THE EFFECTS OF INTERVAL WALKING ON CALORIC EXPENDITURE

by

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ABSTRACT

Purpose: As obesity rates continue to rise in physically inactive individuals, modified training methods should be explored to address exercise adherence. The purposes of the proposed studies were to evaluate the effectiveness of interval walking, intermittent interval walking, and self-paced intermittent interval walking on oxygen uptake ($\dot{V}O_2$) and excess post- exercise oxygen consumption (EPOC). Methods: In Study I and Study II participants completed a 30-min continuous walking protocol at a low-moderate intensity. Each protocol in these studies incorporated the same volume [90 metabolic equivalent-minutes (MET-min)] of exercise. Study I consisted of two interval walking protocols of cycled high-moderate and low-moderate intensities of 30-s work bouts and active recovery bouts of 60 and 120 s and total durations of 24-min-24-s (protocol 1) and 26-min-20-s (protocol 2). Study II consisted of three 10-min intermittent walking bouts of low-moderate intensities, three 8-min-40-s interval walking bouts of 30-s work bouts and active recovery bouts of 120 s, and three 8-min interval walking protocols of 30-s work bouts and active recovery bouts of 60 s. Study III assessed oxygen uptake before, during, and after continuous, intermittent, and intermittent interval walking of a self-regulated moderate RPE range (RPE 12-13), each totaling 30 min. Intermittent walking consisted of three 10-min bouts of walking and intermittent interval walking consisted of cycled 30-s high-moderate:120-s low-moderate intensity walking. Results: Study I: $\dot{V}O_2$ during interval walking was higher ($p < 0.05$) than during continuous walking; however, EPOC differed only between continuous walking and interval walking protocol 1 ($p < 0.05$). Study II: Compared to continuous walking, intermittent walking and both intermittent interval walking protocols elicited higher ($p < 0.05$) cumulative $\dot{V}O_2$ during exercise, and cumulative total 20-min EPOC values were higher as well ($p < 0.05$). Study III: Compared to continuous walking, both self-paced intermittent and intermittent interval walking protocols elicited higher cumulative $\dot{V}O_2$ during exercise periods and higher cumulative total 20-min EPOC values (all $p < 0.05$). Conclusion: These results indicate that moderate-intensity interval and intermittent interval walking protocols elicited higher exercise $\dot{V}O_2$ and EPOC compared with continuous walking of the same volume (90 MET-min) or duration (30 min).

Key Words: EPOC, Interval walking, Intermittent exercise, Metabolism, Aerobic exercise, Body composition

DEDICATION

This dissertation is dedicated to all of my family and friends. Thank you for your kind words, patience, and motivation throughout my dissertation journey. I would especially like to thank my lovely wife, Qshequilla Mitchell; beautiful daughter, Clara Grace; unborn son, Desmond Brock; caring mother, Lelia Mitchell; and hard-working brother, James Mitchell for your support and inspiration.

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CHAPTER I

INTRODUCTION

Adults today are less physically active than generations past, contributing to excess fat accumulation and an increase in the prevalence and incidence of chronic disease, e.g., type II diabetes, cardiovascular disease, hyperglycemia, and obesity (16). Regular physical activity, acquired through intermittent or continuous physical activity, improves a person's health and fitness, regardless of age, sex, or fitness level (1, 7). Current physical activity guidelines state that adults should accumulate either a minimum of 150 minutes per week of moderate-intensity aerobic activity, 75 minutes per week of vigorous-intensity aerobic activity, or a combination of the two intensities that results in the same energy expenditure as either intensity alone (7). Adults who adhere to the current physical activity guidelines reduce all-cause mortality (7); however, a lack of time is often cited as a major barrier to exercise (20), thereby preventing many Americans from meeting current recommendations (13).

Therefore, time-efficient forms of aerobic exercise are important. Current recommendations indicate multiple bouts of at least 10 min/session accumulated over the course of a day are beneficial, but further study regarding bouts of < 10 min is needed to confirm the efficacy of such bouts (7). Walking—a universal form of physical activity that can be performed indoors or outdoors without any special skill requirement (11)—is the preferred physical activity of many adults that meet the minimum physical activity guidelines (19). Additionally, it provides sedentary people with a safe, effective, low impact mode of exercise to meet physical activity guidelines. Light, moderate, and vigorous walking reduces health care costs, incidence rates of chronic diseases, health disparities, and stress (11). Brief, intense walking could prove beneficial to individuals with scheduling constraints (20); however, the extent to which shorter duration (< 10 min), time-efficient forms of walking are beneficial to health is currently unclear.

Interval training consists of intermittent periods of exercise and rest of high-to-low intensity lasting seconds to minutes. This form of training allows people to exercise at higher intensities for shorter durations than traditional training methods. High-intensity interval training includes cycled work intervals of 30-60 s followed by rest periods of 2-4 min (8, 21). Findings to date indicate that fitness improvements with interval training are similar, if not superior to, improvements with traditional training (3, 4, 9, 12, 17); however, high-intensity interval training may be too intense and/or unsafe for unfit adults. High exercise intensities decrease exercise adherence and increase the risk of injury in sedentary and obese/overweight people (6). An exercise prescription that provides lower intensity interval training may reduce the risk of injury and increase exercise adherence, but this has received limited empirical study.

