Of those, 13 participants with an average age of 55.6 years (*SD* = 8.3) underwent 24 weeks of progressive resistance training, while 15 participants with an average age of 60.6 years (*SD* = 11.2) participated in a control group and underwent 24 weeks of home based range of motion exercises. All participants had previously been diagnosed with RA. The exercise training group performed three sets of eight repetitions of each of eight lifts twice weekly. The weight lifting exercises performed were the chest press, leg press, leg extension, seated row, leg curl, triceps extension, standing calf raise, and biceps curl. The lifted weight was equal to 80% of the participants' established 1RM. Compared to the control group, the resistance training group significantly increased lean body mass ($p = 0.01$) and performance in a variety of objective function tests such as a 30 second arm curl test, a 30 second chair test, and a 50 foot walk test (p = 0.027-0.001). Resistance training had no effect on trunk fat mass ($p > 0.05$). The study showed that progressive resistance training was effective in helping patients manage RA. A minimal amount of resistance training had a significant impact on both health and physical function in participants with RA.

Sarcopenia. The monetary impact of sarcopenia in the U.S. has been estimated to be over $18 billion a year. It has been estimated that a 10% reduction in sarcopenia prevalence could result in a decrease in expenditure of $1.1 billion in health care costs (Janssen, Shepard, Katzmarzyk, & Roubenoff, 2004).

Kosek, Kim, Petrella, Cross, and Bamman (2006) evaluated the effect of resistance training on muscular hypertrophy. Forty nine adults were recruited to participate in this study with two groups; a young group, ages 20-35 (12 women, 13 men), and an old group, ages 60-75 (11 women, 13 men). Each group underwent a training program consisting of three days a week of resistance training for 16 weeks. Prior to training each day, the participants warmed up on a treadmill for about five minutes, until they broke a light sweat. The training consisted of three sets of 8-12 repetitions of three exercises. The exercises included knee extensions, leg presses, and squats. The weights lifted were based on the individual's 1RM which was calculated prior to beginning the regimen and two to three days after each participant completed two familiarization sessions to get used to the exercises performed. The participant exercised at a level equal to 80% of their 1RM. When a participant was able to lift 12 repetitions at this weight on at least two sets, their weight was increased. 1RM was calculated at both the midpoint and upon conclusion of the study. The results showed that 16 weeks of resistance training was sufficient to increase myofiber sizes of the older group to the size of the myofibers of the young group during the pre-training period. Although the older group did not experience as great an increase in myofiber size as the younger group, the study showed that resistance training increases myofiber size and decreases sarcopenia rates in the elderly.

Osteoporosis. Nelson et al. (1994) investigated the effects of high intensity strength training on a variety of risk factors for osteoporotic fractures in post-menopausal women. Thirty nine sedentary, estrogen depleted women, between the ages of 50-70, participated in the study. The women were divided into two groups, an exercise group (n = 20), and a control group (n = 19). The exercise group participated in two days per week of high intensity strength training, while the control group remained sedentary. The trial lasted for 52 weeks and consisted of hip extensions, knee extensions, lateral pull-downs, back extensions, and abdominal flexion. The participants worked at a rate equal to 80% of their previously determined 1RM for the first three exercises. For the back extensions and abdominal flexion, the participants were evaluated using the Borg Scale with maximal exertion recorded at a value of 16 (hard). Each session was separated by a minimum of one full day with the 1RM was reevaluated every 4 weeks. The researchers observed that resistance training significantly increased BMD in both the femoral neck and lumbar spine ($p = 0.02$ and $p = 0.04$) respectively. In addition, the resistance training increased muscle mass, strength and dynamic balance in the participants ($p = 0.03$ to $p < 0.001$).

Chien, Yang, and Tsauo (2005) investigated if a 12 week, home based exercise program would be sufficient to increase spinal mobility, function and quality of life in osteoporotic and osteopenic postmenopausal women. Twenty eight postmenopausal women with an average age of 60.3 years (*SD* = 9.3) were recruited to participate in the study. The women were separated into an exercise group and a control group. The exercise group participated in a variety of exercises designed by a physical therapist to increase function and mobility of the trunk. The participants completed the full routine three times every day for a period of 12 weeks. The control group refrained from strength training activities for the entire duration of the study. The researchers reported the program was sufficient to enhance spinal range of motion and motion velocity and to increase quality of life in post-menopausal women.

Assessment of Energy Cost of Physical Activity

Assessment methods. Highly sensitive equipment and both objective and subjective methods are required to measure physical activity and energy expenditure. Many devices have been used to measure physical activity, each with their own strengths and weaknesses in precision, with variations in the methods used to estimate energy expenditure. Objective measures can be used to assess physical activity and to measure the energy expenditure of physical activity. Objective measures include direct observation, motion detection, and global positioning systems. Objective measures to assess energy expenditure include room calorimetry, doubly labeled water, indirect calorimetry (oxygen uptake), heart rate, temperature, and ventilation. Subjective measures to assess physical activity include physical activity records, physical activity logs, 24-hour recall, and questionnaires (Ainsworth, 2010, chap. 4).

Energy expenditure assessment methods. ***Room calorimetry.*** A room calorimeter is a large chamber that is capable of housing a person or persons for a given period of time. While in the chamber, oxygen and carbon dioxide gasses are be collected and analyzed. With measurement of the volume of inspired air, a metabolic chamber makes it possible to measure the energy cost of resting conditions and physical activity. (Seale & Rumpler, 1997).

Doubly labeled water. Doubly labeled water measures energy expenditure through the oral administration of a dose of water that contains alternate isotopes of oxygen (O_2) and hydrogen (H). Referred to as labeled water, these isotopes are not normally found in tap water (H_2O). After the labeled water has been administered to an individual, urine samples are collected to identify metabolized hydrogen for a period lasting up to two weeks. With the estimation of the resting oxygen uptake, the samples are analyzed to identify how long it takes to process and eliminate the isotopes from the body as an estimate of energy expenditure (Conway et al., 2002; Livingstone et al., 1992).

Indirect calorimetry. Indirect calorimetry is a technique used to measure energy expenditure that does not directly measure heat production. Indirect calorimetry estimates the amount of heat generated by the body by measuring the amount of O_2 that the body consumes in response to physical activity. Open circuit spirometry, a commonly used technique for the measurement of oxygen consumption, calculates the volume of oxygen being utilized (VO_2) by subtracting the amount of O_2 being expired from the amount of O_2 being inspired. Highly sensitive metabolic analyzer equipment is used to evaluate the expired gasses and to measure the volume of inspired air (Powers and Howley, 2007).

Heart rate. An individual's heart rate can be used to measure energy expenditure by plugging the value into a mathematical regression equation. The regression equations involve measuring VO_2 for an individual and comparing it to a corresponding heart rate in beats per minute (Shulz, Westerterp, & Brück, 1989; Spurr et al., 1988).

Temperature. Heat is a form of energy, therefore measuring temperature change can provide a proxy measure of a direct measurement of the body energy being released. Humans constantly release heat as the body continuously releases energy at the cellular level. As the body performs work, and the metabolic rate increases, the amount of energy released increases. By measuring the heat released by the body, it is possible to estimate the energy used by the body. This form of measurement is known as direct calorimetry (Powers & Howley, 2007).

Ventilation. Ventilation is simply the act of breathing. Methods such as indirect calorimetry and room calorimetry make use of ventilation to measure energy expenditure (Powers and Howley, 2007; Seale & Rumpler, 1997).

Physical activity assessment methods. ***Physical activity records.*** The purpose of the physical activity record is to provide researchers with a record of the activities that have been performed over a given time. When compared with a measure of the activity energy expenditure or an estimate MET levels, physical activity records can be used to estimate the energy expenditure of a given activity (Conway et al., 2002).

