2-14-2014

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by

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THESIS

Submitted in Partial Fulfillment of the Requirements for the Degree of

Master of Science
Physical Education

The University of New Mexico
Albuquerque, New Mexico

December, 2013

Acknowledgements

I wish to express my sincerest appreciation and gratitude to my thesis chairperson, Dr. Len Kravitz. He has been extremely involved in all aspects of this study from the original conception, protocol development, data collection, statistical analyses, and extensive editing of this manuscript. He has provided an immense amount of guidance, support, and motivation throughout its entirety. Under his mentorship, I have greatly improved my research skills and gained a better understanding and appreciation of the research process.

I greatly appreciate my committee members, Dr. Christine Mermier and Dr. Ann Gibson. Thanks to Dr. Mermier for the support and guidance throughout this study. Her vast experience and expertise has been invaluable from the protocol design, subject recruitment, data collection, and writing. Dr. Gibson's brilliant editing of this manuscript has greatly helped me improve my writing and strive to always do better.

Special thanks to Dr. Cari Hushman for your statistical insight in the data analyses. And finally, thanks to Hung-Sheng Hsu for his help in the collection of this data.

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Abstract

Introduction: Treadmill walking is a commonly chosen exercise routine due its accessibility, low cost, and health benefits. For beginning exercisers or those with conditions that limit walking speeds, modifications to walking programs are needed to facilitate cardiorespiratory improvement. **Purpose:** To examine how oxygen consumption (VO_2), relative exercise intensity (%APHRM), and rating of perceived exertion (RPE) are affected while using a weighted vest during slow inclined treadmill walking. **Methods:** Thirteen untrained women (37±11.2 yr, 69.1±14.4 kg, 30.6±7.4 %Body Fat) performed a standardized walking trial (4-min stages at 0, 5, 10, and 15% gradients) on a treadmill at a constant 1.12 m/s under three weighted vest conditions (0, 10, and 15% of body mass (BM)). VO_2 and heart rate were measured continuously throughout each bout. RPE was recorded at the end of each minute. **Results:** Two-way repeated measures ANOVA revealed significant vest versus gradient interactions for VO_2 and %APHRM. Follow-up contrasts showed a nonlinear relationship between weighted vest conditions and gradient for VO_2 and %APHRM. At 0% gradient there was no significant difference in VO_2 or %APHRM between 0%BM (10.2±1.1 ml/kg/min, 54.2±4.3 %APHRM, respectively) and 10%BM (10.6±1.0 ml/kg/min, 55.6±3.8 %APHRM, respectively) conditions. A significant difference was found in VO_2 and %APHRM when a 15%BM (11.4±1.5 ml/kg/min, 57.4±6.7 %APHRM, respectively) vest was used at 0% gradient. At the highest gradient (15%), there was no significant difference in VO_2 or %APHRM between 10%BM (25.7±1.3 ml/kg/min, 86.7±6.5 %APHRM, respectively) or 15%BM (25.9±1.5 ml/kg/min, 87.9±5.7 %APHRM, respectively); however, both were significantly different from 0%BM (23.6±0.8 ml/kg/min, 82.1±6.9 %APHRM, respectively). A significant difference was shown for VO_2 and %APHRM for both weighted vest conditions compared to no vest at 5% and 10% gradients. No significant interaction was found between weighted vest conditions for RPE. **Conclusion**: Using a weighted vest can increase VO_2 and %APHRM during slow graded treadmill walking, with a 5% increase from 10%BM to 15%BM having no significant impact on perceived exertion.

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List of Abbreviations

%APMHR = percentage of age-predicted maximum heart rate (relative exercise intensity)

ANOVA = analysis of variance

ATP = adenosine triphosphate

BF% = body fat percentage

BM = body mass (kg)

cm = centimeter

IPAQ = International Physical Activity Questionnaire

kcal = kilocalorie

kg = kilogram

MET = metabolic equivalent of task

m/s = meters per second

mph = miles per hour

RPE = rating of perceived exertion

SD = standard deviation

VO_2 = volume of oxygen

Chapter 1

Introduction

Treadmill walking programs, either level or up gradients, are a commonly chosen exercise routine for recreational and clinical settings. This is due to the accessibility of walking, low cost, and various health benefits, such as, increases in cardiorespiratory health, and lower-extremity strength gains (2, 26, 27). However, beginning exercisers, or those with conditions that limit walking speeds, may not be able to safely achieve an exercise intensity that would facilitate cardiorespiratory or musculoskeletal improvement. A potential modification to address these issues is the use of a weighted vest, worn around an individual's torso. Weighted vests require little training to use and may be an ideal way to provide the necessary overload to facilitate desired physiological adaptations of higher exercise intensities for slow walkers.

Prior research has shown progressive increases in energy expenditure using weighted vests from 10-20% of body weight with incremental speeds from 0.89 m/s (2.0 mph) up to 1.78 m/s (4.0 mph). To our knowledge, no study has examined energy expenditure with weighted vests while walking up various gradients at slower speeds (26). Furthermore, previous studies examining weighted vest use for exercise have focused on young, healthy populations where significant physiological changes may not have been as pronounced as compared with untrained individuals (26). By examining the effects of a combination of gradients and vest weights while slow walking, we will be able to provide valuable insight into the formation of new weighted vest exercise programs for beginning exercisers or less-fit individuals.

Purpose of the Study

The purpose of this study was a) to examine the metabolic cost of wearing a weighted vest during slow treadmill walking at incremental grades in untrained females and b) to determine the impact of weighted vest walking at increasing gradients on perceived exertion.

Hypotheses

In this study, the following hypotheses will be tested:

Hypothesis 1: There will be an increase in oxygen consumption for both weighted vest conditions (10%BM and 15%BM) with increasing gradients compared to not wearing a weighted vest.

> Rationale: Puthoff et al. (26) have shown that loads up to 10%BM and 15%BM is sufficient to increase oxygen consumption while walking at 1.12 m/s (2.5 mph) without any incline. Furthermore, prior research has shown that walking up gradients (6-9%) at slow walking speeds (<0.75 m/s) has facilitated increases in the metabolic cost in moderately obese adults (4). The combination of these factors has not been tested in prior research in untrained females.

Hypothesis 2: There will be an increase in relative exercise intensity for both weighted vest conditions (10%BM and 15%BM) with increasing gradients compared to not wearing a weighted vest.

Rationale: Prior research (26) has examined relative exercise intensity in relation to the use of weighted vests in combination with varying speeds; however, this has not been examined while slow walking up various gradients. In more fit populations, an increase in relative exercise intensity has been examined (26); however, this has not been examined in untrained females.

Hypothesis 3: There will be an increase in rating of perceived exertion for both weighted vest conditions (10%BM and 15%BM) with grade compared to not wearing a weighted vest.

Rationale: Prior research has shown associations between RPE and heart rate (10), thus if an increase in relative exercise intensity is observed there should be a comparable increase in RPE.

Scope of the Study

Thirteen untrained female subjects, ages eighteen to fifty-five were recruited from the University of New Mexico campus and from the surrounding community. The protocol was approved by the Institutional Review Board of the University of New Mexico and explained to each participant on an individual basis. Participants completed an informed consent, health history questionnaire, and the International Physical Activity Questionnaire (IPAQ) short form prior to testing. To participate in this study, participants needed to score within the “low” category on the IPAQ short form. This category is defined as not participating in 3 or more days of vigorous activity of at least 20 minutes per day or five or more days of moderate intensity activity, and/or walking of at least 30 minutes per day. Additionally, engaging in any combination of walking, moderate intensity or vigorous intensity activities achieving a minimum of at least 600 MET-minutes per week classifies as “low” physical activity. Subjects were excluded based upon known disease or any health related problems that would interfere with their ability to complete the protocol or compromise their health. As the weighted vest is limited to approximately 19 kg, subjects who weighed more than 125 kg were excluded from participation.

The following variables were measured in this study: height (cm), weight (kg), percentage of body fat (BF%), heart rate (HR), rating of perceived exertion (RPE), and estimated maximal oxygen consumption (estVO_{2max}). Additionally, oxygen consumption (VO_2) was measured throughout each trial. The health history questionnaire asked for self-identifiable variables such as age, sex, ethnicity, and physical activity level.

Limitations

This study was subject to the following limitations:

1. IPAQ questionnaire was a self-reported measure of physical activity which should not be equated to a direct measure of physical activity.

2. Although participants were asked not to exercise 24-hours prior to each trial, the amount of physical activity between trials was not quantified.
3. Only women were included in this study.
4. The weighted vest has a maximum load capacity, hence the maximum weight limit of participants being 125 kg.

Assumptions

The following assumptions were made in this study:

1. Participants followed all pre-test guidelines prior to data collection.
2. Participants refrained from exercise 24-hours prior to each trial.
3. Physical activity level was honestly reported in the IPAQ short form.
4. All subjects truthfully reported that they were absent of any disease or medication use that would affect the outcome of testing.
5. All subjects honestly reported RPE throughout the exercise conditions.

Definitions of Terms

The terms of this study have been defined as follows:

Absolute VO_2: the rate of oxygen consumption by the body independent of body weight.

Bioelectrical Impedance Analysis (BIA): a method of determining body fat, fat free body mass, and total body water by measuring the resistance to low level current passed through the body.

Body Composition: the science of determining the absolute and relative contributions of specific components of the body.