Interval walking training is a form of interval training with lower intensities than traditional interval training protocols. Unlike high-intensity interval training, traditional interval walking training consists of 5 sets of 3 min of low-intensity walking at 40% peak aerobic capacity ($\dot{V}O_{2peak}$) interspersed with 3 min of high-intensity walking intervals at 70% $\dot{V}O_{2peak}$ (14, 15, 18). Interval walking training could provide safe and time-effective interval training that would be tolerable for most adults.

Sawashita et al. (18) found that interval walking showed favorable improvements in body mass index (BMI) and blood pressure, which would aid in the prevention of lifestyle-associated diseases. Similarly, investigators studying the effects of increased physical fitness by interval walking training on lifestyle-related diseases found that low-, middle-, and high-fitness groups all increased $\dot{V}O_{2peak}$ and thigh muscle strength and decreased BMI, % body fat, blood pressure and blood glucose concentration in both sexes after 16 weeks (15). The low-fitness group had the greatest changes from the interval walking training which was performed 4 days per week and consisted of ≥ 5 sets of 3 min of fast walking at ≥ 70% $\dot{V}O_{2peak}$ followed by 3 min of slow walking at ≤ 40% $\dot{V}O_{2peak}$.

Excess post-exercise oxygen consumption (EPOC)—the oxygen uptake elevated above resting levels after exercise—contributes to the energy expended during exercise to promote body fat reduction. Chan and Burns (5) found that sprint-interval exercises elicited EPOC values 43% higher than resting values over a two-hour period post exercise. Hazell et al. (10), however, reported no EPOC differences between 18 min of sprint-interval training (four, 30-s maximal cycling efforts at a 10% body mass resistance, separated by 4 min of active recovery) and 30 min of continuous cycling (70% $\dot{V}O_{2max}$) 24-hr after exercise. Brockman et al. (2) found that continuous or intermittent high-intensity exercises elicited higher EPOC than low-intensity exercise. Findings from these studies demonstrate that results are mixed—some studies show increased EPOC after interval exercise and some show no difference. Differences in volume and intensity of exercises used in these studies may explain the discrepant results.

While EPOC in relation to a variety of moderate- and high-intensity exercises has been studied, effects of interval (cycled high- and low-intensity periods) and intermittent interval (i.e., active walking bouts separated by recovery periods) walking on energy expenditure remain unknown. Accordingly, the overall purpose of this dissertation was to investigate the acute physiological responses of interval walking. Other purposes were: (a) to evaluate the effect of continuous and interval walking on $\dot{V}O_2$ during the walking bouts and EPOC after the walking bouts, (b) to evaluate the effect of intermittent interval walking on $\dot{V}O_2$ during the walking bouts and EPOC after the walking bouts, and (c) to evaluate the effect of self-paced intermittent interval walking intensities on $\dot{V}O_2$ during the walking bouts and EPOC after the walking bouts.

The following hypotheses were tested:

Study1: The interval walking protocol with the highest work:rest ratio would elicit higher exercising $\dot{V}O_2$ values above baseline and higher EPOC values than the other walking protocols;

Study 2: The intermittent interval walking protocols would elicit higher exercising $\dot{V}O_2$ values above baseline and higher EPOC values than the intermittent and continuous walking protocols;

Study 3: Intermittent interval walking bouts with self-paced intensity would elicit higher EPOC values than intermittent and continuous walking protocols with self-paced intensities.

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CHAPTER II

EXCESS POST-EXERCISE OXYGEN CONSUMPTION FOLLOWING THREE WALKING PROTOCOLS

ABSTRACT

Purpose: The purpose of this study was to evaluate metabolic responses of continuous and interval walking in college-aged adults during and immediately following exercise. Methods: Ten healthy adults (4 women, 6 men; mean ± SD age = 24 ± 5 years) completed a 30-min bout of continuous, a 24-min-24-s bout of interval walking (IW1), and a 26-min-20-s bout of interval walking (IW2). Continuous walking was performed at a workload of 3 metabolic equivalents (METs) (~ 4.8 km/h) while IW1 and IW2 were performed at workloads of 30 s:60 s of high-moderate (5 METs) (~ 6.4 km/h):low-moderate (3 METs) (~ 4.8 km/h) intensities and 30 s:120 s of high-moderate:low-moderate intensities, respectively. Each protocol consisted of a volume of 90 MET-min. Oxygen uptake ($\dot{V}O_2$) was measured during exercise as well as over 20 min during supine rest before and after exercise. Post-exercise $\dot{V}O_2$ was used to calculate excess post-exercise oxygen consumption (EPOC). Results: Accumulated O_2 uptake during exercise was higher during IW2 (28,232 ± 2,782 mL) compared to IW1 (26,561 ± 2,685 mL; $p = 0.03$) and continuous walking (24,500 ± 2,427 mL; $p = 0.001$), and higher during IW1 than during continuous walking ($p = 0.001$). EPOC was higher after IW1 (1,268 ± 117 mL O_2) than continuous walking (892 ± 73 mL; $p < 0.05$); the two interval walking protocols were not different (IW2: 1,174 ± 178 mL). Conclusion: These findings show that interval walking elicited

greater energy expenditure during exercise and higher EPOC values compared to continuous walking of a similar volume.