Physical activity logs. The physical activity log is used just as a simplified physical activity record. Participants record the time or type of activities performed in a log book for a given period of time or during specific intervals of time, such as every 30 minutes. Physical activity logs are often used to provide context or an example of the types of activities performed to complement measured energy expenditure of various activities.

Twenty four hour recall. A twenty four hour recall requires the individual to recall all the physical activity the individual has participated in over the past twenty four hours. This recall has individuals describe, often in as much detail as possible, everything that he or she did over the past twenty four hours. Types of activities can include time spent sitting and sleeping, as well as other, more active, activities. Twenty four hour recalls often use MET levels from the Compendium of Physical Activities to estimate energy expenditure over a given amount of time (Ainsworth et al., 2000; Gortmaker et al., 1999).

Questionnaires. Physical activity questionnaires contain a set of questions with a specific underlying goal. Often, questionnaires are used to evaluate a person's average physical activity level, or the individual's physical activity participation over a given period of time, such as one month, or seven days (Conway et al., 2002).

Pedometer. A pedometer is a piece of equipment that can easily be worn by an individual. It is typically worn on the hip and is used to record the number of steps an individual takes in a given amount of time (usually a day). The recorded information can be used to evaluate physical activity either by direct measurement of the number of steps, or by using mathematical equations to more accurately assess the daily physical activity.

Accelerometer. An accelerometer is a device that is worn similar to a pedometer. However, the accelerometer is much more advanced in that it can sense the frequency, intensity and duration of physical activity. The accelerometer is more difficult to read however, as it requires the use of computer based software to retrieve the data from the device. Because of this, accelerometers are more often used by professionals than by the general public.

Heart rate monitor. A heart rate monitor is a device used to monitor and, in some cases, record the heart rate of an individual. There exists a large variety heart rate monitors that range from models built for casual exercisers, to research professionals. The simplest forms of these devices can be worn as wristwatches and are used simply to give an estimate of heart rate during exercise. The more complex models record heart rate more accurately and are commonly used by researchers in a laboratory setting.

Application of Physical Activity Assessment Methods

Bassett et al. (2000) conducted a study to test the validity of four physical activity assessment devices on the measurement of moderate intensity physical activity in 38 men and 43 women between the ages of 19 and 84 years. The devices included a Computer Science and Application (CSA) Inc. model 7164 accelerometer (Shalimar, FL), a Caltrac accelerometer (Muscle Dynamics Fitness Network, Torrance, CA), a Kenz Select 2 accelerometer (Select 2 model, Nagoya, Japan), and a Yamax SW-701 electronic pedometer (Yamasa Corporation, Tokyo, Japan). Participants performed various activities ranging from yard work (mowing the lawn) to conditioning activities (light calisthenics) while wearing the motion sensors and a portable indirect calorimetry system (Cosmed K4b^2, Rome, Italy). Measures were obtained from the four sensors and compared to the results of the indirect calorimetry system. Researchers reported that the data collected from the motion sensors underestimated the energy expenditure for many of the moderate intensity activities, as compared with treadmill walking and running ($p < 0.05$ for all pieces of equipment). It was concluded that the motion sensors were incapable of recording the added energy costs of upper body and arm motions measured with indirect calorimetry.

Hendelman, Miller, Baggett, Debold, and Freedson (2000) used accelerometers and indirect calorimetry to measure various moderate intensity physical activities, including various household and field activities. Twenty-five healthy participants between the ages of 30 and 50 years performed tasks of walking, golf, and various indoor and outdoor household chores to assess the energy cost of each activity. Two accelerometers and one pedometer were worn to assess movement, and a portable indirect calorimetry system was used to measure the energy cost of the movement. The data were compared against the indirect calorimetry and showed that the accuracy of the accelerometers for estimating energy expenditure depended on the type of activity performed. The investigators concluded that accelerometers underestimated energy expenditure of most activities due to their inability to measure movements and energy expenditure of the arms and upper body.

Crouter, Clowers, and Bassett (2006) tested the accuracy of an updated algorithm to estimate energy expenditure data from an ActiGraph accelerometer. They developed a two-regression model that, applied to the counts recorded from the accelerometer to estimate the energy expenditure of physical activity. Participants were 24 men and 24 women, between the ages of 21 and 69 years, with no contraindications to exercise. The participants completed activities listed within three routines. Twenty participants completed each routine while wearing both an ActiGraph accelerometer and a portable indirect calorimetry system for a total of 60 completed trials. Of the 60 completed trials, 45 were selected to be used to develop the new two-regression model, while the other 15 trials were used in an effort to validate the findings. The researchers showed that the new two-regression algorithm was more accurate in predicting energy expenditure when compared to the indirect calorimetry system than the original single regression model developed by Freedson, Melanson, and Sirard (1998). The investigators concluded that the two-regression model attempted to take into consideration energy expenditure from arm and upper body movements that are undetectable by the accelerometer. However, accelerometry was less accurate in predicting the energy cost of physical activity than indirect calorimetry.

Compendium of Physical Activities

Both the 2007 ACSM-AHA recommendations and the 2008 Physical Activity Guidelines recommend that strength training activities be performed throughout the week to enhance health and prevent chronic diseases. To identify the intensity of the strength training activities, many people refer to the Compendium (Ainsworth et al., 2011). The Compendium provides both measured and estimated metabolic equivalent (MET) levels for various resistance training exercises. Because not all resistance training activities have been measured to assess MET levels, estimated MET levels have been applied to some activities. Estimated MET levels are based on similar activities with measured MET levels. It is optimal to have the measured MET level for all activities in the Compendium, including resistance training activities.

The Compendium (Ainsworth et al., 2000) is widely used as a resource to identify the energy cost of physical activities. Originally published in 1993, and revised in 2000 and 2011, the Compendium was designed to assist scientists to easily classify and compare physical activities based on the type of activity and the energy cost of the activity (Ainsworth et al., 1993; Ainsworth et al., 2000; Ainsworth et al., 2011). The Compendium uses a five digit code to classify individual activities. The code organizes activities into larger categories ranging from conditioning and sports to household and occupational activities. The first two digits identify activity categories (e.g. Conditioning - 02, Sports - 15) and the remaining three digits identify specific activities within each category. For example, the conditioning activity weight lifting (power lifting or body building, vigorous effort), is classified as 050 and when combined with the first two digits (Conditioning activity + weight lifting) the five digit code is 02050. Each activity is assigned a MET value that is either a directly measured value of the activity or an estimated value based on measured values of similar activities. Although the Compendium is comprehensive in the inclusion of activities, it is important to continue to update the Compendium by accurately measuring the MET levels of as many activities as possible. The MET intensities of many activities, ranging from household chores to intense sporting events have been measured using indirect calorimetry, however the need exists for accurate measurement of all activities in the Compendium.

The MET levels for many of the resistance training activities in the conditioning section of the Compendium have been measured. However, most activities have been measured in more than one study. Other activities have not been measured before; instead the MET intensities have been estimated values based on the energy cost of similar activities. Thus, direct assessment of the energy cost of resistance training activities is needed. Table 1 presents the resistance training activities listed in the 2000 version of the Compendium of Physical Activities.