Body Mass Index: body weight expressed relative to stature (BMI = weight [kg]/height^2 [m])

Maximal Oxygen Consumption (VO_2max): the maximal rate of oxygen consumption by the body.

Main Effect: the effect of an independent variable on a dependent variable across the levels of any other independent variables.

Metabolic Cost: The amount of energy consumed as a result of performing a given work task.

r: a linear statistical correlation representing a relationship between the dependent and independent variables on a 0.00±1.00 scale.

R: a non-linear statistical calculation representing a relationship between variables on a 0.00±1.00 scale.

Rating of Perceived Exertion (RPE): a subjective rating based on an individual's perception of exercise intensity.

Relative VO_2: the rate of oxygen consumption by the body in relation to body weight.

Respiratory Exchange Ratio (RER): the ratio of carbon dioxide production to oxygen consumption, as measured from expired gas analysis indirect calorimetry.

Standard Error of Estimate: the standard deviation of the errors of estimate from the regression line.

Significance of the Study

There is little research examining the use of weighted vests in relation to walking exercises. Additionally, prior research has focused on young, healthy subjects (26). No prior studies have examined the combination of slow treadmill walking and incremental inclines with the use of weighted vests in untrained women. This study attempted to discover the relationship in oxygen consumption between increasing gradients and the use of weighted vests while slow walking This information may aid in the development of new exercise protocols for populations of lower fitness levels or in individuals with limited walking speeds. The development of new, effective exercise methods to aid in increased caloric expenditure is important to the fields of clinical and applied exercise physiology, as well as personal fitness training.

Chapter 2

Review of Related Literature

This chapter contains the literature review and is divided into the following sections: (a) introduction, (b) the science of calorimetry, (c) the natural walking pace of adults, (d) the effect of load placement on the caloric expenditure of walking, (e) the effect of weighted vest walking on caloric expenditure, (f) the effect of treadmill walking on exercise intensity, (g) walking versus running: impact on caloric expenditure, (h) joint stress with weight bearing and load, and (i) summary.

Introduction

The scientific literature indicates that the cumulative effects of walking may reduce the risk for developing coronary heart disease, help in the treatment of hypertension, improve insulin/glucose metabolism for the prevention or management of type 2 diabetes, and aid in the treatment of some musculoskeletal diseases (11, 14, 21). Walking programs are one of the most common forms of exercise advocated by exercise professionals due to the simplicity of the exercise, low participation cost, and numerous health benefits. While walking programs may have many positive health benefits for a wide range of people, one of the primary aims for many exercise enthusiasts is increasing caloric expenditure (kilocalories per minute) for weight loss goals. However, individuals with above average fitness levels or those suffering from ambulatory physical limitations may not to be able to realize their desired health or weight management goals from traditional walking methods. This review will highlight research on energy expenditure of walking and present several evidence-based ideas for incorporating newer strategies for walking exercise program designs.

The Science of Calorimetry

The science of measuring caloric expenditure is referred to as calorimetry. The word calorimetry comes from the Latin word *calor*, meaning heat, and *metry* from the Greek word *metron* which refers to measurement. This science utilizes the understanding that cellular energy (in the form of ATP from carbohydrates and fats) is about 30% efficient for muscular work, with 70% of the energy degrading to heat. Since this heat production is equivalent to the rate of cellular reactions for work, the direct or indirect measurement of heat proves to be an accurate measurement of energy expenditure.

The science of calorimetry dates back to the 19th century with the use of devices called bomb calorimeters, which are sealed metal chambers surrounded by a container of known volume of water. Heat flow from the combustion of food in the chamber crosses the wall and heats the container of water; the change in water temperature is used to determine the measurement of heat exchange. Thus, bomb calorimeters are a direct measure of calorimetry, as scientists can ignite a food source directly within an oxygen-rich environment to measure the heat released. A kilocalorie is the amount of heat required to raise the temperature of one kilogram of water (approximately 33.8 ounces or one liter) by one degree from 14.5°Celsius (58°Farenheit) to 15.5°Celsius (60°Farenheit).

Thus, food is burned under controlled conditions in the bomb calorimeter, breaking chemical bonds, and releasing free energy and heat. This burning is chemically similar to the metabolic breakdown of food in cellular respiration within the human body.

From the efforts of such early research, scientists quantified the calories derived from fats, carbohydrates, proteins, and alcohol. This method of measurement was later adapted to measure oxygen consumption, carbon dioxide production and heat production in humans, by having an individual sit or exercise in a large, enclosed, insulated chamber. Due to the impractical limitations of using a big chamber to measure energy expenditure, indirect methods were developed to measure kilocalorie expenditure, based on the expired measurements of oxygen, carbon dioxide and ventilation (air moved in and out of the lungs). This is called indirect calorimetry, and it is the widely used technique for measuring energy expenditure of exercise in exercise physiology laboratories.

The Natural Walking Pace of Adults

Most healthy adults (approximately age 30) tend to naturally select a walking pace of approximately 2.8 mph (30). Researchers have hypothesized this preferred walking pace is the result of a minimal energy phenomenon, wherein, the central nervous system selects the person’s preferred walking speed as a way to lessen the body's energy expenditure (19). Willis and colleagues (30) have found that this preferred walking speed might also be due to changes in fuel utilization. In most adults, fat is the primary fuel source at speeds equal to and below 2.8 mph, which serves as a metabolic walking threshold speed. Above this speed, carbohydrate oxidation (breakdown) abruptly increases resulting in an increased perception of effort, due to carbohydrates being a limited fuel source as compared to fat. As a result, preferred walking speed appears to be naturally selected due to the most economical fuel conditions in the muscle, in which fat oxidation is the primary fuel source. A person's natural walking speed is habitually determined by the central nervous system's valuation of the most economical walking gait for optimal fat fuel utilization (30).

With aging and inactivity, there is often a diminished capacity of musculoskeletal functioning of the lower body gait muscles (19). This may necessitate the recruitment of additional motor units and perhaps an additional proportion of less economical fast twitch muscle fibers (which predominantly use carbohydrates as their fuel source) to generate necessary force for walking. Thus, there is a decline in walking speed and a change in gait characteristics in the elderly.

What is Brisk Walking?

The American College of Sports Medicine (ACSM) (25) recommends that most adults accumulate 30-60 minutes per day of moderate intensity exercise on at least five days per week; or vigorous intensity exercise 20-60 minutes per day on at least three days per week (or a combination of both). However, the term “brisk walking” is open to interpretation. A brisk walk for some may be a leisurely walk for others. So how do walking exercisers determine a moderate intensity walk to meet ACSM guidelines? Scientifically, walking at an intensity of 3-6 METs (metabolic equivalent, a physiological measurement expressing the energy cost of physical activity) is considered moderate intensity exercise. Marshall et al. (18) determined that walking at a pace of ≥100 steps per minute has been shown to equate to moderate intensity exercise as recommended by ACSM. At a rate of 100 steps per minute, current recommendations for moderate intensity physical activity would be equivalent to walking at least 3000 steps in 30 minutes at least five days per week. This can easily be tracked with any pedometer or pedometer application (app) on a mobile device. A walker could also accumulate three daily walks of 1000 steps in ten minutes over five days each week.

Murtagh and associates (22) examined 82 recreational walkers at a self-selected brisk walking pace. The average walking speed for the participants was approximately 3.5 mph, with subjects able to accurately meet moderate-intensity exercise levels by self-selecting their pace. Similar goals were also reached in older adults (60-85 years); however, the average self-selected walking pace was just a little slower (3.3-3.5 mph) (24). This indicates the term "brisk" is an accurate term for attaining a moderate-intensity walk, though the actual walking speed may vary depending on age and individual fitness levels.

The Effect of Load Placement on the Caloric Expenditure of Walking

There are a number of methods and combinations of adding weight to the body, such as wearing a backpack, ankle weights, carrying hand weights, or wearing a weighted vest. However, not all methods of adding load have the same effect on energy expenditure. Much of the energy cost of walking is a result of the activation of muscles that act to perform work on the body's center of mass, swinging the legs relative to the center of mass, and supporting body weight (7). Changes in load position can alter the rotational torque functioning around the body's center of mass resulting in differences in muscle activation and metabolic cost (7). Thus, not all forms of a given mass will equate to equal amounts of energy expenditure (29). Exercise professionals need to educate clients that different forms of loaded exercise vary widely in their caloric expenditure requirements from the body. Furthermore, some forms of load distribution are very unsafe for the body. For example, weights placed on the feet (i.e., heavy boots) and ankle weights have been shown to be five to six times less efficient (meaning higher caloric expenditure) than hand weights carried closely to the body while walking (12). However, weights placed on the feet and ankles while walking may lead to metatarsalgia (an overuse injury to the forefoot), serious repetitive stress injuries, or even a stress fracture. In addition, carrying a weight (up to 18% body weight) in one hand is more energy demanding than carrying the same total weight distributed between two hands. However, this asymmetrical loading is a very complex behavior in terms of balance (29), and thus is not a safe option during sustained walking (perhaps acceptable for short

≤1-minute spurts of walking in a circuit or metabolic training class) for most exercise enthusiasts.