Key Words: EPOC, Interval walking, Aerobic exercise, Body fat

INTRODUCTION

Exercise and calorie restriction have been recommended for weight reduction and management; however, only 52% of U.S. adults met minimum physical activity guidelines in 2011(1). Many Americans state that lack of time is a major barrier to meeting the current recommendations (5). As physical inactivity among U.S. adults continues to rise, modified training methods that require less time should be considered to help remove the perceived barrier of lack-of-time. Interval training, for example, has been shown to provide greater or similar benefits to traditional training in a shorter time (8, 9, 17, 32) and may represent a time-efficient strategy to increase physical activity or exercise (12).

Interval training consists of intermittent periods of exercise and rest lasting seconds or minutes at various intensities. Several studies have shown elevated oxygen uptake capacity ($\dot{V}O_{2max}$) and physiological improvements (8, 9, 31) associated with interval training compared to traditional continuous training, regardless of age, sex, or health status (8, 9, 15, 17, 25, 32, 34). Traditional high-intensity interval training, however, is performed at high intensities (85-90% $\dot{V}O_{2max}$), which places greater strain on the cardiovascular system and may be contraindicated for some adults (10). Accordingly, lower-intensity interval training protocols have been studied and investigators have shown that interval training at lower intensities can effectively elicit positive physiological adaptations (13, 18).

One such form of low-intensity exercise that can be performed using intervals is walking. Walking is a common and practical form of weight-bearing exercise that reduces life-style related risks of chronic diseases. Traditional interval walking training is a type of interval training that consists of 3-min repeated cycles of high ($\geq$ 70% peak oxygen uptake, $\dot{V}O_{2peak}$) and low walking ($\leq$ 40% $\dot{V}O_{2peak}$) intensities (22, 24). Because interval walking training intensities are lower than most traditional interval training protocols, they may reduce injury risk and improve exercise adherence. To date, interval walking training has been shown to improve body mass index, $\dot{V}O_{2peak}$, knee extension and flexion strength, and blood pressure when compared to continuous walking (19, 22, 24, 29). A modified interval walking training protocol consisting of a 2 min:1 min ratio of low-intensity (40% $\dot{V}O_{2peak}$) to vigorous-intensity (70% $\dot{V}O_{2peak}$) exercise was utilized by Campbell et al. (10), who found a reduction in low density lipoprotein. Limited research has evaluated the metabolic responses of modified interval walking training protocols.

In addition to health effects associated with acute physiological responses that occur during interval walking, some health effects may be associated with excess post-exercise oxygen consumption (EPOC), defined as the elevated rate of oxygen uptake above the resting value after exercise (30). The magnitude of EPOC depends on both exercise intensity and duration (7). Petrofsky et al. (26) found that energy used during 6 min of high-intensity exercise caused a shift in metabolism that lasted more than 24 hours, and EPOC 5 times greater than the caloric expenditure during the 6 minutes of exercise. Exercises that elicit higher $\dot{V}O_2$ during exercise and higher EPOC after exercise may contribute to an increased caloric deficit in obese and overweight people.

Even though high-intensity interval exercise has been shown to elicit significantly higher EPOC values compared to continuous exercise, the ideal exercise and active recovery ratios of interval walking have not been clearly established. Furthermore, no research to date has examined the effect of lower intensity interval walking exercise on EPOC. The purpose of this study, therefore, was to compare metabolic (energy expenditure) responses of continuous and interval walking protocols in adults during and immediately following exercise. We hypothesized that the interval walking protocols would produce higher $\dot{V}O_2$ during exercise and higher EPOC following exercise.

METHODS

All procedures were approved by the local Institutional Review Board.

Study participants

Ten adults (4 women and 6 men), aged 19-40 provided written informed consent prior to participation in the study. A priori power analysis (G power; ANOVA: Repeated measures, within factors) revealed that a minimum of 9 participants would be necessary to observe a moderate effect (effect size = 0.3, $\alpha = 0.05$, power = 80%, noncentrality parameter = 12.15, critical $F = 3.63$) for the EPOC outcome measure. The variance observed by Townsend et al. was used in this analysis (33). Each participant completed a medical history and Physical Activity Readiness Questionnaire to screen for health risks that would preclude participation in moderate- intensity exercise. Any person classified as high risk, defined by the American College of Sports Medicine as having, "one or more signs/symptoms of or diagnosed cardiovascular, pulmonary, and/or metabolic disease" (14), was excluded from the study.