Table 1

Resistance training activities listed in the 2000 version of the Compendium of Physical Activities

Measured Activities	Code	METs	Activity
	02026	2.5	Calisthenics, sit-ups, heavy, vigorous effort
	02025	5.3	Calisthenics, push-ups, heavy, vigorous effort
	02050	6.0	Resistance (weight lifting - free weight, nautilus or universal-type), power lifting or body building, vigorous effort
	02040	8.0	Circuit training, including some aerobic movement with minimal rest, general, vigorous intensity
	02035	5.3	Circuit training, including some aerobic movement with minimal rest, general, moderate intensity
	02057	4.0	Resistance training, free weights, circuit training, moderate
	02056	3.5	Resistance training, free weights, circuit training, light
	02054	3.3	Resistance training, 1-3 sets of 8 RM or 1 set of 15 RM, no weight mentioned
	02052	5.0	Resistance (weight) training, squats, slow or explosive effort, 60-80% 1 RM
	02061	5.0	Health club exercise classes/gym/resistance training, general, combined in one visit
Estimated Activities			
	02027	8.0	Calisthenics, pull-ups, heavy, vigorous
New Activities			Lunges
			Modified Pull-Ups

Measurement of Resistance Training Activities

Resistance training exercises have significant health enhancing benefits in adults and are listed as a moderate intensity activity in the 2008 DHHS Physical Activity Guidelines for Americans. Since the energy cost of most, but not all, types of resistance training activities listed in the Compendium have been measured directly, research is needed to confirm the energy cost of resistance training. Table 2 shows an overview of published studies that identify the energy cost of resistance training activities.

Bloomer (2005) examined the energy expenditure of moderate duration resistance and aerobic exercise. Both modalities were matched for the time and intensity required to complete the activities. Ten healthy men with an average age of 24.3 years participated in this study. Inclusion criteria were previous experience with both aerobic and resistance training, training regularly (three to six times per week) for six months prior to beginning the study, an ability to perform a 1RM full range squat with 1.5 times the participant's body weight, and a VO_2 max greater than 40 ml/kg/min when measured on a cycle ergometer. Within two weeks of participating in the tests to assess inclusion criteria, the participants returned to the laboratory to perform a 30 minute continuous cycling protocol at a workload equal to 70% VO_2 max or a 30 minute intermittent squatting protocol at 70% of the participant's 1RM. The order of exercise mode was randomly determined and separated by one to two weeks. Participants completed 5-12 repetitions at a specific weight, followed by a 90-120 second recovery period. Heart rate and expired gasses were monitored continuously throughout each trial. Results showed that the total energy expenditure and VO_2 were higher in the aerobic exercise (M = 32.61 ml/kg/min, SD = 1.67) than in resistance training (*M* = 20.22 ml/kg/min, *SD* = 1.28). The MET intensity of resistance training was about six METs, which is regarded as a moderate-to-vigorous intensity activity. Comparison of the work performed per minute of activity showed higher work rates in the resistance training protocol than in the aerobic protocol (*M* = 20.93 kJ/min, *SD* = 1.14 to *M* = 11.16 kJ/min, *SD* = 1.13). This was found to be significant ($p < 0.0001$). However, the heart rate response was nearly identical in both aerobic training (*M* = 160.12 bpm, *SD* = 4.82) and squat training (*M* = 160.24 bpm, *SD* = 4.16). The researchers concluded that while resistance training did not expend as much energy as aerobic exercise, resistance training was sufficiently intense to be classified as a moderate-to-vigorous intensity activity. If resistance training was performed regularly (at least 4-5 times per week), the researchers concluded it could be used to meet the energy expenditure requirements needed to improve and maintain health and body weight.

Haddock and Wilkin (2006) examined the effects of the volume of resistance training on energy expenditure and post exercise energy consumption. Fifteen healthy females, with an average age of 24.2 years and currently enrolled in a resistance training program were chosen to participate in the study. At baseline, the participants were introduced to the equipment used for assessment of VO_2 and for the resistance training. The participants then completed a trial to estimate their eight repetition max (8RM) on nine different exercises; bench press, leg press, lat pull-down, leg curl, overhead press, knee extension, bicep curl, triceps pull-down, and abdominal crunch. When the participants returned for the first day of testing they underwent one of two possible protocols. The order was randomized and counterbalanced for each participant. After completing one protocol, the second protocol was conducted two days later at the same time of the day. The first protocol was the one-set protocol. The participants performed one set each of the nine exercises at the 8RM that had previously been established. After one exercise was completed, the participants were given a 90 second rest period and then moved to the next exercise. The three-set protocol was exactly the same as the one-set protocol except that following the ninth exercise, the participants immediately began the circuit again for an additional two rounds. Metabolic data (VO_2 and Respiratory Exchange Ratio) were recorded continuously throughout both trials and for 120 minutes following each trial utilizing a portable metabolic cart. Results showed that the energy expended per minute was similar in both the one set (M = 15.5 kJ/min, SD = 0.63) and three set (M = 15.1 kJ/min, SD = 0.84) protocols. The researchers concluded that although there was a pronounced increase in total energy expenditure in the three-set protocol (M = 963.6 kJ, SD = 51.5) when compared to the one-set protocol (M = 333.0 kJ, SD = 15.9), the energy expenditure during the post exercise period was not affected by the duration of the resistance training in either the one set (M = 644.3 kJ, SD = 26.8) or three set (M = 663.2 kJ, SD = 31.4) protocol. Using the equation below, METs can be computed from kJ/min: METs=(kJ/min)*3.5^{-1}*body weight $(kg)^{-1}$*48 (Mackinnon, Ritchie, Hooper & Abernethy, 2003). Accordingly, using the average weight of the participants (M = 63.5 kg, SD = 2.4) the MET levels were 3.35 and 3.26 METs for the one and three-set protocols respectively.

Phillips and Ziuraitis (2003) evaluated the energy cost and intensity of a single set resistance training protocol described by the ACSM Position Stand, *The Recommended Quality and Quantity of Exercise for Developing and*

Maintaining Cardiorespiratory and Muscular Fitness (Pollock et al., 1998), in six men and six women between the ages of 21 and 33 years. Participants were healthy, active and familiar with resistance training and the equipment used in the study, [Cybex (Lumex Inc., Ronkonkoma, NY) and Hi Tech (Hi Tech Professional Strength Systems, Paso Robles, CA) strength training machines]. The trial consisted of three separate sessions. The first session was used to collect resting metabolic data and to familiarize participants with the data collection equipment, a CosMed $K4b^2$ (Rome, Italy) calorimetry system and the resistance training equipment. Session two was used to obtain a 15 rep max (15RM) for each of the eight lifts evaluated in the study. The 15RM was established by having the participant perform 15 repetitions at a light weight, then, following a 2-3 minute rest period, subsequently adding weight until the participant could no longer complete 15 repetitions. This 15RM was established for each of the eight lifts being performed. The third session consisted of the measurement of energy expenditure during the 15RM protocol. Energy expenditure was measured in kcal/min. Men worked at a significantly ($p < 0.008$) higher rate ($M = 5.63$ kcal/min, $SD = 0.7$) than women ($M = 3.41$ kcal/min, $SD = 0.5$). This higher work rate is likely due to men lifting a significantly heavier load than women ($p < 0.0001$). The average work rate for all participants was 4.52 kcal/min ($SD = 1.3$). In terms of METs, the total energy expenditure for the activity was 3.9 METs ($SD = 0.4$) for men and 4.2 METs ($SD = 0.6$) for women. Results showed that the ACSM single set resistance training protocol offers a feasible way to perform moderate intensity physical activity (3-6 METs) as defined by ACSM (2010). However, additional sets and/or repetitions are required to increase the time of the activity in order to elicit the health benefits associated with greater amounts (450 to 750 MET-min/wk) of physical activity as described by Haskell et al. (2007).

