The Metabolic Cost of Slow Graded Treadmill Walking With a Weighted Vest in Untrained Females

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Abstract

Introduction: Treadmill walking programs are a commonly chosen exercise routine due to the accessibility of walking, low cost, and various health benefits. For beginning exercisers or those with conditions that may limit walking speeds, modifications to walking programs may be needed to facilitate cardiorespiratory or musculoskeletal improvement. **Purpose:** The purpose of this study was to examine how oxygen consumption, relative exercise intensity, and rating of perceived exertion are affected while using a weighted vest during slow inclined treadmill walking. **Methods:** A sample of 13 (37±11.15 yr) women performed a standardized walking test (4-min stages at 0, 5, 10, and 15% gradients) on a treadmill at a constant 1.12 m/s (2.5 mph) under three weighted vest conditions (0, 10, and 15% of body mass (BM)) . **Results:** Two-way repeated measures ANOVA revealed significant vest versus gradient interaction for VO_2 and relative exercise intensity. Follow-up contrasts showed a non-linear relationship between weighted vest conditions and gradient for VO_2 and relative exercise intensity. The effects of the weighted vest conditions were more prominent with increasing gradient when compared to no gradient. No significant interaction was found between weighted vest conditions for rating of perceived exertion despite a significant main effect RPE difference between both weighted vest conditions compared to no vest. **Conclusion**: Using a weighted vest can increase the metabolic costs and relative exercise intensity of slow graded treadmill walking. A 5% increase from 10%BM to 15%BM can increase metabolic costs and relative exercise intensity with no significant increase in perceived exertion.

Summary Overview of This Research and Applied Workouts From Study

1. 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.
2. 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.
3. Another modification to address limitations in walking speed is the use of various grades with and without a weighted vest.

4. From our research, no other study has examined the energy expenditure and metabolic effects of wearing weighted vests while slow walking up various gradients at slower speeds. Slow walking at 2.5 mph was completed in all trials of this study.

Key Result Applications:

1. When walking at 0% grade, there is no significant difference in metabolic costs of wearing no vest and wearing a 10%BM (i.e., 10% of person's body mass) weighted vest (Figures 1-3). While walking at 2.5 mph (0% grade) an untrained female would have to wear a weighted vest of about 15%BM for a significant change in caloric expenditure. This would elicit a 12% increase in kilocalorie expenditure.

2. When walking at a 5% and 10% grade, the energy expenditure is significantly higher when wearing a 10%BM weighted vest as compared to wearing no vest. An untrained female will expend 13% more calories when wearing a 10%BM to 15%BM weighted vest. A 10%BM weighted vest (walking at 5% and/or 10% grade) is recommended since the data shows no significant difference in kilocalorie expenditure between wearing a 10%BM and 15%BM weighted vests.

3. When walking at a 15% grade, the energy cost of 10%BM and 15%BM is significantly greater (11% higher caloric expenditure) than wearing no vest. However, since there is no significant difference in walking at 15% with a 10%BM and 15%BM vest, a 10%BM vest is recommended.

4. No significant interaction between weighted vest and grade was observed in RPE (Figure 4). However, the main effects (0% grade, 5% grade, 10% grade and 15% grade combined) of weighted vest showed that there is a significant difference in subjective assessment from wearing no vest and wearing the 10%BM and 15%BM vests. Interestingly, subjects did not detect a significant RPE difference between wearing a 10% or 15% vest (at any grade).

5. As can be seen in Table 2, when slow walking (2.5 mph) on a treadmill (with or without a weighted vest) the gradient has the greatest effect on caloric expenditure. Regardless of vest weight (0%BM, 10%BM, or 15%BM), walking up a grade meaningfully increases energy expenditure. The average (0%BM, 10%BM, 15%BM vest combined) caloric value for gradients (walk speed 2.5 mph) are as follows:

0% Grade =3.56 kcal/min

5% Grade = 4.93 kcal/min

10% Grade = 6.9 kcal/min

15% Grade = 8.7 kcal/min

Five Suggested Walking Workouts from this Research

From this research, the following walking workouts are suggested for personal trainers to progressively introduce to their entry-level female clients.