Participants reported to the laboratory on four separate occasions; all participants were instructed to refrain from caffeine, alcohol, food consumption 2 hours prior to testing and moderate to vigorous exercise for at least 24 hours prior to each visit. A 24-hour history form was used to verify adherence to the aforementioned guidelines.

Experimental Design

The modified Balke-Ware Treadmill Protocol (4) and International Physical Activity Questionnaire (short version) (11) were administered during the initial visit to evaluate participants' current fitness and physical activity levels. Participants with a cardiorespiratory fitness level ≥ 70th percentile via the Balke-Ware Treadmill Protocol were excluded from the study to minimize fitness differences. Height (Seca, Gayamills, WI), weight (Tanita BWB-800, Japan), waist and hip circumference (Gulick II Measuring Tape, Gayamills, WI), and percent body fat via 3-site skinfolds (men: chest, abdomen, and thigh; women: suprailiac, tricep, and thigh) (16, 27) were measured for each participant.

After the initial session, participants returned two days later to complete the first experimental trial. Experimental trials consisted of one continuous walking and two interval walking protocols performed on a treadmill (Quinton, Seattle, WA) in a moderate temperature environment (~22-23 °C) with a minimum of 48 hours between each exercise session. Participants performed each walking protocol within 1 hour of the same time of day as the initial session. Walking treatments in each exercise session were counterbalanced and the order of the counterbalanced trials was randomly assigned to participants.

The continuous walking protocol consisted of participants walking continuously for 30 min at a low-moderate workload of 3 metabolic equivalents (METs) (~ 4.8 km/h) (2, 3). Interval walking protocols consisted of cycled work and active rest bouts of high-moderate and low-moderate intensities. Each interval walking work bout was set at a workload of 5 METs (6.4 km/h) (2, 3) and active recovery workload of 3 METs (4.8 km/h). The first interval walking protocol (IW1) consisted of a 24-min-24-s bout of walking (19% shorter duration than continuous walking) and work:active recovery bouts of 30 s:60 s. The second interval walking protocol (IW2) consisted of work:active recovery bouts of 30 s:120 s totaling 26-min-20-s (11% shorter duration than continuous walking). Each protocol consisted of the same volume of 90 MET-min. Figure 1 summarizes the exercise protocols.

Prior to each exercise trial, baseline oxygen uptake ($\dot{V}O_2$) was measured using a metabolic cart (TrueMax 2400, Parvo Medics, Sandy, UT) during a 20-min supine rest period. $\dot{V}O_2$ was recorded continuously and averaged every 30 s; baseline $\dot{V}O_2$ was taken as the average of the final 5 min (33). During each walking protocol, $\dot{V}O_2$ was measured continuously and rating of perceived exertion (RPE; using the 6-20 Borg scale) (6) and heart rate (HR; Polar, Lake Success, NY) were measured every 5 min. Exercising $\dot{V}O_2$ was calculated as $\dot{V}O_2$ during walking minus $\dot{V}O_2$ at baseline. To calculate EPOC, $\dot{V}O_2$ was measured during supine rest for 20 min immediately following each walking protocol (28).

Statistical Analyses

Area under the curve (20) was used to calculate EPOC and exercising accumulated O_2 uptake. EPOC values also were totaled every 5 min during the 20-min recovery period. Repeated measures analysis of variance (ANOVA) was used to analyze overall EPOC,$\dot{V}O_2$ during exercise, during- and post- exercise mean heart rate and exercise RPE values among experimental trials. Five-min cumulative EPOC values were analyzed between treatments using a two-way repeated measures ANOVA (treatment × time). Bonferroni post-hoc comparisons were used, when applicable, to determine individual differences between treatments. All data were analyzed using SPSS, v. 22 (Statistical Package for the Social Sciences; Armonk, NY) and $\alpha = 0.05$ was used for all hypothesis tests.