Several studies have suggested that the duration of resistance training must be increased from a standard single set to multiple sets in order to elicit health benefits (Bloomer, 2005; Haddock & Wilkin, 2006; Phillips & Ziuraitis, 2003). One way to increase the duration of the resistance training session is to increase the amount of time it takes to complete each repetition of a selected exercise. Mazzetti, Douglas, Yocum, and Harber (2007) investigated the relationship between contraction speed and energy expenditure in resistance training exercises. Nine male participants between 18 and 26 years participated in this study. All participants were healthy and had a minimum of two years experience with resistance training. After undergoing two familiarization sessions to become accustomed to the resistance training procedures and the gas collection equipment and to determine the participant's 1RM, the participants initiated the study trials. The trials consisted of four separate protocols performed on separate days. The order in which the trials were completed was randomized and counterbalanced. The four protocols included a control protocol (an eight minute resting VO_2 measurement), a slow protocol (four sets of eight repetitions at 60% of the recorded 1RM with a four second count for each rep), an explosive protocol (four sets of eight repetitions at 60% of the recorded 1RM with a two second eccentric phase followed by an explosive concentric phase), and a heavy explosive protocol (six sets of four repetitions at 80% of the recorded 1RM with a two second eccentric phase followed by an explosive concentric phase). Each participant was instructed to rest for 20 minutes prior to each trial, and for 60 minutes following completion of each trial in order to collect the expired air and analyze the O_2 and CO_2 content of the expired air. The researchers concluded that energy was expended at a higher rate during the explosive protocol than during slow or heavy explosive protocols. Measurements were broken into the first half of the exercise (sets 1-2 for the explosive and slow protocols and sets 1-3 of the heavy explosive protocol) and the second half (sets 3-4 of the explosive and slow protocols and sets 4-6 of the heavy explosive protocol). Results showed that during the first half of exercise, work rates were at 5.66 kcal/min (*SD* = 1.41) for the slow protocol, 6.34 kcal/min (*SD* = 1.64) for the explosive protocol, and 5.73 kcal/min (*SD* = 1.43) for the heavy explosive protocol. The second half of activity had values of 7.19 kcal/min (*SD* = 1.55) for the slow protocol, 8.21 kcal/min (*SD* = 1.97) for the explosive protocol, and 6.78 kcal/min (*SD* = 1.57) for the heavy explosive protocol. Kcal/min may be converted to METs using the following steps: 1) Dividing kcal/min by 4.9 to obtain L/min (e.g. (5.66 kcal/min)/4.9=1.16 L/min), 2) Converting L/min to ml/kg/min by dividing the L/min value by the body weight in kg (mean body weight for the study was 82.3±16.7 kg) and multiplying by 1000 (e.g. (1.16 L/min)/(82.3 kg)*1000=14.09 ml/kg/min), and 3) Converting ml/kg/min to METs by dividing by 3.5ml/kg/min (e.g. (14.09 ml/kg/min)/(3.5)=4.03 METs (www. utpb.edu).

Circuit resistance training is a popular exercise method to enhance muscular strength and coordination. Developed in the 1970's, circuit training combines longer periods of exercise, with lower weights and shorter rest periods (Wilmore et al., 1978). Beckham and Earnest (2000) studied the effects of circuit resistance training on energy expenditure. Eighteen females and 12 males between the ages of 18 and 45 years participated in the study. Prior to participating in the trial, anthropometric data, including skinfolds, height, and weight were collected, a VO_2 max test was administered (Bruce protocol), and a 1RM was established for each participant. The 1RM was established on both a leg press and lat pull-down machine by progressively adding weight until the participant was unable to complete one full repetition. The participants then completed a 14 minute video workout they would be performing in the intervention. After completing their video workout, the participants returned to the laboratory to complete one of two trials. Each trial was identical except that one trial involved the use of a 1.4 kg bar for both men and women (light resistance protocol) and the other incorporated the use of a 5.9 kg bar for women and a 10.5 kg bar for men (moderate resistance protocol). The order of the trials was randomized and participants were given a 48 hour time period between trials to allow for recovery. The trials consisted of performing a circuit of exercises that were delivered through the video. Exercises included squats, standing rows, modified clean and press, shoulder presses, deadlifts and lateral raises. Caloric expenditure was calculated in kcal/min. The values for women were calculated for the light resistance (M = 3.62 kcal/min, SD = 0.45) and for the moderate resistance (M = 4.04 kcal/min, SD = 0.45) protocols. For the men, the values were 4.99 kcal/min (SD = 0.83) for the light resistance protocol, and 6.21 kcal/min (SD = 1.00) for the moderate resistance protocol. These values translated to MET levels of 3.86 and 4.09 for women and men respectively at moderate resistance, and 3.46 and 3.69 METs for women and men at light resistance. Table 2 shows an overview of published studies identifying the energy cost of resistance training activities.

Table 2

Overview of published studies identifying the energy cost of resistance training activities

Authors	**Participants**	**Ages (years)**	**Protocol**	**METs**
Beckham and Earnest, 2000	30 (12 Males, 18 Females)	18-45	Video-based Resistance Training	3.5 - 4.1
Bloomer, 2005	10 Males	24.3	Resistance and Aerobic Training	6.0 (Resistance), 9.3 (Aerobic)
Haddock and Wilkin, 2006	15 Females	24.2	Resistance Training Volume (1 vs 3 sets)	3.3 (1 set), 3.4 (3 sets)
Phillips and Ziuraitis, 2003	12 (6 Males, 6 Females)	21-33	ACSM Resistance Training Protocol	3.9 (Males), 4.2 (Females)
Mazzetti et al., 2007	9 Males	18-26	Resistance Training (Various Protocols)	4.0 - 5.8

Summary

Physical activity is effective in reducing the risks for many chronic diseases and conditions that result in increased morbidity and mortality and it improves quality of life and mental health (Cornelissen & Fagard, 2005; Donnelly et al., 2009; Healy, 2007; Helmrich, 1991; LaMonte, Blair, & Church, 2005; Nocon et al., 2008; Padilla, Wallace, & Park, 2005; Phillips & Winett, 2010; Warburton, Nicol, & Bredin, 2006). Measuring the energy cost of resistance training is important to quantify the metabolic processes occurring during resistance training, and to know how to better recommend resistance training to individuals to obtain the greatest benefit in health. The Compendium of Physical Activities is a comprehensive list of activities and the associated MET levels used to estimate the energy costs of physical activity. While the Compendium contains many activities with objectively measured MET intensities, not all activities have been measured using indirect calorimetry. In particular, some resistance activities reported in the Compendium have estimated MET intensities and others have been measured only once. Thus, studies are needed to provide measured MET intensities for resistance training activities to replace the estimated MET intensities and to confirm the MET intensities listed in the Compendium of Physical Activities.

Chapter 3

METHODS

Participants

Twelve healthy men between the ages of 18-30 participated in this trial. Inclusion criteria consisted of (a) a minimum of one year of significant resistance training experience, (b) the ablity to demonstrate proper technique in the resistance training exercises selected for this trial (c) nonsmokers, (d) free of symptoms of cardiovascular disease and hypertension, non-diabetic, (e) not currently taking any prescription drugs at the time of the trial, (f) able to speak, comprehend, and read English, and (g) must have less than 25% body fat. The absence of prescription medicine is important to ensure that there are no interactions from the medicine on the measurement of the oxygen cost of exercise. Significant resistance training experience is defined as having performed weight training activities, with proper technique, a minimum of three days a week for the past year. Proper resistance training technique was evaluated using criteria described in the National Strength and Conditioning Association's (NSCA) Exercise Technique Manual for Resistance Training (NSCA, 2008) and evaluated by a Certified Strength and Conditioning Specialist (Jesse Vezina) prior to enrollment in the study. Participants were recruited through posters placed on campus at Arizona State University Polytechnic campus and through word of mouth. Prior to performing any study activities, participants read and signed an informed consent approved by the Arizona State University Office of Research and Integrity.

Study Design and Description of Activities

The purpose of the study was to evaluate the energy cost of four modes of resistance training (push-ups, curl-ups, lunges, and pull-ups) to be presented in the Compendium of Physical Activities. Using a cross-sectional study design, subjects made one visit to the Exercise Physiology Laboratory at Arizona State University Polytechnic Campus to complete the resistance training activities. Eligibility criteria was determined through completion of a self report questionnaire developed for this study about the subject's weight lifting experience and through observation of the participant's ability to successfully complete each of the exercises being performed in the study. Health status was assessed by a modification of the physical activity readiness questionnaire (PAR-Q) to include smoking status and medication use.