The 'Free-Ride' Walking Phenomenon

The "free-ride" walking phenomenon was coined in the mid-1980s by researchers who were fascinated by the large loads African women could carry on their heads; this style of load carrying is known as headloading. Researchers found that African women experienced in headloading could carry up to 20% of their body mass without expending any more energy than they used when walking in an unloaded state (17). This gave rise to the "free-ride hypothesis", which posited that a load up to a certain weight could be carried on the head without any extra energy expenditure. It has been speculated that "some element of training and/or anatomical change since childhood may allow these women to carry heavy loads economically" (17). A more recent study comparing less-experienced African women headloaders to women without any headloading experience challenges this "free-ride hypothesis" (16). This phenomenon requires further study.

Abe and colleagues (1) observed a similar energy-saving effect in subjects carrying a backpack at a load equal to 15% of body mass during slow walking (<1.5 m/s). However, this effect ceases with walking speeds above 1.5 m/s (approximately 3.35 mph). This energy-saving effect is also observed when loads are carried in the hands (6.5 to 13.5 lbs in each hand) during slower walking speeds. Abe and colleagues summarize the total energy cost to the body from the hand and arm muscles holding weight during slow walking are negligibly small. Additionally, and perhaps more importantly (from a safety standpoint), it becomes problematic with traditional types of dumbbells (or kettlebells) to even grip or hold the weights for a sustained period of time (such as 30-minute walk). Thus this is not a worthy option for exercise professionals to recommend to clients.

The Effect of Weighted Vest Walking on Caloric Expenditure

Weighted vests are a type of exercise equipment that is gaining attention from exercise professionals and fitness enthusiasts. Weighted vests can be used in many different types of workouts and most vests are adjustable to add more or less weight as needed (typically 5% to 20% of a person’s body weight). Additionally, weighted vests are worn on the torso making them a more natural addition to an exerciser's center of gravity.

A study conducted by Puthoff and associates (26) examined walking energy expenditure with incremental treadmill speeds ranging from 2.0 mph to 4.0 mph and vest weights ranging from 10% to 20% of body mass. They found that energy expenditure increases as vest weight and walking speed increase; however, the relationship between vest weight and walking speed was not entirely linear. As walking speed increases, the effect of wearing a weighted vest has a more pronounced impact on energy expenditure. These findings have many practical implications in the design of walking programs. For instance, walking at slow speeds (0.89-1.12 m/s) may require use of a heavier vest to achieve the aspired increases in energy expenditure, while walking at faster speeds (1.56-1.79 m/s) will see a more pronounced increase in energy expenditure with less weight needed to facilitate the increase. Additionally, weighted vest walking may be beneficial for those persons with an inability to walk briskly, adding just 10% of body mass at a slower walking speed (0.89 m/s) may produce a similar relative exercise intensity of a faster walking speed without added mass (26). Thus, weighted vest walking and exercise is a viable training strategy to increase exercise intensity for all fitness levels and is a strategic approach exercise professionals can incorporate with clients.

The Effect of Treadmill Walking on Exercise Intensity

Increasing grades while walking on a treadmill is a common way to increase the intensity of walking exercises, especially in those individuals unable to reach faster walking speeds or in obese populations where injuries associated with excess joint loading is of concern. Ehlen and colleagues (4) found that obese individuals were able to achieve an adequate exercise stimulus for weight management with speeds as low as 0.76 m/s (1.7 mph) with the addition of inclines between 6-9%. Additionally, slower walking speeds at a moderate incline (< 9%) reduced the load placed on the lower extremity joints in comparison to faster walking speeds (1.5 m/s) with no incline. Incline walking may also be appropriate for older populations or those suffering from joint problems. Currently, no standardized recommendations are available for the use of incline during walking bouts. Therefore, exercise professionals are encouraged to individualize the incline to the fitness level and perceived effort of each client.

Walking vs. Running: Impact on Caloric Expenditure

A fundamental principle of physics is that movement of a specific mass over a given distance requires the same amount of energy. In theory, to walk or run a given distance should require the same amount of energy regardless of speed (8). While this principle is sometimes observed in quadripeds running a mile compared to leisurely walking the same distance (13), humans tend to expend a greater amount of energy when running (~30% higher depending on intensity) than when walking the same distance (8). More research is needed to better clarify this comparison.

Joint Stress with Weight Bearing and Load

When engaging in any weight bearing activity involving repetitive joint movement, stress on those joints is always of concern, whether exercising with or without additional load. Articular cartilage (found in knee joints) is a lubricated surface that absorbs and transfers load to allow joint movement without friction. Moderate joint loading (30 minutes of 60% of one repetition maximum) has been shown to actually benefit articular cartilage by decreasing markers of inflammation (5). However, excessive exercise, such as seen in ultra-endurance runners, can lead to deterioration of articular cartilage similar to that seen in osteoarthritis patients (9). Therefore, exercise professionals should be aware that moderate joint loading (as in walking) can be beneficial, but extreme overuse can lead to detrimental joint harm.

Summary

With proper modifications, walking programs can be tailored to meet the needs of all fitness levels with the added benefit of less joint stress in comparison to high impact exercises. There are many ways to alter walking programs to meet the target intensity of exercisers of all fitness levels. These may include walking at different speeds, wearing weighted vests while walking, adjusting the grade while on a treadmill, and adapting existing interval training programs to walking. Exercise professionals are encouraged to incorporate and combine any of these modifications to meet the needs and goals of their clients.

Chapter 3

Methodology

This chapter is divided into the following sections: a) setting, b) participants, c) procedures, d) research design, and e) statistical analysis.

Setting

All testing sessions were completed at the University of New Mexico's Exercise Physiology Laboratory, in Johnson Center.

Participants

Thirteen untrained female subjects, ages eighteen to fifty-five, were recruited from the University of New Mexico campus and surrounding community to participate in this study. The protocol was approved by the Institutional Review Board of the University of New Mexico and explained to each subject individually. Participants were given the informed consent (Appendix A), and completed a health history questionnaire (Appendix B) and the International Physical Activity Questionnaire (IPAQ) (Appendix C) short form prior to testing. Subjects were excluded based upon known acute illness, history of cardiovascular, metabolic or pulmonary disease, or any injuries that would interfere with their ability to complete the protocol or compromise their health. Additionally, subjects were excluded if they weighed over 125 kg. Only subjects scoring in the "low active" category were chosen for this study. Participants were verbally informed of the procedures and possible discomforts and risks of the study prior to beginning the exercise trials.

Procedures

Sampling

Subjects were recruited using a convenience sampling technique. Volunteers were screened for potential participation in this study based on inclusion/exclusion criteria obtained from the health history questionnaire and IPAQ. Participants were recruited by word of mouth, flyers, and email list-serves around the University of New Mexico campus and surrounding areas.

Prior to each visit to the University of New Mexico Exercise Physiology Lab, subjects were asked to limit caffeine and food consumption four hours prior to testing, and to refrain from exercise 24 hours before testing. Additionally, subjects were asked to wear comfortable exercise clothes for each trial. Upon arrival for the first trial, subjects were presented with the approved consent form and informed of the testing procedures. After the participants understood the procedures to be followed, the informed consent was signed, and the participants completed the health history questionnaire and IPAQ short form to screen for factors that could eliminate them from participation.

Height (cm) was measured via a stadiometer mid-inspiration while barefoot and body mass (BM) (kg) was measured clothed while barefoot. Next, body fat percentage (BF%) was estimated via bioelectrical impedance analysis (BIA) while in a standing position with the device held at chest level. BF% and height were only measured on the first visit. BW was measured prior to each exercise trial to account for weight fluctuations.

Submaximal Exercise Test

A six-minute walk test (3) was administered with no weighted vest to determine the subject's estimated VO_{2max}. This test was also performed prior to each exercise trial to serve as a warm-up. The speed chosen from the first 6-minute walk test was used for each warm-up. The subjects walked on a treadmill for two minutes with 0% incline at an exercise intensity equal to 50-70% of the subject's age-predicted maximal heart rate (220-age), as determined by the use of a heart rate monitor. Following the first two minutes of walking, the treadmill's incline was increased to 5% for a period of four minutes, with heart rate and speed recorded at the end of the test. This has been shown to be a reliable method of estimating VO_{2max} in the subject sample tested (older females) (20).

Exercise Trials

Following the 6-minute walk test, subjects rested for ten minutes or until their HR returned to pre-exercise levels. Each subject was randomly assigned to one of three exercise conditions: 1) no vest (0%BM), 2) wearing a vest weighing 10% of the subject's body weight (10%BM), or 3) wearing a vest weighing 15% of the subject's body weight (15%BM). For each trial, subjects walked at a constant 1.12 m/s (2.5 mph) with incremental gradient increases (0%, 5%, 10%, and 15%) for four minutes each (16 minutes total walking time). Following the first eight minutes (inclines 0% and 5%), subjects rested for ten minutes or until a pre-exercise heart rate was achieved. Subjects were given an opportunity to rest for the same amount of time between the 10% and 15% incline stages. Oxygen consumption (VO_2) and heart rate (HR) were measured throughout each exercise trial. The rating of perceived exertion (RPE) was measured using the Borg RPE scale (6-20) every minute throughout each exercise trial. A minimum of 48 hours separated each exercise trial to limit physiological changes between trials. No more than ten days elapsed between each session.