Warm-up: a 5 to 10 minute self-selected warm-up at 0% grade is recommended for all of the following workouts.

The goal intensity for all of these workouts is a 'somewhat hard' to 'hard' level of perceived exertion

Workout 1. Metabolic Base Walking with a Weighted Vest

Walking Speed: 2.5 mph

Treadmill Grade: 0%

Vest Weight: 15% body weight

Duration: 20 to 60 minutes as established by ACSM guidelines

Workout 2. Step-Wise Graded Walking (no vest or vest)

Walking Speed: 2.5 mph

Vest Weight (if worn): 10% body weight

Treadmill Gradient increases in the following:

0% grade for 4 minutes

5% grade for 4 minutes

10% grade for 4 minutes

15% grade for 2 minutes

5% grade for remainder of workout duration

Duration: 20 to 60 minutes as established by ACSM Guidelines

Workout 3: Interval Walk Training (no vest or vest)

Walking Speed: 2.5 mph

Vest Weight (if worn): 10% body weight

Interval Workout with the following intervals:

Work Interval: 10% or 15% grade for 2 minutes

Recovery Interval: 0% grade for 4 minutes

Repeat Work and Recovery Intervals a duration 20 to 30 minutes as established by ACSM guidelines

Workout 4. Three Big Effort Walk Workout (no vest or vest)

Walking Speed: 2.5 mph

Vest Weight (if worn): 10% body weight

Grade: 5% grade

Three times (at the beginning, middle and end of the walking workout) during the walk, take the treadmill grade to 15% and walk for 1.5 minutes. After 1.5 minutes return grade to 5% and continue.

Duration: 20 to 60 minutes as established by ACSM Guidelines

Workout 5. Interval Hill Walk Workout (no vest or vest)

Walking Speed: 2.5 mph

Vest Weight (if worn): 10% body weight

Interval Workout with the following intervals:

Work Interval: 10% or 15% grade for 45 seconds

Recovery Interval: 5% grade for 3 minutes

Repeat Work and Recovery Intervals duration 20 to 30 minutes as established by ACSM guidelines

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.

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.

Methodology

This section 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.

<u>Submaximal Exercise Test</u>

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).

<u>Exercise Trials</u>

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. The alpha level for significance was set at $P < 0.05$.

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 {$F(2,24)=28.35$, $P <0.05$} ($F= 28.35$, $P < 0.05$), 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.
$P < 0.05$.