During a single study visit, participants performed a series of four resistance training activities in a randomly chosen order using a complete randomized block design. The oxygen uptake and heart rate response to exercise and rest periods between exercises were monitored continuously. Prior to exercise initiation, body weight, height, percent body fat, resting oxygen uptake, and the resting heart rate were measured. Oxygen uptake and heart rate was measured constantly during exercise and was recorded every five seconds. Each exercise was performed for one minute guided by a metronome set at a rate of 40 beats per minute. The participants moved in one direction on one beat and return to the beginning direction on the next beat to allow for a total of 20 repetitions of each exercise per set. If the subject was unable to maintain cadence, he was given one attempt to correct himself. If the participant was unable return to the proper cadence, the exercise was stopped and the rest phase began. Between each exercise participants were given a rest period long enough to allow them to return to a metabolic rate within one ml/kg/min of their resting metabolic rate before beginning the next resistance exercise. Participants performed the same series of exercises three times during a circuit rotation of the four exercises to attempt to simulate a real life resistance training session.

Description of the Resistance Training Activities. ***Push-ups.*** Push-ups were performed by lying on the floor with hand and toes contacting the ground. The participant pressed down through his hands and by extending his arms, raising his body up off the ground while keeping his body in proper alignment. When the participant returned to the floor, he continued to support his weight with his arms (not resting on his chest). The participant lowered himself until he felt light contact between himself and the floor. The participant failed the exercise if he rested on his chest, was unable to raise himself up from the floor, or was unable to maintain cadence and was unable to return to cadence after one attempt.

Curl-ups. Abdominal crunches were performed in accordance to the ACSM protocol (ACSM, 2010). The participant lied on his back with his feet flat on the floor and his hands on the floor by his side. A piece of tape was placed at the tips of the participant's fingers, and another piece of tape was placed six inches from that piece. On cadence the participant raised his shoulders off the floor and slid his fingers to the other piece of tape. The participant failed the exercise if he was unable to reach the second piece of tape on two consecutive repetitions or if he failed to maintain cadence and was unable to return to cadence after one attempt.

Lunges. Lunges were performed by having the participant stand upright and step forward on cadence. The participant stepped forward with one leg, then dropped into a lunge with the front foot flat on the floor and the rear foot up on the toes. The rear knee should lightly contact the ground and the front knee should be positioned over the front toe but not in front of it. The participant alternated legs with this exercise so 10 repetitions were completed with each leg for a total of 20 repetitions. Participants failed the exercise if they were unable to lower themselves so that their back knee contacts the ground for two consecutive repetitions or they were unable to maintain cadence and were unable to return to cadence after one attempt.

Pull-ups. Pull-ups were performed by having the participant stand beneath a bar. The participant reached up and should be able to reach the bar with his arms fully outstretched. The participant was allowed to bend his knees in order to balance himself as he hangs from the bar. The participant pulled himself up toward the bar until his chin was above the bar, then lower himself back down. The participant performed full repetitions until he completed 20, or he failed to complete a repetition or was unable to maintain cadence. The participant failed the exercise if he was unable to raise his chin above the bar for two consecutive repetitions, or if he was unable to maintain cadence and was unable to return to cadence after one attempt.

For all exercises if the participant failed the exercise he immediately began the rest period and the number of repetitions was recorded. If a participant failed to complete an exercise, he was still be allowed to attempt the same exercise in subsequent circuits.

Randomization of the Resistance Training Activities

Participants were assigned an exercise order based on the randomization schedule determined prior to the start of the study. A complete block randomized sampling procedure was applied to subjects based on their order of assessment as presented in Table 3. The four sequences were repeated three times to represent a random assignment of resistance exercise for the 12 subjects in the study.

Table 3

Order of Exercise Sequences

Sequence	Exercise 1	Exercise 2	Exercise 3	Exercise 4
1	Curl-up	Pull-up	Lunge	Push-up
2	Pull-up	Lunge	Push-up	Curl-up
3	Lunge	Push-up	Curl-up	Pull-up
4	Push-up	Curl-up	Pull-up	Lunge

Procedures

The study activities were completed during one laboratory visit lasting about 1.5 hours. The participant arrived at the ISTB3 Laboratory (room 183). Prior to making the study visit, participants were well rested (greater than seven hours of sleep) to ensure that they were physiologically ready to participate in physical activity, fasted for four hours to assure that the results were not confounded by the digestions of various food substances, and free of caffeine to assure that metabolism was not chemically affected at the time of the trial. The study procedures were performed in the following order:

Informed consent and demographic data. Participants provided informed consent and completed the questionnaires designed to record their age and previous resistance training experience. This took about 5 minutes.

Practicing the resistance exercises. Participants practiced each of the exercise techniques for one minute each. After one minute, if the participant still required time to acquire the cadence or technique, he was given an additional minute to practice. The purpose of this was to allow the participant to warm up and prepare for physical activity, as well as to give the participant an opportunity to practice the exercises in cadence with the metronome. This activity took about 10 minutes.

Weight. Body weight in kg was measured using a Detecto metric weighing scale (Webb City, MO). This measurement was taken and recorded twice to assure accuracy. This activity took about 3 minutes.

Body composition. Body composition and percent fat were evaluated using the BodPod (Concord, CA). These measurements were used to assure that the participant had a body fat percentage below 25%.

Height. Body height was measured in centimeters three times with subjects standing in bare feet and back to the height apparatus using a stadiometer (Shorr Board). This took about 5 minutes.

Resting metabolic rate and resting heart rate. Subjects were connected to a portable heart rate monitor (Polar Electro OY Heart Rate Monitor, FS3c, Kempere, Finland) and a portable indirect calorimetry unit (Oxycon Mobile, Jäger, Würzburg, Germany) to assess their resting heart rate and oxygen uptake prior to the start of the resistance training.

Resistance training activities. Each of the four resistance exercises was referred to as a circuit. The participant was randomly assigned one of the four possible sequences. After a four minute rest period to obtain baseline resting metabolic measurements, the participant performed each exercise in order for one minute each in cadence with the metronome. Twenty repetitions were completed per minute. After completion of each exercise the participant began a rest period lasting a minimum of two minutes. The participant continued to rest until he achieved a metabolic rate within 1.0 ml/kg/min of his resting metabolic rate before beginning the next exercise. If the participant was unable to complete the full 20 repetitions, or was unable to maintain proper cadence and was unable to return to cadence after one attempt, the rest period immediately began and the number of completed repetitions was recorded. After completing all four exercises, the participant rested until he achieved a metabolic rate within 1.0 ml/kg/min of his resting metabolic rate, then repeated the circuit for a second time through and third time.

Completion of the exercise testing session. Upon completion of the repeated 3 circuits, subjects had the monitoring equipment removed. Before leaving the laboratory, subjects were advised that they may feel some soreness from performing the exercises and were advised to stretch properly and to refrain from resistance training until they have recovered from the exercise session.

Protection of Subjects from Injury and/or Harm

Subjects were monitored by the lead study investigator, a Certified Strength and Conditioning Specialist, and were evaluated for proper technique before and during the trials, to prevent muscular injury. If the participant was no longer able to complete the exercises in a safe, controlled manner, the trial was stopped. Heart rate and oxygen uptake were monitored constantly throughout the trial and any abnormalities resulted in an immediate cessation of the trial.

Data Management

Collected data was recorded on a form developed for this study and kept in a locked file cabinet. Only the lead investigator and three assistants had access to the files. Backup copies of the data were kept in a secure file on the computer.