Equipment

Body fat percentage was measured using bioelectrical impedance analysis (model # HBF-306C, Omron, Lake Forest, IL). All six-minute walking tests and exercise trials were conducted on a treadmill (model # C9661, Precore, Woodinville, WA). The Hyperwear Pro weighted vest (Austin, TX) was used for loaded walking conditions. VO_2 was measured via a metabolic cart (TrueOne 2400, Parvo Medics, Sandy, UT) and HR was measured using a heart rate monitor (model # A3, Polar, Lake Success, NY) with the transmitter strap worn around the chest.

Research Design

The following measures were assessed to insure the internal validity of the study:

1. Participants were given instructions prior to reporting to the testing site for each exercise session. These instructions included: no exercise 24 hours prior to each testing session, no caffeine, and no eating four hours prior to each session.

2. All subjects were asked to refrain from holding onto the treadmill during each exercise trial.
3. Each subject was scheduled with a minimum of 48 hours between each trial to ensure adequate recovery time. Additionally, trials were scheduled no more than ten days apart to limit physiological fluctuations.

Statistical Analysis

Statistical Procedures

A two-way repeated-measure ANOVA was performed using the Statistical Package of the Social Science (SPSS, version 21.0, Chicago, IL) to test for the interaction of grade and weighted vest conditions and main effects. When a significant F value was observed, post hoc comparisons were performed to identify the mean differences. The alpha level for significance was set at $P < 0.05$.

Chapter 4

Results

The results of this study are presented in the following sections: (a) data screening and statistical assumption tests, (b) descriptive characteristics of the participants, (c) metabolic measurements, and (d) rating of perceived exertion (RPE).

Data Screening and Statistical Assumptions Tests

Initially, data were inspected for missing values using the Explore feature in SPSS. None were found. Next, descriptive data were inspected for minimum and maximum values. No outliers were identified for any dependent variable. The Shapiro-Wilk's test was used to test for normality of the data distribution. All weighted vest by grade values were found to be normally distributed ($P > 0.05$).

Since analysis of variance designs with repeated measures (within-subject factors) are susceptible to the violation of the assumption of sphericity, this was tested using Mauchly's test of sphericity. The interaction analysis between VO_2 and relative intensity violated Mauchly's test of sphericity ($P < 0.05$). The may be because sphericity is often violated with repeated measures designs of small sample sizes, such as the present investigation. Therefore, the Greenhouse-Geisser correction was employed for these analyses.

Descriptive Characteristics of the Subjects

The physical characteristics of the participants (N=13) are presented in Table 1. Only untrained women were recruited to participate in this study. All participants completed this study without complication; therefore, the data from all participants were included in the statistical analyses.

The participants ranged in age from 21 to 55 yr (37.5±11.2 yr) with an average height and weight of 163.2±5.2 cm and 69.1±14.4 kg, respectively. The average BF% of the participant's was 30.6±7.4%, with an average BMI of 26.0±5.6. The Ebelling Treadmill Test estimated an average VO_{2max} of 34.6±3.2 ml/kg/min.

Table 1. Mean (SD) demographic data for 13 untrained women

Age (yr)	37.0±11.2
Weight (kg)	69.1±14.4
Height (cm)	163.2±5.2
BMI	26.0± 5.6
BF (%)	30.6±7.4
estVO_{2max} (ml/kg/min)	34.8±3.2

Metabolic Measurements

The interaction effect of weighted vest and gradient condition in regards to oxygen consumption (VO_2) are presented in Figure 1. A significant interaction between vest condition and gradient {$F(6,72)=4.27$, $P < 0.05$} was found. A significant interaction between weighted vest and gradient condition was also found in relative exercise intensity (%APMHR) {$F(6,72)=2.42$, $P < 0.05$} and kilocalories {$F(6,72)=5.38$, $P < 0.05$} (Figures 2 and 3, respectively). Due to these significant interactions, the simple effects of weighted vest condition at each gradient were examined (Table 2). Simple effects analysis found greater increases in VO_2, caloric expenditure, and %APMHR as gradient increased; however, no difference in metabolic costs were noted at 0% gradient while wearing 10%BM (Figures 1-3). Additionally, no significant difference was found between 10%BM and 15%BM at the highest gradient (15%).

Table 2. Simple effects of vest weight at each treadmill gradient.

	Oxygen Consumption (ml/kg/min)	**Caloric Expenditure (kcal/min)**	**Relative Exercise Intensity (%APMHR)**
0% Gradient			
0%BM	10.2 (1.1)	3.4 (0.7)	54.2 (4.3)
10%BM	10.6 (1.0)	3.5 (0.8)	55.6 (3.8)
15%BM	11.4 (1.5)*†	3.8 (1.0)*†	57.4 (6.7)*†
5% Gradient			
0%BM	13.9 (1.0)	4.6 (0.9)	61.2 (5.7)
10%BM	14.9 (0.9)*	5.0 (1.1)*	64.0 (5.4)*
15%BM	15.4 (1.6)*†	5.2 (1.3)*†	66.0 (7.3)*†
10% Gradient			
0%BM	19.0 (0.6)	6.4 (1.3)	69.9 (6.3)
10%BM	20.5 (0.7)*	7.0 (1.5)*	73.9 (6.8)*
15%BM	21.2 (0.8)*†	7.3 (1.7)*†	77.0 (7.8)*†
15% Gradient			
0%BM	23.6 (0.8)	8.2 (1.8)	82.1 (6.9)
10%BM	25.7 (1.3)*	8.9 (2.0)*	86.7 (6.5)*
15%BM	25.9 (1.5)*	9.1 (2.0)*	87.9 (5.7)*

Values are mean (SD). BM, body mass; % APMHR, percentage of age-predicted maximal heart rate; kcal/min, caloric expenditure.
* Significantly different from 0%BM; † significantly different from 10%BM.
$P < 0.05$.

One of the interests we had for this study was to also examine the overall effects of each weighted vest condition on metabolic costs and perceived exertion. The main effect results of each weighted vest condition are shown in

Table 3. A significant main effect was found for VO_2 {F(2,24)=34.70, P <0.05}, caloric expenditure {F(2,24)=28.35, P <0.05}, and %APMHR {F(2,24)=13.94, P <0.05}.

Table 3. Comparison of vest weight main effects for metabolic data and perceived exertion.

	Oxygen Consumption (ml/kg/min)	**Caloric Expenditure (kcal/min)**	**Relative Exercise Intensity (%APMHR)**	**Rating of Perceived Exertion (RPE)**
0% BM	16.7 (5.2)	5.7 (2.2)	12.0 (1.7)	10.8 (3.0)
10% BM	17.9 (5.8)*	6.1 (2.5)*	13.0 (1.8)*	12.5 (2.9)*
15% BM	18.5 (5.7)*†	6.3 (2.5)*†	13.4 (1.9)*†	13.0 (2.8)*

Values are mean (SD). BM, body mass; % APMHR, percentage of age-predicted maximal heart rate; kcal/min, caloric expenditure; RPE, rating of perceived exertion.
* Significantly different from 0%BM; † significantly different from 10%BM.
P < 0.05.

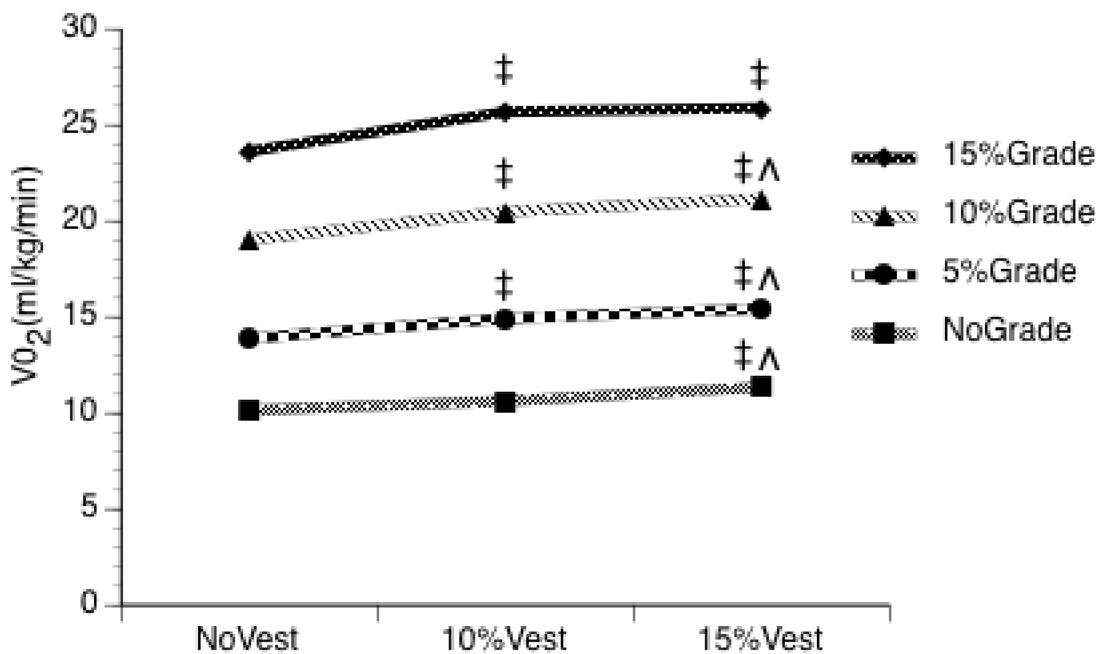

Figure 1- Average oxygen consumption at each weighted vest condition.
‡ Significantly different from 0%BM; Λ significantly different from 10%BM. P < 0.05.