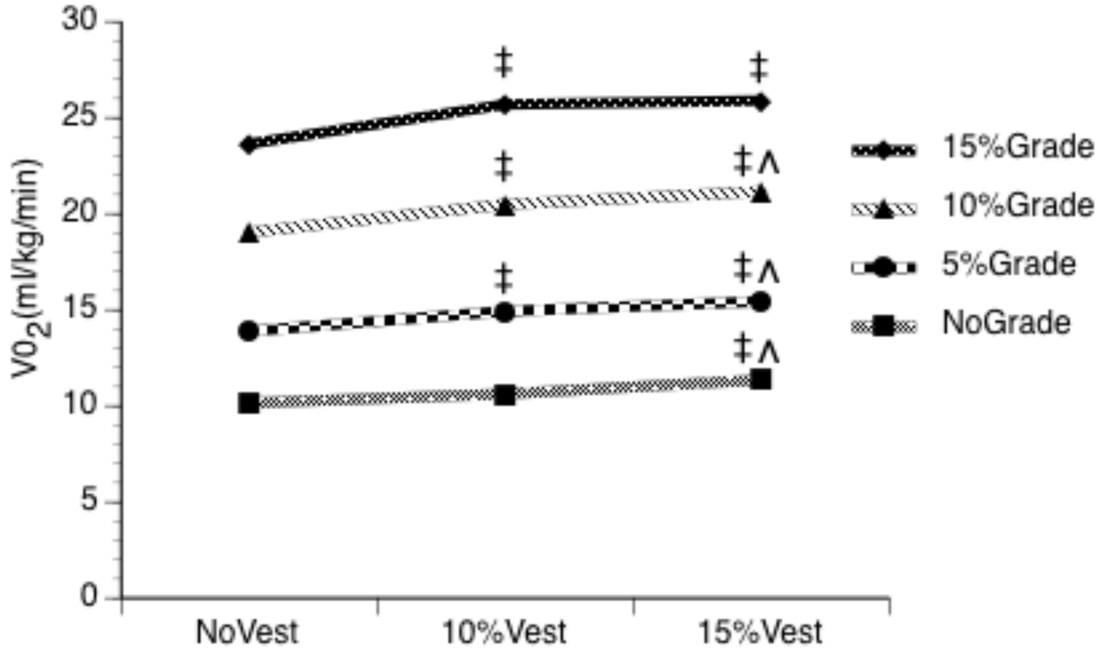

Figure 1- Average oxygen consumption at each weighted vest condition.
‡ Significantly different from 0%BM; ∧ significantly different from 10%BM. $P < 0.05$.

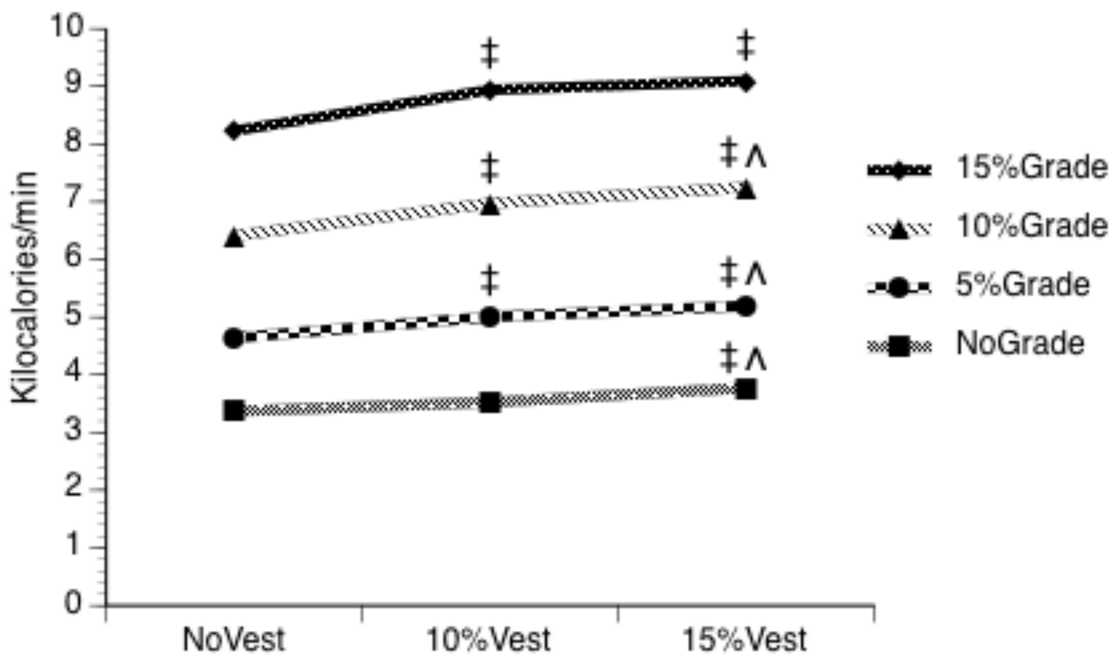

Figure 2- Average energy expenditure at each weighted vest condition.
‡ Significantly different from 0%BM; ∧ significantly different from 10%BM. $P < 0.05$.