Data Analysis

Data were analyzed at Arizona State University by the primary investigator. Descriptive statistics for all study values were averaged using means and standard deviations for continuous data and percentages for nominal and ordinal data. Average oxygen uptake values (in ml/kg/min) were calculated for each of the individual exercises. Oxygen uptake values were converted to METs using the equation (ml/kg/min)/3.5=METs. MET levels of the individual activities obtained in this study were averaged with measured values for the same activities listed in the Compendium. All statistical analysis were evaluated using Microsoft Excel (Microsoft Office Excel 2007; Microsoft, Redmond, Washington, USA).

Chapter 4

RESULTS

The purpose of the study was to determine the energy cost of four individual modes of resistance training (push-ups, curl-ups, pull-ups, and lunges). The study sample was recruited from gyms on and around Arizona State University's Polytechnic campus. Fifteen participants were screened for the study and 13 fit all inclusion and exclusion criteria. Of the two participants who did not fit the criteria one was unable to perform the exercises and the other was too old to participate. Of the 13 individuals who fit all the criteria, all but one participated and completed the trial. The individual who did not participate dropped out because of time constraints. The ethnicity and education level of the remaining 12 participants is presented in Table 4.

Table 4

Ethnicity and Education of Participants

		Years of Collegiate Education					
	n	Year 1	Year 2	Year 3	Year 4	Other - N/A	Other - Graduated
White	8	0	1	3	1	2	1
White/Hispanic	2	0	1	0	1	0	0
White/Asian	1	0	0	1	0	0	0
Black or African American	1	0	0	1	0	0	0

Other demographic data of the study sample, including age and descriptive characteristics is presented in Table 5.

Table 5

Demographics of the Group (N=12)

	MEAN	SD
Age (years)	23.6	2.84
Weight (kg)	74.5	6.94
Height (cm)	174.2	7.27
% Body Fat	12.03	4.44
Years Training	5.7	3.42

Metabolic data were recorded every five seconds for each participant throughout the trial. The average time taken to complete the trial was 72 min (SD=5.9). This average included a five minute baseline period prior to beginning the trial and a four minute recovery period after completing the last exercise. The average resting metabolic rate for all participants was 4.53 ml/kg/min (SD=0.92). After the resting metabolic rate was recorded, participants began the trial. Each exercise was performed three times. The first trial was used as a warm-up/practice round and was not included in the calculation of the mean energy expenditure of each exercise. The mean values for each trial and for the overall mean are presented in Table 6.

Table 6

Mean and Standard Deviation for Oxygen Uptake for Each Exercise (ml/kg/min)

	Trial I*		Trial II		Trial III			
	M	SD	M	SD	M	SD	M (Trials II & III)	SD (Trials II & III)
Push-Ups	10.43	1.93	11.42	2.16	11.73	2.34	11.57	1.99
Curl-Ups	10.12	1.85	10.92	1.42	11.06	1.65	10.99	1.48
Pull-Ups	10.38	3.41	10.89	3.92	10.86	2.07	10.87	2.51
Lunges	13.53	2.45	14.16	1.75	14.21	2.14	14.18	1.78

*Trial I was a practice session and the VO_2 recorded was not used to create the mean VO_2

The mean values of each of the activities were converted to METs in order to compare the data with existing MET levels in the Compendium of Physical Activities (Ainsworth et al., 2011). The MET values of push-ups (3.3 METs), curl-ups (3.1 METs), pull-ups (3.1 METs), and lunges (4.1 METs) were classified as moderate intensity activities as described by the US Physical Activity Guidelines for Americans (US DHHS, 2008).

Additionally, all heart rate (HR) data were recorded every 5 seconds. The mean values for HR are presented in table 7.

Table 7

Mean and Standard Deviation HR Values for Each Exercise in Beats per Minute

	Trial I*		Trial II		Trial III			
	M	SD	M	SD	M	SD	M (Trials II & III)	SD (Trials II & III)
Push-Ups	107.3	18.2	114.0	22.7	120.0	17.2	110.0	31.9
Curl-ups	92.7	13.4	99.9	13.4	100.6	14.9	94.1	26.2
Pull-Ups	120.1	18.4	121.6	22.9	127.4	20.9	117.2	34.1
Lunges	105.6	19.4	111.5	18.9	116.1	16.2	106.9	30.3

*Trial was a practice and the HR recorded was not used to create the mean HR

Chapter 5

DISCUSSION

This study examined the energy expenditure of four individual modes of resistance training: push-ups, pull-ups, curl-ups, and lunges. The outcome of the study demonstrates that each of the four resistance training techniques fall within the category of moderate intensity activity (3-5.9 METs) as defined by the US Physical Activity Guidelines for Americans (US DHHS, 2008). This classification is based on mean values of energy expenditure as recorded every five seconds during the individual exercises. Although higher values were observed for each exercise (lunges most often) that would have been classified as high intensity exercise (≥6.0 METs), these values were typically witnessed toward the later stages of the exercises as the participants neared volitional fatigue. It is unlikely that an individual would perform an exercise for a duration long enough to achieve these values in a typical workout session. It is possible that if an individual were to perform a given exercise for a duration long enough to achieve steady state oxygen uptake values they may have achieved higher MET values, however this is unlikely given that a typical resistance exercise performed in a gym lasts no longer than one minute. This was evidenced by the fact that the average pull-up session lasted only 29.3 seconds. Thus, this group of highly trained men recruited for the study was unable to perform a set of pull-ups for even 30 seconds. Given this fact, it is unlikely that an individual would be able to perform any of these exercises long enough to establish a steady state aerobic response.

Previous studies have examined the energy expenditure of similar activities (Beckham & Earnest, 2000; Jing & Wenyu, 1991). However, resistance training can be performed in countless different ways. Strength training can be performed to develop strength, power, hypertrophy, or endurance, and each different style of training requires different times spent under tension, different intensities, different repetition ranges and different percentages of maximal effort. In order to truly identify the energy expenditure of resistance training, each mode must be tested at various intensities and repetition ranges. Given that some forms of resistance training last as little as 20 seconds (or less) it becomes very difficult to identify the energy expenditure of the individual activities.

The intense effort displayed in weight training over a short period of time is classified as an anaerobic activity. In anaerobic activity the body uses glucose stores within the muscle to produce ATP energy during the short intense bursts of energy rather than oxygen that produces ATP energy in the mitochondria during submaximal activity (Zatsiorsky & Kraemer, 2006). Because weight training exercises uses an anaerobic energy system, measuring the oxygen uptake may not be the most accurate way to assess the energy expenditure of these activities. However, until a reliable method for measuring the energy expenditure of anaerobic activities is developed, the only way to assess energy expenditure is to measure oxygen uptake.

This study has attempted to accurately measure four anaerobic activities (push-ups, pull-ups, curl-ups, and lunges) through the most accurate method possible, indirect calorimetery. Individual activities were measured individually rather than examining the activities as a group, as has been reported in other studies (Beckham & Earnest, 2000; Phillips & Ziuraitis, 2003). Thus, this study provides a significant contribution to the 2011 Compendium of Physical Activities to identify the MET levels for each resistance training activity. In the 2000

Compendium, previous citations for weight training included the exercises measured in this study within the section for conditioning activities and groups them together in a category identified as "calisthenics" (Ainsworth, 2000). The MET value was listed as 8.0 METs, classified as vigorous intensity. The current study found that the oxygen cost of these resistance training activities ranged from 3.11 METs to 4.05 METs, classified as moderate intensity. This MET value is much lower than the estimated MET value for the combined calisthenics activities. The combined calisthenics activities in the 2000 Compendium include jumping jacks along with the resistance training activities. This poses a problem in that jumping jacks are considered as an aerobic activity, quite different from the anaerobic strength training exercises in which they are grouped. This could also explain why the estimated energy expenditure of these activities is so much higher in the 2000 Compendium than observed in this study for weight training activities. Since the energy systems are different between weight training and jumping jacks, individuals performing jumping jacks would easily be able to achieve a steady state VO_2 as this exercise can be done for multiple minutes without fatigue. In addition, the MET values for calisthenics score in the 2000 Compendium were estimated because no studies were located to identify the energy cost of jumping jacks and weight training. In comparison, the weight training MET values in this study were measured in controlled laboratory conditions. Thus, differences in the types of activities presented and the use of measured versus estimated MET values explains the differences in the MET values reported by the Compendium.