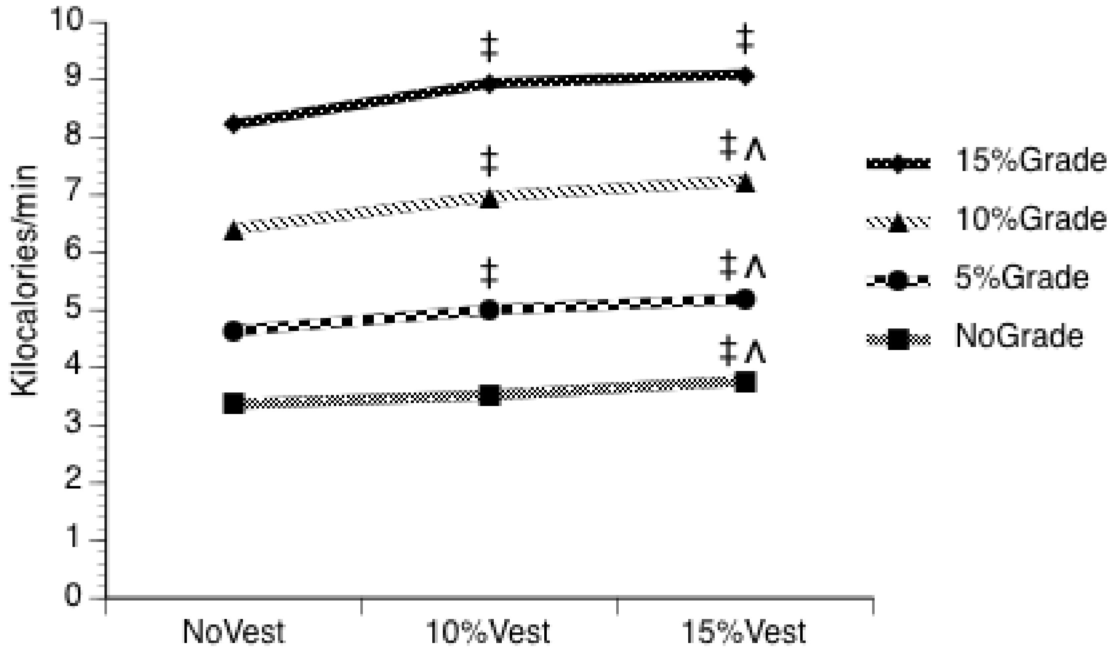

Figure 2- Average energy expenditure at each weighted vest condition.
‡ Significantly different from 0%BM; Λ significantly different from 10%BM. P < 0.05.

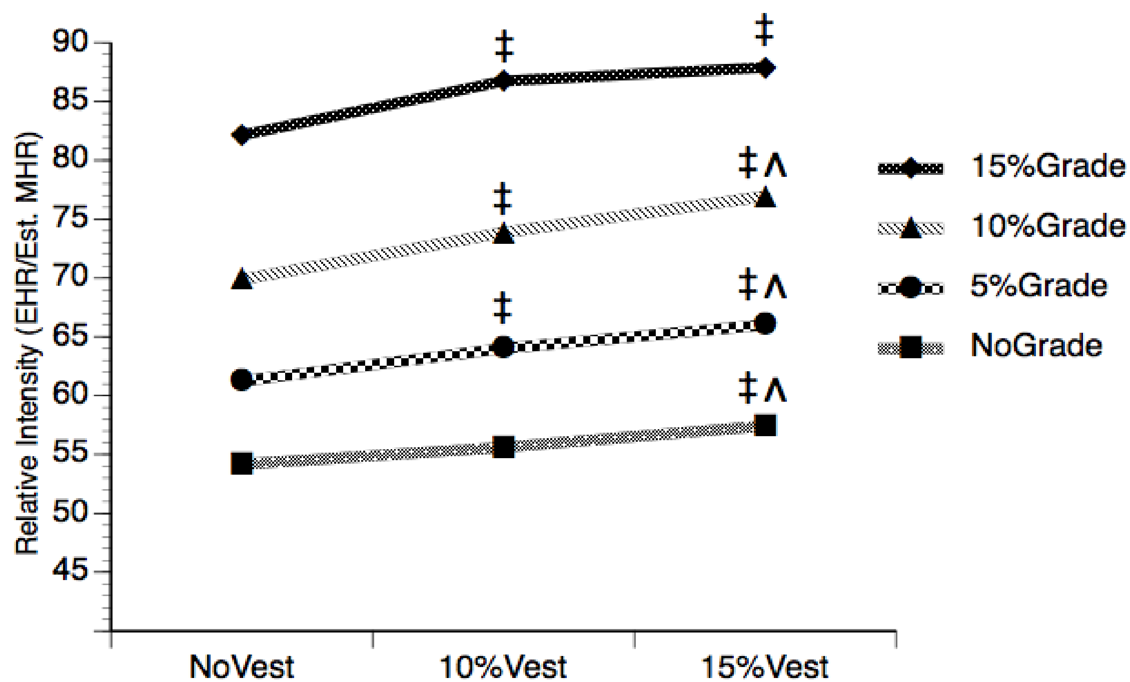

Figure 3- Average relative exercise intensity (%APMHR) for each weighted vest condition.
‡ Significantly different from 0%BM; Λ significantly different from 10%BM. P < 0.05.

Rating of Perceived Exertion

No significant interaction was found for RPE; however, as RPE was a variable of interest in this study, the main effect of RPE was analyzed (F=14.59, P < 0.05) (see Figure 4). Despite no significant interaction in RPE, main effects analysis indicates a significant difference was found between 10%BM and 15%BM compared to no weighted vest. However, no significant differences were found in the 5%BM increase from 10%BM to 15%BM in RPE.

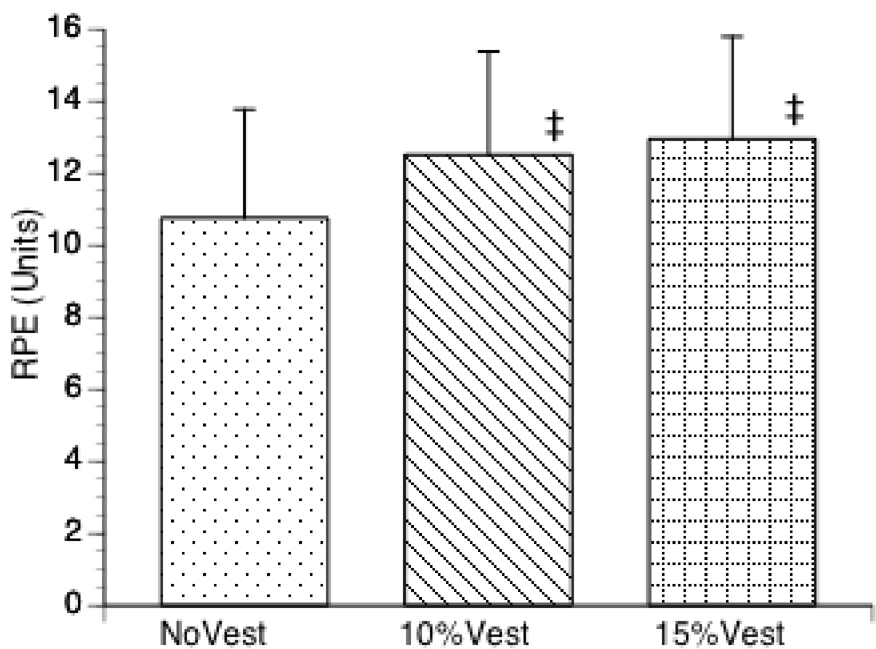

Figure 4- Rating of Perceived Exertion (RPE) for each weighted vest condition.
‡ Significantly different from 0%BM. P < 0.05.

Chapter 5

Discussion

The discussion of the results is presented in the following sections: (a) metabolic cost, (b) relative exercise intensity, (c) gradient, (d) perceived exertion, and (e) conclusions.

Metabolic Cost

The results of this study support the hypothesis that using a weighted vest increases oxygen consumption (VO_2) during graded slow walking (1.12 m/s). Several points can be made through examination of the metabolic data. First, the changes in VO_2 are not entirely linear as weighted vest and gradient increases. As gradient increases, the effect of vest mass has a greater effect on metabolic cost; however, a significant increase in metabolic cost was not seen until the vest weight reached 15% body mass (BM) with no gradient. This may have been due to a "free-ride" phenomenon, as observed by Abe et al. (1), which has been described as speed dependent. Our present data supports this phenomenon, as this "free-ride" effect diminished following the addition of any gradient. Furthermore, an increase in vest weight from 10%BM to 15%BM had no additional effect on metabolic cost at the highest gradient (15%). This may be due to biomechanical differences associated with graded walking (6).

These interactions between weighted vest condition and gradient have implications on the selection of vest mass during a walking program. For women that walk at a slow pace without gradient, a higher vest mass is required to facilitate cardiorespiratory health benefits associated with moderate intensity exercise (>3 METs) (25). However, as gradient increases a lower vest mass is needed to elicit increases in metabolic cost, with the difference in VO_2 from 10%BM and 15%BM being diminished at the highest gradient (15%).