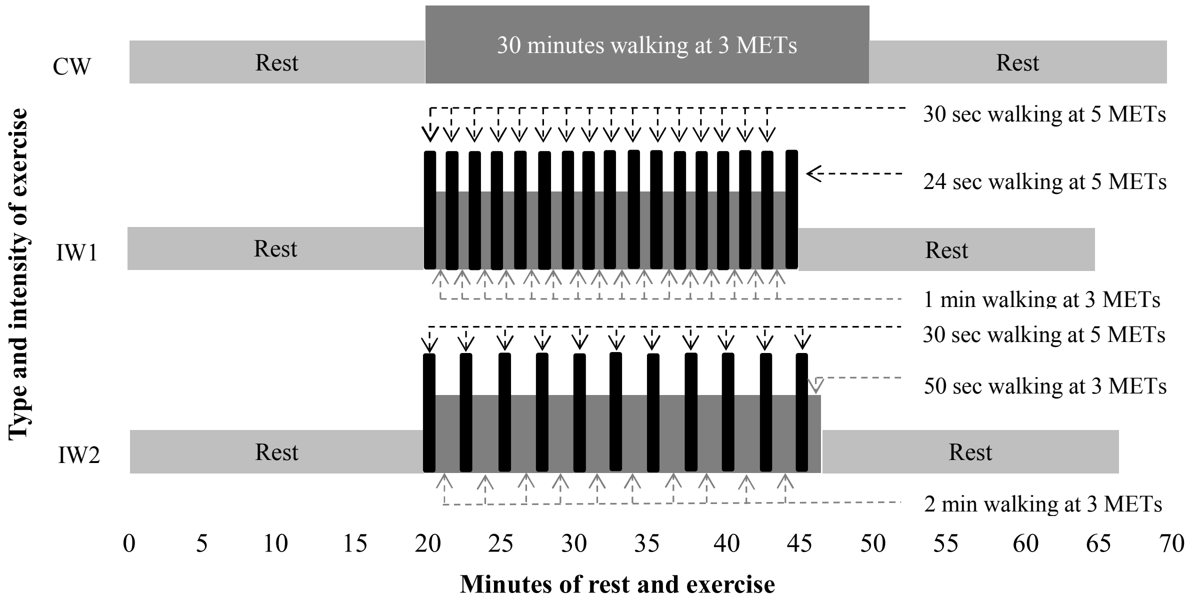
CW
Rest
30 minutes walking at 3 METs
Rest
30 sec walking at 5 METs
24 sec walking at 5 METs
IW1
Rest
Rest
1 min walking at 3 METs
30 sec walking at 5 METs
50 sec walking at 3 METs
IW2
Rest
Rest
2 min walking at 3 METs
Type and intensity of exercise
0 5 10 15 20 25 30 35 40 45 50 55 60 65 70
Minutes of rest and exercise

Figure Caption

Figure 1. Schematic representation of the three walking protocols. CW = continuous walking; IW1 = interval walking protocol 1; IW2 = interval walking protocol 2.

RESULTS

The physical characteristics of the study participants (n = 10) are displayed in Table 1. One female was excluded from the study due to a cardiorespiratory fitness level ≥ 70th percentile via the modified Balke-Ware Treadmill Protocol (4).

O_2 uptake above baseline that was accumulated during exercise is shown in Figure 2. The total O_2 uptake during IW2 (28,232 ± 2,782 mL) was higher than both continuous walking (24,500 ± 2, 427 mL; $p = 0.001$) and IW1 (26,561 ± 2, 685 mL; $p = 0.03$). Similarly, accumulated O_2 was higher during IW1 than continuous walking ($p = 0.001$).

IW1 resulted in higher accumulated 20-min EPOC than continuous walking (1,268 ± 117 mL vs. 892 ± 73 mL; $p < 0.05$), but EPOC after IW2 (1,174 ± 178 O_2) was not different than the other protocols.

Continuous walking produced during exercise and EPOC caloric energy expenditures of 123 kcal and 4.5 kcal, respectively. The interval walking protocols produced accumulated during exercise energy expenditures of 133 kcal (IW1) and 141.2 kcal (IW2) and accumulated 20-min EPOCs of 6.3 kcal (IW1) and 5.9 kcal (IW2). The cumulative caloric energy expenditures (during exercise + accumulated 20-min EPOC) for the three walking protocols were 127 kcal (continuous walking), 139 kcal (IW1), and 147 kcal (IW2).

Figure 3 shows the EPOC following each exercise bout. IW1 elicited an approximately 25% higher EPOC in the first 5 min relative to continuous walking ($p = 0.04$), but it was not different from EPOC after IW2. After the first five minutes, EPOC for all treatments declined rapidly, reaching near baseline $\dot{V}O_2$ at 10 min post exercise.

Average HR during IW1 was higher than that during continuous walking (108 ± 3 vs. 103 ± 3 beats/min, respectively; $p = 0.02$), but HR during IW2 (103 ± 2 beats/min) was not different than the other treatments (both $p > 0.05$). Despite the higher average HR during IW1, treatments were not different from one another at the end of the 20-min post-exercise period (continuous walking: 69 ± 3 beats/min; IW1: 68 ± 3 beats/min; IW2: 68 ± 2 beats/min; $p = 0.97$). Even though average HR during IW1 was higher than during continuous walking, this did not translate in to a higher average RPE (9 ± 0.71 vs. 8 ± 0.5; $p = 0.77$), nor was average RPE different than either of these treatments during IW2 (8 ± 0.53; one-way ANOVA $p = 0.77$).

Table 1. Descriptive characteristics of participants (men: n = 6; women: n = 4).

Variable	Mean ± SD
Age (y)	24 ± 5
Height (cm)	171 ± 6.9
Body mass (kg)	77.3 ± 21.8
Waist circumference (cm)	78.1 ± 12.2
Hip circumference (cm)	99.3 ± 12.0
% body fat	10.7 ± 4.3
MET-min/wk	3804 ± 1847

Table 2. Descriptive characteristics of participants (men: n = 6).