It is interesting to note however, that although the reported energy expenditure for aerobic activities such as jumping jacks is higher than values for the resistance training activities measured in this study, people typically are able to perform activities such as jumping jacks for multiple minutes without fatigue. In contrast, not one well trained male was able to complete pull-ups for even one full minute on any of his three attempts. Although the oxygen uptake is undoubtedly higher in the jumping jacks, it would appear that people are working much harder when attempting the pull-ups. This is evidenced by the fact that the participants always experienced volitional fatigue before completing the activity.

Until a more accurate way of evaluating anaerobic energy expenditure is developed, researchers will continue using aerobic measurement methods to record all types of energy expenditure. This will pose a problem when the evaluation of resistance training is the primary outcome. Individuals are trained to control their breathing while performing resistance training activities. Weight lifters are taught to inhale while performing the eccentric portion of the exercise and exhale while performing the concentric portion of the exercise to prevent them from utilizing the Valsalva maneuver. The Valsalva maneuver consists of holding one's breath for concentric portion of a lift in order to generate more internal force. Although this technique is considered dangerous it is used by lifters, sometimes subconsciously, in order to press out an additional repetition. Although all lifters in this study were advised to breathe normally and not to invoke the Valsalva maneuver, some participants felt inclined to perform the maneuver, especially during the pull-up portion of the exercise. Rhythmic breathing proved to be incredibly difficult for all participants. Additionally, all weight lifters in this study had at least one year of experience. When they were told to breathe normally, they often defaulted to their normal lifting breathing pattern which was to inhale for the eccentric phase of the lift and exhale for the concentric phase of the lift. This change in normal breathing patterns could potentially confound the aerobic monitoring equipment.

It could be that a better way to evaluate energy expenditure in resistance training would be to record the post-exercise recovery VO_2. It has been demonstrated that resistance training invokes a larger oxygen debt and will require a longer recovery period than aerobic training even if they are being performed at the same intensity (Burleson, O'Bryant, Stone, Collins, & Triplett-McBride, 1998). It is possible that by measuring the recovery VO_2, higher intensities may have been witnessed in the resistance training activities.

Also of note is the artificial way the resistance exercises were performed in this study as compared with usual resistance training practices. In a gym setting, there will be a continual elevation of oxygen uptake over resting values during the resistance training sessions due to individuals taking minimal rest times between exercises. While we tried to mimic a typical resistance training session, the research study design imposed several constraints. Between exercises the participant sat until they returned to within 1 ml/kg/min of their resting oxygen uptake. During an actual resistance training session, it is unlikely that an individual would wait to return to a resting metabolic rate before performing the next exercise. Instead, their VO_2 would continue to rise as they performed repetitive sets of exercises without resting in between. In the current study, the oxygen uptake values were highest by the end of the exercise and often higher than the average 3 to 4 MET values. Therefore, although the metabolic cost of one set of these exercises has been found to be between 3 and 4 METs, it is likely that the energy expenditure experienced by an individual performing these exercises in a gym would be much greater than a moderate intensity effort.

This study has demonstrated the energy expenditure of four modes of moderate intensity resistance training. As noted earlier, this study was performed under very strict conditions that would most likely not apply to a real life resistance training session. Although this study will contribute to the literature by providing an evidence-based MET value for the Compendium of Physical Activities, additional modes and intensities of resistance training need to be studied in order to fully understand how the energy costs of resistance training. Additionally, it is important for researchers to continue to work to identify better and more accurate ways to evaluate energy expended in anaerobic activities.

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APPENDIX A

HUMAN SUBJECTS PROCEDURES

Recruitment Flier

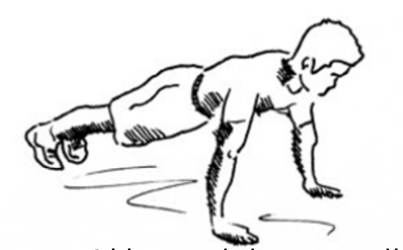
!!!PARTICIPANTS NEEDED!!!

For a research study examining the oxygen cost of resistance training exercises.

You will be required to perform a series of resistance training exercises including push-ups, pull-ups, sit-ups, and lunges.

Requirements:

- Male
- Between the ages of 18-30
- Non-smoker
- No signs of CVD or Diabetes
- Must be able to perform the exercises required for this study



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CONSENT FORM
A Measurement of the Energy Expenditure of
Resistance Training Exercises in Young Men

INTRODUCTION

The purposes of this form are to provide you (as a prospective research study participant) information that may affect your decision as to whether or not to participate in this research and to record the consent of those who agree to be involved in the study.

RESEARCHERS

Dr. Barbara Ainsworth Ph.D., MPH (Professor, ASU) and Jesse Vezina (MS graduate student in Exercise and Wellness) have invited your participation in a research study.

STUDY PURPOSE

The purpose of the research is to determine the amount of energy expended in each of four modes of resistance training (push-ups, pull-ups, curl-ups, and leg lunges). Research has been conducted to determine the energy expenditure of many forms physical activity; however the research is limited in terms of resistance training activities. Given the potential health benefits of resistance training it is important to further understand the amount of energy that is expended when an individual performs these activities.

DESCRIPTION OF RESEARCH STUDY

If you decide to participate, then as a study participant you will join a study involving research of the energy expenditure of resistance training exercises. You will perform each of the four exercises (push-ups, pull-ups, curl-ups, and leg lunges) a total of three times. During the time you perform the exercises, your heart rate and energy expenditure will be monitored constantly. The order of the exercises will be randomized and you will be assigned to one of four possible exercise orders. The energy expenditure and heart rate will be recorded and averaged with other participants in order to calculate the average energy expenditure of each exercise.

If you say YES, then your participation will last for an hour and a half, at ISTB3 lab 183. This building is next door to the Exercise and Wellness building on the ASU Polytechnic campus. About 30 men will participate in this study, and of those, twenty four men will be selected to enroll in this study.

RISKS

As with any physical activity, there is always a risk of injury or soreness to the muscle being used. These risks will be minimal and you will be under constant supervision by a National Strength and Conditioning Association certified trainer in order to minimalize the risk of injury associated with resistance training.

BENEFITS
Although there may be no direct benefits to you, the possible benefits of your participation in the research are that we will be better able to understand how much energy is used during resistance training. The results of this study will be added to the 2011 Compendium of Physical Activities designed to provide the energy cost of many activities performed during the day. This will allow people to know how much energy they use while performing conditioning activities you will perform in this study.

NEW INFORMATION
If the researchers find new information during the study that would reasonably change your decision about participating, then they will provide this information to you.

CONFIDENTIALITY
All information obtained in this study is strictly confidential unless disclosure is required by law. The results of this research study may be used in reports, presentations, and publications, but the researchers will not identify you. In order to maintain confidentiality of your records, Dr. Ainsworth will assign each participant a code (i.e., 1, 2, 3). This number will be used to keep track of all information in the study. Your name will only appear on the consent form and will be kept separate from the other information. All paper information will be kept in a locked file cabinet in Dr. Ainsworth's office. All electronic information will be kept in a secure, password protected computer. Only the primary investigator (Dr. Ainsworth) and the co-investigator (Jesse Vezina) will have access to the information.