Relative Exercise Intensity

Our study found similar results in relation to relative exercise intensity (%APHRM), supporting the hypothesis that a weighted vest can increase relative exercise intensity when used with a combination of gradients. While these findings demonstrate an increase in %APHRM with the use of a weighted vest, a non-linear association between vest mass and gradient was observed. A significant increase was not seen in %APMHR without gradient, until a vest weight of 15%BM was used. Furthermore, no significant difference was found between vest weights at the highest gradient (15%).

Interestingly, Puthoff et al. (22) found that the influence of weighted vest on VO_2 is more important than that of relative exercise intensity. Contrariwise, these findings were not observed in the present study in relation to weighted vest and gradient on VO_2 and relative exercise intensity. Puthoff et al. suggested the difference in %APMHR and VO_2 with increasing speed was observed due to the use of young, healthy subjects. The present study did not observe a similar difference in our untrained subject sample. It is difficult to determine if the discrepancy between results is due to the difference in subject samples or the impact of gradient. It is likely that our untrained subjects would elicit greater changes in %APMHR than those observed in a young, healthy population due to fitness level, as %APMHR has been shown to be highly fitness dependent (23).

Gradient

Based on the results shown in Table 2, the effect of gradient appears to have a greater influence on metabolic cost than that of vest weights up to 15%BM. Under no condition did either weighted vest condition equate to the next gradient interval. However, this may be indicative of the larger gradient increments used (5% increments) in the present study or the maximum vest weight examined being 15%BM; however, it is questionable if our untrained sample could safely tolerate walking at 15% incline with a weighted vest above 15%BM. Puthoff et al. (26) have shown a similar interaction when examining walking velocity and weighted vest use below 15%BM. Vests weights of 15-20%BM elicited exercise intensities equivalent to higher walking speeds in a non-weighted condition. While the relationship of walking speed was not examined in the present study, Ehlen et al. (4) have found that slow walking speeds, even at modest inclines (6%) result in exercise intensities that equate to or exceed faster walking speeds. Our findings illustrate the significant impact of gradient on exercise intensity in less-fit individuals, as the incorporation of just 5% gradient resulted in a greater impact on metabolic cost (4.6 kcal/min) than did 15%BM with no gradient (3.8 kcal/min). These findings suggest that while weighted vests up to 15% BM may not facilitate exercise intensities (57.4 %APMHR) proportional to 5% gradient increases (61.2 %APMHR), weighted vest use may be a viable supplement to increase metabolic parameters at a given gradient increment to expend more calories. Lower extremity joint loading was not measured in the present study. Ehlen et al. (4) found decreased lower extremity joint loading while slow walking up gradients up to 9% in obese individuals. Future research should examine this aspect of graded walking with weighted vests, as there exists a strong positive relationship between level walking speed and lower extremity joint loading (15).

Perceived Exertion

Interestingly, perceived exertion followed a different trend than that of VO_2 and %APMHR. Borg's RPE scale is a widely used psychometric tool to assess a subjective perception of effort that is strongly correlated with heart rate changes (28). Despite the significant interactions observed in VO_2 and %APMHR, no significant interaction was seen for RPE in weighted vest with gradient in the present study. However, examination of the main effects identified a significant difference between both weighted vest conditions when compared to no vest. This has practical implications for those who may not be able to walk at higher velocities, but are seeking ways to achieve higher exercise intensities. Additionally, as opposed to faster walking, slow walking reduces the perceived exertion of exercise, potentially resulting in increased activity time and exercise adherence (10). The use of a weighted vest up to 15%BM may be a viable supplement to an uphill walking program to maximize caloric expenditure while having minimal impact on perceived exertion.

Conclusions

Several conclusions can be drawn from this study. First, the interaction between weighted vests and gradient does not produce a linear relationship with metabolic cost. Second, the use of a weighted vest with incrementally increasing gradients produces a similar relationship between VO_2 and %APMHR in less-fit females. Lastly, a 5% increase in BM from 10 to 15% does not equate to a higher perception of exertion. This has practical implications on the selection of a walking protocol for less-fit exercisers and fitness professionals working with this population. While it has been shown that slow walking up gradients has less of an impact on joint stress than fast walking (4), future research is needed to examine the impact of weighted vest use in combination with gradient on joint stress.

Appendices

APPENDIX A

The University of New Mexico

Consent to Participate in Research

The metabolic cost of slow graded treadmill walking with a weighted vest in untrained females

HRPO-13-070

04/15/2013

Purpose and General Information

You are being asked to participate in a research study that is being done by Dr. Len Kravitz, who is the Principal Investigator, and his associates. This research is being done to evaluate the amount of calories that are burned with slow walking while wearing weighted vests at various grades on a treadmill. Treadmill walking programs, either level or inclined, are a commonly chosen exercise routine. These programs are generally accessible to the public and have various health benefits, such as, increases in heart and lung health and improvements in strength in the legs. However, beginning exercisers or those with conditions that limit walking speeds may not be able to safely achieve an exercise intensity that would cause these benefits. A potential way to address this is to use a weighted vest to provide an increased exercise intensity for slower walkers. Prior research has examined the use of weighted vests in physically fit populations; however, no studies have examined the use of weighted vests in less fit populations using various treadmill grades and slow walking speeds. You are being asked to participate because you are a woman who does not regularly exercise and does not have any chronic medical conditions. Approximately 13 people will take part in this study at the University of New Mexico.

This form will explain the study to you, including the possible risks as well as the possible benefits of participating. This is so you can make an informed choice about whether or not to participate in this study. Please read this Consent Form carefully. Ask the investigators or study staff to explain any words or information that you do not clearly understand.

What will happen if I participate?

If you agree to be in this study, you will be asked to read and sign this Consent Form. After you sign the Consent Form, the following things will happen:

Overview and First Visit

1. You will be asked to visit the Exercise Physiology Lab in Johnson Center on the University of New Mexico main campus three times over a 1-3 week timeframe.

2. Each visit will be separated by at least 48 hours with no more than 10 days between visits.

3. Prior to each visit, you will be asked to not exercise 24 hours before testing and to not consume food or caffeine 4 hours before testing.

4. The first visit will take approximately 1-2 hours, while the second and third visits will take approximately 1 hour each.

5. During your first visit, you will fill out paperwork including a HIPAA form, health history questionnaire, the International Physical Activity Questionnaire (IPAQ), and consent form. Your resting heart rate, height and weight will be measured, and body fat will be estimated via bioelectrical impedance analysis (BIA). This measurement is done using a hand-held device that uses a very small electrical current between two electrodes to measure resistance. The resistance is converted to % body fat with an equation based on your sex, age, height, and weight.

6. A submaximal 6 minute walking test (Ebbeling treadmill test) will be performed with no weighted vest to estimate your maximal oxygen consumption (VO2max). This test requires you to walk for 6 minutes at a constant intensity of approximately 50-70% of your maximal heart rate (prediction based on your age) at a 5% incline on a treadmill.

7. Following the 6 minute walking test, you will rest for 10 minutes or however long it takes for your heart rate to return to resting values.

8. You will randomly be assigned to either of three conditions: 1) wearing a weighted vest weighing 10% of your body weight, 2) wearing a vest weighing 15% of your body weight, or 3) wearing no vest.

9. You will wear a heart rate monitor (strap around chest) and a mouth piece and noseclip setup that is connected to a gas analyzer to measure your exhaled oxygen and carbon dioxide throughout each trial. Rating of perceived exertion (how hard you feel you are working) on a scale of 6-20 will be recorded at the end of each exercise stage.

10. You will walk on a treadmill at a constant speed of 2.5 mph with incremental inclines (0%, 5%, 10%, and 15%) for 4 minutes each.

11. Following 4 minutes of walking at 0% incline and 4 minutes at 5% incline (8 minutes total walking), the mouthpiece and noseclip will be removed and you will rest for 10 minutes.

12. The same process will be repeated for 10% incline and 15% incline. (Total walking time for all stages is 16 minutes).

13. Your next visit will be scheduled before leaving and each trial must be no less than 48 hours apart.

Second Visit

1. Your weight will be measured upon arrival and you will perform a 6 minute warm-up upon arrival at the same intensity as the Ebbeling 6 minute walk test performed during the first visit.

2. Your will rest for 10 minutes or however long it takes for your heart rate to return to resting values and follow the same procedure as the first visit for one of the remaining vest conditions.

Third Visit

1. Same as second visit but with final vest condition.

Participation in this study will take a total of 3-4 hours over a period of 1-3 weeks.

What are the possible risks or discomforts of being in this study?

Every effort will be made to protect the information you give us. However, there is a small risk of loss of privacy and/or confidentiality that may result in stigmatization, hardship or inconvenience. There are small risks associated with submaximal exercise testing including the following: brief feelings of nausea, lightheadedness, muscle cramps, or dizziness.

There are risks of stress, emotional distress, inconvenience and possible loss of privacy and confidentiality associated with participating in a research study.

For more information about risks and side effects, ask the investigator.

How will my information be kept confidential?

Your name and other identifying information will be maintained in locked files, available only to authorized members of the research team, for the duration of the study. For any information entered into a computer, the only identifier will be a unique study identification (ID) number. Any personal identifying information and any record linking that information to study ID numbers will be destroyed when the study is completed. Information resulting from this study will be used for research purposes and may be published; however, you will not be identified by name in any publications.