Variable	Mean ± SD
Age (y)	24 ± 5
Male height (cm)	174.5 ± 4.5
Male body mass (kg)	85.0 ± 18.6
Male waist circumference (cm)	81.7 ± 11.7
Male hip circumference (cm)	100.7 ± 11.6
Male % body fat	10.4 ± 4.7
Male MET-min/wk	4750 ± 1666

Table 3. Descriptive characteristics of participants (women: n = 4).

Variable	Mean ± SD
Age (y)	24 ± 5
Female height (cm)	166.0 ± 7.0
Female body mass (kg)	65.9 ± 23.7
Female waist circumference (cm)	72.8 ± 12.4
Female hip circumference (cm)	97.2 ± 14.1
Female % body fat	11.2 ± 4.1
Female MET-min/wk	2385 ± 1065

Figure 2

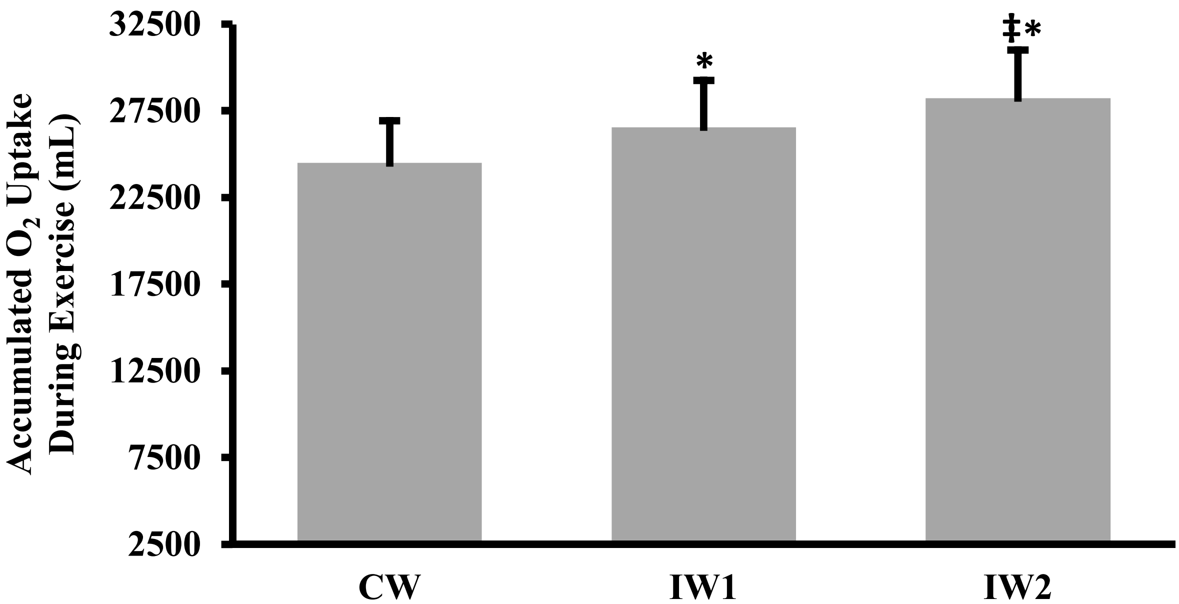

Figure 3

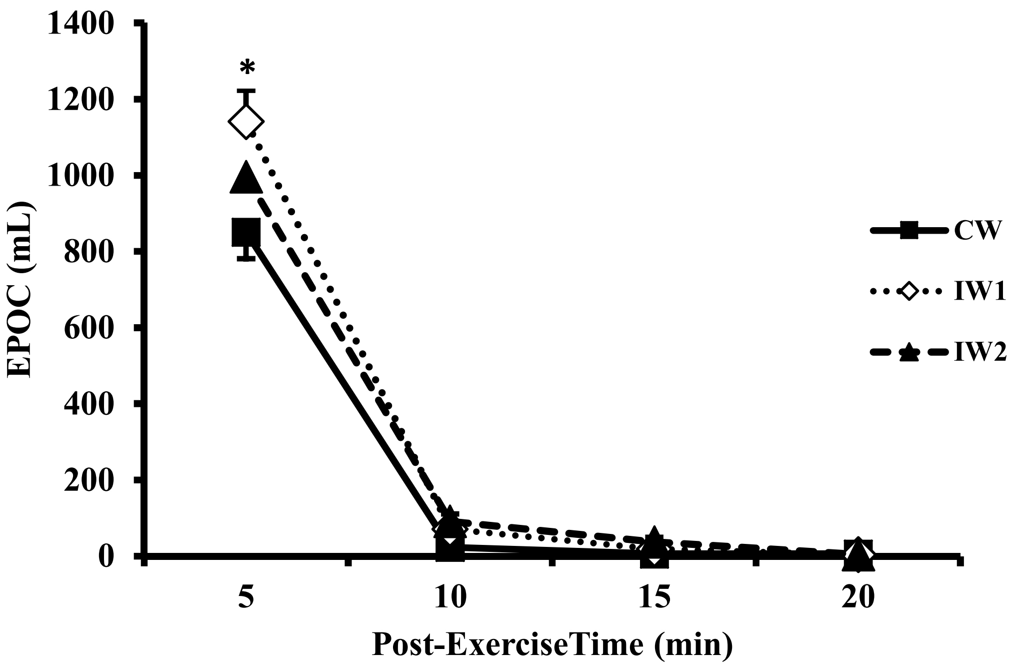

Figure Captions

Figure 2. Mean ± SD oxygen uptake during continuous and interval walking equivalent to 90 MET-min. CW = continuous walking, IW1 = interval walking protocol one, and IW2 = interval walking protocol two. * Significantly different from CW ($p = 0.001$); ‡ significantly different from IW1 ($p = 0.03$).

Figure 3. Mean ± SD cumulative 5-min EPOC values during the 20-min recovery period following continuous and interval walking equivalent to 90 MET-min. CW = continuous walking; IW1 = interval walking protocol one; and IW2 = interval walking protocol two. Values are means ± SD. * Significantly different from CW ($p = 0.04$).

DISCUSSION

The purpose of this study was to compare energy costs above baseline during and after continuous and interval walking protocols of the same volume (90 MET-min) to compare acute changes in metabolic rate. The primary finding was that the interval walking protocols, despite having shorter durations (IW1: 19% shorter duration; IW2: 11% shorter duration) than continuous walking, produced significantly higher accumulated O_2 uptake and EPOC values than continuous walking.

This study supports the observation that interval walking may provide greater benefits than continuous walking. Sawashita et al. (30) found that a short combination of mild caloric restriction and high-intensity interval walking may prevent lifestyle-associated disease and improve health in middle-aged and older overweight adults. Similarly, Nemoto et al. (24) noted that high-intensity interval walking may protect against age-associated increases in blood pressure and decreases in thigh muscle strength and peak aerobic capacity. Morikawa et al. (23) reported that interval walking training increased oxygen consumption, thigh muscle strength, BMI, and % body fat in adults with low, moderate, and high fitness after 4 months of training.

Rapid and prolonged components of EPOC contribute to the overall post-exercise oxygen consumed above baseline. We hypothesized that interval walking would produce higher during exercise $\dot{V}O_2$ and higher EPOC following exercise due to possible greater disturbance to homeostasis. These results suggest that during the rapid component of EPOC, greater restoration of both phosphocreatine and oxygen stores in the muscle occurred following interval walking due to its higher exercise intensities