WITHDRAWAL PRIVILEGE
It is ok for you to say no. Even if you say yes now, you are free to say no later, and withdraw from the study at any time. Your decision will not affect your relationship with Arizona State University or otherwise cause a loss of benefits to which you might otherwise be entitled. Your participation is voluntary and nonparticipation or withdrawal from the study will not affect your grade or status with ASU.

COSTS AND PAYMENTS
The researchers want your decision about participating in the study to be absolutely voluntary. Yet they recognize that your participation may pose some inconvenience. In order to minimalize your inconvenience, you will invited to schedule an appointment at a time most convenient for you. There is no payment for your participation in this study.

COMPENSATION FOR ILLNESS AND INJURY
If you agree to participate in the study, then your consent does not waive any of your legal rights. However, no funds have been set aside to compensate you in the event of injury.

VOLUNTARY CONSENT

Any questions you have concerning the research study or your participation in the study, before or after your consent, will be answered by Dr. Barbara Ainsworth (EAW, Room 106 7350 E. Unity, ph: (480) 727-1924) or Jesse Vezina (ph: (217) 778-7008).

If you have questions about your rights as a subject/participant in this research, or if you feel you have been placed at risk; you can contact the Chair of the Human Subjects Institutional Review Board, through the ASU Office of Research Integrity and Assurance, at (480) 965-6788.

This form explains the nature, demands, benefits and any risk of the project. By signing this form you agree knowingly to assume any risks involved. Remember, your participation is voluntary. You may choose not to participate or to withdraw your consent and discontinue participation at any time without penalty or loss of benefit. In signing this consent form, you are not waiving any legal claims, rights, or remedies. A copy of this consent form will be given (offered) to you.

Your signature below indicates that you consent to participate in the above study. By signing below, you are granting to the researchers the right to use your likeness, image, appearance and performance - whether recorded on or transferred to videotape, film, slides, and photographs - for presenting or publishing this research.

_____________________________ ________________________ ___________

Subject's Signature Printed Name Date

INVESTIGATOR'S STATEMENT

"I certify that I have explained to the above individual the nature and purpose, the potential

benefits and possible risks associated with participation in this research study, have answered

any questions that have been raised, and have witnessed the above signature. These elements of Informed Consent conform to the Assurance given by Arizona State University to the Office for Human Research Protections to protect the rights of human subjects. I have provided (offered) the subject/participant a copy of this signed consent document."

Signature of Investigator___________________________ Date_____________

Modified PAR-Q

YES	NO	
____	____	1. Has your doctor ever said that you have a heart condition and that you should only do physical activity recommended by a doctor?
____	____	2. Do you feel pain in your chest when you do physical activity?
____	____	3. In the past month, have you had chest pain when you were not doing physical activity?
____	____	4. Do you lose your balance because of dizziness or do you ever lose consciousness?
____	____	5. Do you have a bone or joint problem (for example, back, knee, or hip) that could be made worse by a change in your physical activity?
____	____	6. Is your doctor currently prescribing drugs (for example, water pills) for your blood pressure or heart condition?
____	____	7. Do you know of any other reason why you should not do physical activity?
____	____	8. Are you currently taking any prescription medications?
____	____	9. Are you a smoker?

Demographics Information

1. **What is your age?** ______

2. **Are you Hispanic or Latino?**

____ Yes (1)
____ No (2)

3. **Which one or more of the following would you say is your race?**

____ White (1)
____ Black or African American (2)
____ Asian (3)
____ Native Hawaiian or Other Pacific Islander (4)
_____ American Indian or Alaska Native (5)
____ Other [specify]_______________ (6)

4. **What year are you in college?**

___ Year 1 (1)
___ Year 2 (2)
___ Year 3 (3)
___ Year 4 (4)
___ Other ______________________

5. **How many years how you been weight training?** ______

Institutional Review Board Approval

ASU Knowledge Enterprise Development

Office of Research Integrity and Assurance

To:	Barbara Ainsworth EAW, Room
From:	Carol Johnston, Chair Biosci IRB
Date:	02/08/2011
Committee Action:	**Expedited Approval**
Approval Date:	02/08/2011
Review Type:	Expedited F4 F7
IRB Protocol #:	1102005983
Study Title:	A Measurement of the Energy Expenditure of Resistance Training Exercises in Young Men
Expiration Date:	02/07/2012

The above-referenced protocol was approved following expedited review by the Institutional Review Board.

It is the Principal Investigator's responsibility to obtain review and continued approval before the expiration date. You may not continue any research activity beyond the expiration date without approval by the Institutional Review Board.

Adverse Reactions: If any untoward incidents or severe reactions should develop as a result of this study, you are required to notify the Biosci IRB immediately. If necessary a member of the IRB will be assigned to look into the matter. If the problem is serious, approval may be withdrawn pending IRB review.

Amendments: If you wish to change any aspect of this study, such as the procedures, the consent forms, or the investigators, please communicate your requested changes to the Biosci IRB. The new procedure is not to be initiated until the IRB approval has been given.

Please retain a copy of this letter with your approved protocol.

APPENDIX B

PARTICIPANT DATA

Participant Data Round 1: Oxygen uptake (ml/kg/min)

	Baseline	Push-Ups I	Curl-ups I	Pull-Ups I	Lunges I
Participant 1	3.97	7.98	10.02	9.39	12.02
Participant 2	3.25	7.98	8.60	4.69	8.99
Participant 3	4.17	11.05	11.50	10.41	12.55
Participant 4	4.96	12.63	9.06	16.64	16.08
Participant 5	5.51	8.92	9.62	10.01	13.83
Participant 6	4.43	9.34	9.40	8.07	11.01
Participant 7	4.23	9.55	7.39	16.59	13.34
Participant 8	3.63	11.32	9.58	10.22	16.58
Participant 9	4.58	12.75	9.94	7.30	14.28
Participant 10	4.85	11.33	11.93	10.33	14.65
Participant 11	4.11	8.75	9.81	11.31	11.66
Participant 12	6.72	13.55	14.63	9.60	17.32

Participant Data Round 2: Oxygen uptake (ml/kg/min)

	Push-Ups II	Curl-ups II	Pull-Ups II	Lunges II
Participant 1	9.85	11.08	9.84	13.12
Participant 2	8.28	8.78	6.44	11.82
Participant 3	13.16	9.87	13.23	13.67
Participant 4	15.04	12.84	6.60	17.42
Participant 5	9.37	11.32	9.84	14.55
Participant 6	10.42	9.02	7.51	11.38
Participant 7	9.25	9.27	10.51	12.99
Participant 8	11.53	11.20	11.69	15.45
Participant 9	12.45	11.37	20.70	14.05
Participant 10	13.02	11.38	13.48	15.29
Participant 11	10.38	11.76	12.30	14.03
Participant 12	14.26	13.18	8.50	16.16

*All values presented in ml/kg/min

Participant Data Round 3: Oxygen uptake (ml/kg/min)

	Push-Ups III	Curl-ups III	Pull-Ups III	Lunges III
Participant 1	9.45	11.06	13.20	12.60
Participant 2	7.97	9.38	7.78	13.49
Participant 3	10.27	9.74	13.07	13.62
Participant 4	14.57	11.29	10.25	18.57
Participant 5	14.65	11.95	13.35	10.02
Participant 6	10.45	9.08	8.42	13.24
Participant 7	10.85	9.59	10.37	13.24
Participant 8	12.79	11.52	11.39	16.04
Participant 9	9.72	11.32	9.52	13.82
Participant 10	13.89	10.65	14.43	15.09
Participant 11	11.26	11.92	12.45	14.45
Participant 12	14.88	15.20	9.08	16.28

*All values presented in ml/kg/min