Information from your participation in this study may be reviewed by federal and state regulatory agencies, and by the UNM Institutional Review Board (IRB) which provides regulatory and ethical oversight of human research. There may be times when we are required by law to share your information. However, your name will not be used in any published reports about this study.

What are the benefits to being in this study?

There may or may not be direct benefit to you from being in this study. However, your participation may help find out more about your body in terms of body fat percentage, your estimated cardiorespiratory fitness level, and how your body responds to a new form of exercise.

What other choices do I have if I don't participate?

Taking part in this study is voluntary so you can choose not to participate.

Will I be paid for taking part in this study?

You will be compensated $25 within 90 days via check following the completion of all trials in this study. You will not be compensated if you drop out prior to completing all of the trials in this study.

What will happen if I am injured or become sick because I took part in this study?

If you are injured or become sick as a result of this study, UNMHSC will provide you with emergency treatment, at your cost.

No commitment is made by the University of New Mexico Health Sciences Center (UNMHSC) to provide free medical care or money for injuries to participants in this study.

In the event that you have an injury or illness that is caused by your participation in this study, reimbursement for all related costs of care will be sought from your insurer, managed care plan, or other benefits program. If you do not have insurance, you may be responsible for these costs. You will also be responsible for any associated co-payments or deductibles required by your insurance.

It is important for you to tell the investigator immediately if you have been injured or become sick because of taking part in this study. If you have any questions about these issues, or believe that you have been treated carelessly in the study, please contact the Institutional Review Board (IRB) at (505) 272-1129 for more information.

How will I know if you learn something new that may change my mind about participating?

You will be informed of any significant new findings that become available during the course of the study, such as changes in the risks or benefits resulting from participating in the research or new alternatives to participation that might change your mind about participating.

Can I stop being in the study once I begin?

Yes. You can withdraw from this study at any time without affecting your access to future health care or other services to which you are entitled. .

The investigators have the right to end your participation in this study if they determine that you no longer qualify to take part, if you do not follow study procedures, or if it is in your best interest or the study's best interest to stop your participation.

HIPAA Authorization for Use and Disclosure of Your Protected Health Information (HIPAA)

As part of this study, we will be collecting health information about you and sharing it with others. This information is "protected" because it is identifiable or "linked" to you.

Protected Health Information (PHI)

By signing this Consent Document, you are allowing the investigators and other authorized personnel to use your protected health information for the purposes of this study. This information may include: personal health information, and testing results.

In addition to researchers and staff at UNM and other groups listed in this form, there is a chance that your health information may be shared (re-disclosed) outside of the research study and no longer be protected by federal privacy laws. Examples of this include disclosures for law enforcement, judicial proceeding, health oversight activities and public health measures.

Right to Withdraw Your Authorization

Your authorization for the use and disclosure of your health information for this study shall not expire unless you cancel this authorization. Your health information will be used or disclosed as long as it is needed for this study. However, you may withdraw your authorization at any time provided you notify the UNM investigators in writing. To do this, please send letter notifying them of your withdrawal to:

Len Kravitz

MSC 04 2610

1 University of New Mexico

Albuquerque New Mexico 87131

Please be aware that the research team will not be required to destroy or retrieve any of your health information that has already been used or shared before your withdrawal is received.

Refusal to Sign

If you choose not to sign this consent form and authorization for the use and disclosure of your PHI, you will not be allowed to take part in the research study.

What if I have questions or complaints about this study?

If you have any questions, concerns or complaints at any time about the research study, Len Kravitz, Ph.D. , or his associates will be glad to answer them at (505) 277-2658 Monday-Friday 8 am- 5 pm. If you need to contact someone after business houros or on weekends, please call (505)-350-8370 and ask for Jeremy McCormick. If you would like to speak with someone other than the research team, you may call the UNM IRB office at (505) 272-1129. The IRB is a group of people from UNM and the community who provide independent oversight of safety and ethical issues related to research involving human participants.

What are my rights as a research participant?

If you have questions regarding your rights as a research participant, you may call the Human Research Protections Office (HRPO) at (505) 272-1129 or visit the HRPO website at http://hsc.unm.edu/som/research/hrrc/.

Consent and Authorization

You are making a decision whether to participate in this study. Your signature below indicates that you read the information provided (or the information was read to you). By signing this Consent Form, you are not waiving any of your legal rights as a research participant.

I have had an opportunity to ask questions and all questions have been answered to my satisfaction. By signing this Consent Form, I agree to participate in this study and give permission for my health information to be used or disclosed as described in this Consent Form. A copy of this Consent Form will be provided to me.

______________________________ ________________________ ______/__________

Name of Adult Participant (print) Signature of Adult Participant Date

I have explained the research to the participant and answered all of his/her questions. I believe that he/she understands the information in this consent form and freely consents to participate.

______________________________ ________________________ ______/__________

Name of Research Team Member   Signature of Research Team Member   Date

Child Assent

You are making a decision whether to participate (or to have your child participate) in this study. Your signature below indicates that you read the information provided (or the information was read to you).

______________________________   ________________________   ______/___________

Name of Child Participant   Signature of Child Participant   Date

______________________________   ________________________   ______/___________

Name of Parent/Child's Legal Guardian   Signature of Parent/Legal Guardian   Date

APPENDIX B

HEALTH HISTORY QUESTIONNAIRE (RESEARCH ONLY 5/20/02)

Subject #______________________________ Date___/___/___

*Phone #: home*_________________________ *cell*_______________

Date of Birth ___/___/___ Age____ Gender____ Ethnicity_______ Phone (W)__________________

Address (home)____zip___________

email______________________________________

Primary health care provider and health insurance____

(Only for information/emergency contact)

Person to contact in case of emergency: **name**______________________________**phone** #_____________

♦♦

MEDICAL HISTORY

Self-reported: Height______ Weight______

Physical injuries:____

Limitations____

Have you ever had any of the following cardiovascular problems? Please check all that apply.

Heart attack/Myocardial Infarction____ Heart surgery ____ Valve problems ______

Chest pain or pressure ____ Swollen ankles ____ Dizziness ______

Arrhythmias/Palpitations ____ Heart murmur ____

Shortness of breath ______ Congestive heart failure ____

Have you ever had any of the following? Please check all that apply.

Hepatitis/HIV ______ Depression ______ Cancer (specify type) _______

Rheumatic fever ______ High blood pressure______ Thyroid problems ______

Kidney/liver disease _____Obesity_____ Total cholesterol >200 mg/dl_____
Diabetes (specify type) _____Asthma_____ HDL cholesterol <35 mg/dl_____
Emphysema _____Stroke_____ LDL cholesterol >135 mg/dl _____
Trygylcerides>150 mg/dl _____

Do immediate blood relatives (biological parents & siblings **only**) have any of the conditions listed above? If yes, list the problem, and family member age at diagnosis.
____

Is your mother living? Y N Age at death______ Cause____________________

Is your father living? Y N Age at death______ Cause____________________

Do you currently have any condition not listed that may influence test results? Y N

Details____

____

Indicate level of your overall health. Excellent ____ Good ____ Fair ____ Poor_____

Are you taking any medications, vitamins or dietary supplements now? Y N

If yes, what are they?____

Do you have allergies to any medications? If yes, what are they?

____

Are you allergic to latex? Y N

Have you been seen by a health care provider in the past year? Y N

If yes, elaborate

____

Have you had a prior treadmill test? Y N. If yes, when?______________ What were the results?

____

Have you ever experienced any adverse effects during or after exercise (fainting, vomiting, shock, palpitations, hyperventilation)? Y N If yes, elaborate.____

____

♦♦

LIFESTYLE FACTORS

Do you now or have you ever used tobacco? Y N If yes: type ________________

How long?______ Quantity____/day Years since quitting______________

How often do you drink the following?

Caffeinated coffee, tea, or soda _______oz/day Hard liquor _______oz/wk
Wine_________oz/week

Beer _______oz/wk

Indicate your current level of emotional stress. High____ Moderate ____ Low____

♦♦♦

PHYSICAL ACTIVITY/EXERCISE

Physical Activity

Minutes/Day (*Weekdays*) Minutes/Day (*Weekends*)

______/______ average ______/_____ average

Do you train in any activity (eg. jogging, cycling, swimming, weight-lifting)? Y N

How well trained are you?

Vigorous Exercise (>30 Minute sessions)

_________Minutes/hours a week

♦♦

WOMEN ONLY

Please check the response that most closely describes your menstrual status:

_____ Post-menopausal (surgical or absence of normal menstrual periods for 12 months)

_____ Eumenorrheic – Normal menstrual periods (~every 28 days)

_____ Amenorrheic – Absence of normal menstrual periods for at least 3 months

_____ Oligomenorrheic – Irregular menstrual periods with occasional missed cycles.

This subject meets the medical screening criteria to participate in this study? Y N

____
Name of Investigator/ Research Team Member (print)

____ __________________

(Signature of Investigator/ Research Team Member) Date

____
Name of Principal Investigator (print)

____ __________________

(Signature of Principal Investigator) Date

APPENDIX C

INTERNATIONAL PHYSICAL ACTIVITY QUESTIONNAIRE

We are interested in finding out about the kinds of physical activities that people do as part of their everyday lives. The questions will ask you about the time you spent being physically active in the **last 7 days**. Please answer each question even if you do not consider yourself to be an active person. Please think about the activities you do at work, as part of your house and yard work, to get from place to place, and in your spare time for recreation, exercise or sport.