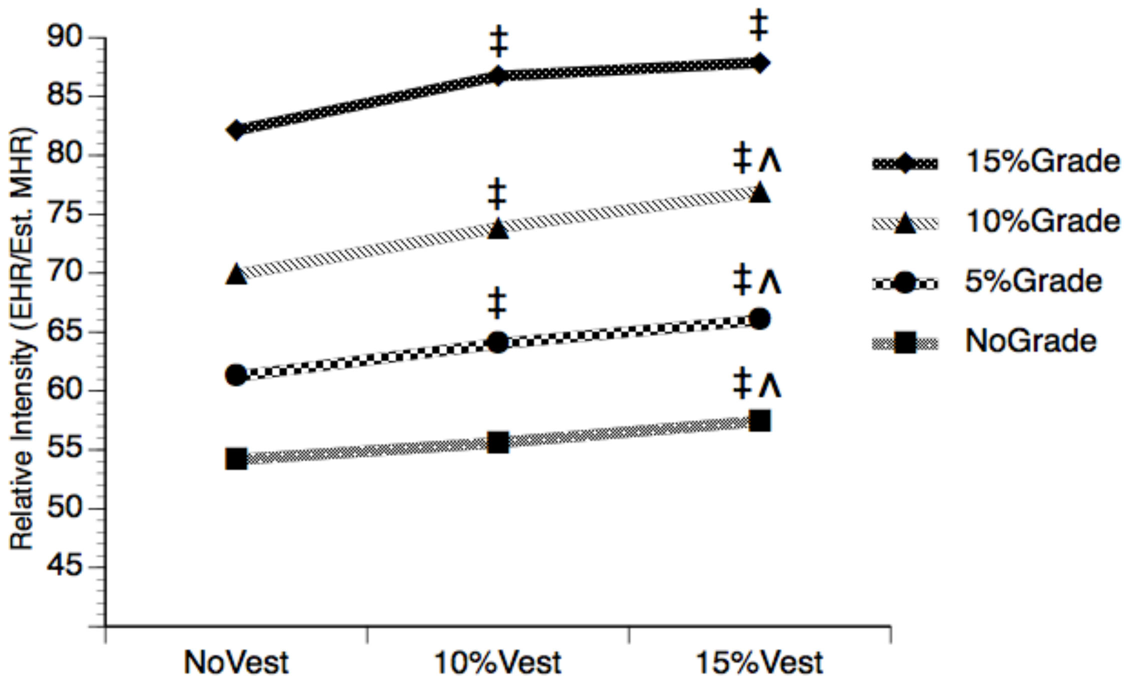

Figure 3- Average relative exercise intensity (%APMHR) for each weighted vest condition.
‡ Significantly different from 0%BM; Λ significantly different from 10%BM. P < 0.05.

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.

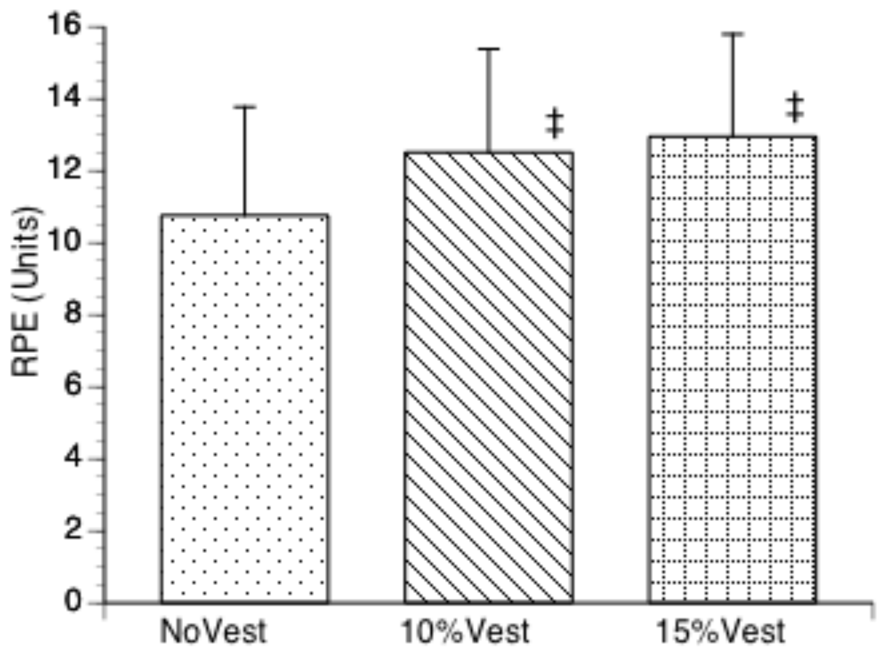

Figure 4- Rating of Perceived Exertion (RPE) for each weighted vest condition.
‡ Significantly different from 0%BM. $P < 0.05$.

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%).

<u>Relative Exercise Intensity</u>

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 weighted 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, through examination of the main effects, there was 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.

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