than continuous walking. Similarly, elevated levels of epinephrine or norepinephrine following interval walking may account for the greater oxygen consumption post-exercise. Conversely, the prolonged component of EPOC had a minimum affect if any on the 20-min EPOC, due to the noted rapid $\dot{V}O_2$ decline near baseline $\dot{V}O_2$ following 5-min post-exercise. Mini EPOCs following 30-s of high-moderate intensity work bouts of walking could account for the higher accumulated during exercise $\dot{V}O_2$ associated with the interval walking protocols.

The findings of higher exercising $\dot{V}O_2$ and EPOC associated with the acute interval walking protocols suggests that these protocols may provide adults with a modified exercise prescription that provides a greater stimulus for weight loss and fitness improvements in adults that do not currently meet the minimum physical activity guidelines. An adult completing the walking protocols 5 days for 4 weeks would accumulate 2,540 kcals (continuous walking), 2,782 kcals (IW1), and 2,942 kcals (IW2), with IW2 eliciting the highest monthly caloric expenditure than the other walking protocols.

This moderate-intensity form of interval walking may provide middle-aged and older adults with a way to progress to higher exercise intensities with shorter duration bouts of exercise of equal volume to continuous walking. Interval walking is a mode of exercise that has been under-researched and further studies are needed to determine if moderate-intensity interval walking of similar and different work-to-rest ratios have similar effects in sedentary or obese adults.

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CHAPTER III

THE IMPACT OF MODERATE-INTENSITY INTERMITTENT INTERVAL WALKING ON EPOC

ABSTRACT

Purpose: To evaluate the effects of continuous and intermittent walking on oxygen uptake ($\dot{V}O_2$) during exercise and excess post-exercise oxygen consumption (EPOC) after exercise. Methods: Four women and six men (mean ± SD age = 24 ± 5 years) completed one 30-min continuous walking, three 10-min intermittent walking, three 8-min 40-s interval walking (IIW2), and three 8-min interval walking (IIW1) protocols of the same volume [90 metabolic equivalent (MET)-min]. Baseline $\dot{V}O_2$ and EPOC were monitored for 20-min and accumulated O_2 uptake was calculated as area under the curve. Results: Accumulated O_2 uptake and EPOC associated with intermittent walking (39,186 ± 4,290 mL; EPOC: 2,582 ± 339 mL), IIW1 (36,964 ± 3,789 mL; EPOC: 3,365 ± 507 mL), and IIW2 (35,804 ± 3,979 mL; EPOC: 3,083 ± 339 mL) were higher than measured with continuous walking (24,500 ± 2,427 mL; EPOC: 892 ± 73 mL; all $p < 0.05$). Conclusion: Moderate-intensity intermittent walking and intermittent interval walking protocols resulted in higher energy expenditure during and after exercise—as reflected by accumulated O_2 uptake and EPOC, respectively—compared to moderate-intensity continuous walking of similar volume in college-aged men and women.