Think about all the **vigorous** activities that you did in the **last 7 days**. **Vigorous** physical activities refer to activities that take hard physical effort and make you breathe much harder than normal. Think *only* about those physical activities that you did for at least 10 minutes at a time.

1. During the **last 7 days**, on how many days did you do **vigorous** physical activities like heavy lifting, digging, aerobics, or fast bicycling?

   _____ **days per week**

   ☐ No vigorous physical activities → ***Skip to question 3***

2. How much time did you usually spend doing **vigorous** physical activities on one of those days?

   _____ **hours per day**

   _____ **minutes per day**

   ☐ Don't know/Not sure

Think about all the **moderate** activities that you did in the **last 7 days**. **Moderate** activities refer to activities that take moderate physical effort and make you breathe somewhat harder than normal. Think only about those physical activities that you did for at least 10 minutes at a time.

3. During the **last 7 days**, on how many days did you do **moderate** physical activities like carrying light loads, bicycling at a regular pace, or doubles tennis? Do not include walking.

_____ **days per week**

☐ No moderate physical activities → ***Skip to question 5***

4. How much time did you usually spend doing **moderate** physical activities on one of those days?

_____ **hours per day**

_____ **minutes per day**

☐ Don't know/Not sure

Think about the time you spent **walking** in the **last 7 days**. This includes at work and at home, walking to travel from place to place, and any other walking that you might do solely for recreation, sport, exercise, or leisure.

5. During the **last 7 days**, on how many days did you **walk** for at least 10 minutes at a time?

_____ **days per week**

☐ No walking ➡ ***Skip to question 7***

6. How much time did you usually spend **walking** on one of those days?

_____ **hours per day**

_____ **minutes per day**

☐ Don't know/Not sure

The last question is about the time you spent **sitting** on weekdays during the **last 7 days**. Include time spent at work, at home, while doing course work and during leisure time. This may include time spent sitting at a desk, visiting friends, reading, or sitting or lying down to watch television.

7. During the **last 7 days**, how much time did you spend **sitting** on a **week day**?

_____ **hours per day**

_____ **minutes per day**

☐ Don't know/Not sure

APPENDIX D

Data Collection Sheet

The metabolic cost of slow graded treadmill walking with a weighted vest in untrained females

Subject Number: Study Number:________________________________

Age:___________________ Date:____________________

Ht (cm):________________ Resting Heart Rate:________________

Wt (kg): _______________ BIA Body Fat %: _______________________

Trial#_____________________

Test (Circle one): No Vest, Vest 10%, Vest 15%

Ebbeling Treadmill Test

Heart Rate @ 6 minutes:______________________

Speed @ 6 minutes:__________________________

Time	**Speed (mph) / Incline (%)**	**HR (bpm)**	**RPE**	**Comments**
Rest	0			
1 min	2.5/0%			
2 min	2.5/0%			
3 min	2.5/0%			
4 min	2.5/0%			
5 min	2.5/5%			
6 min	2.5/5%			
7 min	2.5/5%			
8 min	2.5/5%			
Rest (10 min or to baseline)				
9 min	2.5/10%			
10 min	2.5/10%			
11 min	2.5/10%			

12 min	2.5/10%			
13 min	2.5/15%			
14 min	2.5/15%			
15 min	2.5/15%			
16 min	2.5/15%			

General Test Comments

Technitian
Initials:___________________________

References

1. Abe D, Yanagawa K, Niihata S. Effects of load carriage, load position, and walking speed on energy cost of walking. *Appl Ergon*. 2004;35(4):329-35.

2. Chien MY, Wu YT, Hsu AT, Yang RS, Lai JS. Efficacy of a 24-week aerobic exercise program for osteopenic postmenopausal women. *Calcif Tissue Int*. 2000;67(6):443-8.

3. Ebbeling CB, Ward A, Puleo EM, Widrick J, Rippe JM. Development of a single-stage submaximal treadmill walking test. *Med Sci Sports Exerc*. 1991;23(8):966-73.

4. Ehlen KA, Reiser RF, 2nd, Browning RC. Energetics and biomechanics of inclined treadmill walking in obese adults. *Med Sci Sports Exerc*. 2011;43(7):1251-9.

5. Franciozi CE, Tarini VA, Reginato RD et al. Gradual strenuous running regimen predisposes to osteoarthritis due to cartilage cell death and altered levels of glycosaminoglycans. *Osteoarthritis Cartilage*. 2013.

6. Gordon MJ, Goslin BR, Graham T, Hoare J. Comparison between load carriage and grade walking on a treadmill. *Ergonomics*. 1983;26(3):289-98.

7. Griffin TM, Roberts TJ, Kram R. Metabolic cost of generating muscular force in human walking: insights from load-carrying and speed experiments. *J Appl Physiol*. 2003;95(1):172-83.

8. Hall C, Figueroa A, Fernhall B, Kanaley JA. Energy expenditure of walking and running: comparison with prediction equations. *Med Sci Sports Exerc*. 2004;36(12):2128-34.

9. Helmark IC, Petersen MC, Christensen HE, Kjaer M, Langberg H. Moderate loading of the human osteoarthritic knee joint leads to lowering of intraarticular cartilage oligomeric matrix protein. *Rheumatol Int*. 2012;32(4):1009-14.

10. Hills AP, Byrne NM, Wearing S, Armstrong T. Validation of the intensity of walking for pleasure in obese adults. *Prev Med*. 2006;42(1):47-50.

11. Hu FB, Sigal RJ, Rich-Edwards JW et al. Walking compared with vigorous physical activity and risk of type 2 diabetes in women: a prospective study. *JAMA*. 1999;282(15):1433-9.

12. Knapik JJ, Reynolds KL, Harman E. Soldier load carriage: historical, physiological, biomechanical, and medical aspects. *Mil Med*. 2004;169(1):45-56.

13. Kram R, Taylor CR. Energetics of running: a new perspective. *Nature*. 1990;346(6281):265-7.

14. Lee IM, Rexrode KM, Cook NR, Manson JE, Buring JE. Physical activity and coronary heart disease in women: is "no pain, no gain" passe? *JAMA*. 2001;285(11):1447-54.

15. Lelas JL, Merriman GJ, Riley PO, Kerrigan DC. Predicting peak kinematic and kinetic parameters from gait speed. *Gait Posture*. 2003;17(2):106-12.

16. Lloyd R, Parr B, Davies S, Partridge T, Cooke C. A comparison of the physiological consequences of head-loading and back-loading for African and European women. *Eur J Appl Physiol*. 2010;109(4):607-16.

17. Maloiy GM, Heglund NC, Prager LM, Cavagna GA, Taylor CR. Energetic cost of carrying loads: have African women discovered an economic way? *Nature*. 1986;319(6055):668-9.

18. Marshall SJ, Levy SS, Tudor-Locke CE et al. Translating physical activity recommendations into a pedometer-based step goal: 3000 steps in 30 minutes. *Am J Prev Med*. 2009;36(5):410-5.

19. Martin PE, Rothstein DE, Larish DD. Effects of age and physical activity status on the speed-aerobic demand relationship of walking. *J Appl Physiol*. 1992;73(1):200-6.

20. Mitros M, Gabriel KP, Ainsworth B et al. Comprehensive evaluation of a single-stage submaximal treadmill walking protocol in healthy, middle-aged women. *Eur J Appl Physiol*. 2011;111(1):47-56.

21. Morris JN, Hardman AE. Walking to health. *Sports Med*. 1997;23(5):306-32.

22. Murtagh EM, Boreham CA, Murphy MH. Speed and exercise intensity of recreational walkers. *Prev Med*. 2002;35(4):397-400.

23. Ozemek C, Cochran HL, Strath SJ, Byun W, Kaminsky LA. Estimating relative intensity using individualized accelerometer cutpoints: the importance of fitness level. *BMC Med Res Methodol*. 2013;13:53.

24. Parise C, Sternfeld B, Samuels S, Tager IB. Brisk walking speed in older adults who walk for exercise. *J Am Geriatr Soc*. 2004;52(3):411-6.

25. Pescatello LS, American College of Sports Medicine. *ACSM's guidelines for exercise testing and prescription*. 9th ed. Philadelphia: Wolters Kluwer/Lippincott Williams & Wilkins Health; 2014, xxiv, 456 p. p.

26. Puthoff ML, Darter BJ, Nielsen DH, Yack HJ. The effect of weighted vest walking on metabolic responses and ground reaction forces. *Med Sci Sports Exerc*. 2006;38(4):746-52.

27. Rooks DS, Kiel DP, Parsons C, Hayes WC. Self-paced resistance training and walking exercise in community-dwelling older adults: effects on neuromotor performance. *J Gerontol A Biol Sci Med Sci*. 1997;52(3):M161-8.

28. Scherr J, Wolfarth B, Christle JW, Pressler A, Wagenpfeil S, Halle M. Associations between Borg's rating of perceived exertion and physiological measures of exercise intensity. *Eur J Appl Physiol*. 2013;113(1):147-55.

29. Watson JC, Payne RC, Chamberlain AT, Jones RK, Sellers WI. The energetic costs of load-carrying and the evolution of bipedalism. *J Hum Evol*. 2008;54(5):675-83.

30. Willis WT, Ganley KJ, Herman RM. Fuel oxidation during human walking. *Metabolism*. 2005;54(6):793-9.