Key Words: Oxygen consumption, Intermittent exercise, Aerobic exercise, Metabolism

INTRODUCTION

The prevalence of overweight and obese adults is a public health challenge in the United States. Adherence to current physical activity guidelines can provide an array of benefits to the public (28); however, many Americans do not meet the current activity guidelines. Current physical activity guidelines state that adults can obtain the daily physical activity goal of 30 min each day (5 days per week) from multiple bouts of moderate intensity exercise ≥ 10 min (12) which may encourage more people to exercise (9).

Walking—one of the most common and simplest forms of weight-bearing exercise—provides minimal risk, low cost, requires minimal equipment, is relatively easy to implement in daily activities, and is a mild and tolerable beginning exercise for sedentary individuals (21, 22). Previous research has indicated that intermittent walking (3 × 10 min) in healthy, unfit males was as beneficial as 30 min of continuous walking (23). Additionally, healthy men increased high-density lipoprotein subfraction at 24 and 48 hours after intermittent walking (9), and sedentary-overweight women indicated greater intention and self-efficacy to participate in future multiple 10-min walks than a single 30-min walk (11). Even exercise performed < 10 minutes can result in enhanced fitness and health benefits for sedentary people (18), and such an approach may be more tolerable than longer bouts. Limited research, however, has investigated the acute effects of intermittent exercises on excess post-exercise oxygen consumption (EPOC).

In a study conducted by Lyons et al. (19), three 10-min bouts of upper-body exercise elicited a significantly higher combined EPOC magnitude than a similar intensity [60% peak oxygen uptake ($\dot{V}O_{2peak}$)] continuous bout of 30 min of upper-body exercise. Almuzaini et al. (3) found a higher combined 20-min EPOC magnitude after two 15-min cycling bouts (7,410 ± 1,851 mL) than after one 30-min cycling bout (5,278 ± 1,305 mL). Similarly, Potteiger et al.

(26) investigated the effects of one 30-min, two 15-min, and three 10-min walking protocols (all at 70% $\dot{V}O_{2max}$) on EPOC. They found that the cumulative 20-min EPOCs from the intermittent exercises (two 15-min; 3,247 ± 1,327 mL; three 10-min; 4,060 ± 1,055 mL) were significantly higher than the 20-min EPOC (1,848 ± 1,586 mL) after the continuous exercise (one 30-min).

Generally, studies examining the acute effects of performing intermittent versus continuous training has shown that intermittent exercises elicit higher cumulative EPOC than a single continuous bout of exercise (3, 17, 19, 26). Few studies, however, have quantified the effect of intermittent walking on EPOC, and no studies have examined the acute effects of intermittent interval bouts of walking in terms of exercise $\dot{V}O_2$ and EPOC. The primary purpose of this study, therefore, was to examine exercise $\dot{V}O_2$ and EPOC responses to one 30-min continuous, three 8-min interval, three 8-min 40-s interval, and three 10-min continuous walking protocols. We hypothesized that the intermittent interval walking protocols would elicit higher exercising $\dot{V}O_2$ values above baseline and higher EPOC values than the intermittent and continuous walking protocols.

METHODS

Study participants

Six men and four women completed a Physical Activity Readiness Questionnaire and medical history questionnaire to classify them based on the American College of Sports Medicine's (ACSM) risk classification (15). Current physical activity and fitness levels of each participant were obtained via the International Physical Activity (short version) Questionnaire (10) and a modified Balke-Ware Treadmill Protocol (4), respectively. Low or moderate risk participants with a cardiorespiratory fitness level < 70th percentile were eligible to participate in the study.

Protocol

Prior to arrival, participants were asked to avoid consumption of food during the preceding 2 hours. Verification of pre-test guideline adherence was assessed before each trial via a 24-hour history form. On the initial session, height, weight, hip and waist circumference, and percent body fat were measured via a scale (Tanita BWB-800, Japan), stadiometer (Seca, Gaysmills, WI), measuring tape (Gulick II Measuring Tape, Gaysmills, WI), and sum of 3 skinfolds (16, 25), respectively. An experienced technician collected all measurements based on ACSM guidelines (15).

Participants completed one continuous, one intermittent, and two intermittent interval walking protocols; each consisting of the same volume [90 metabolic equivalent (MET)-min]. The walking protocols were performed on a treadmill (Quinton, Seattle, WA) at 0% grade in a controlled temperature environment (~22-23 °C). Walking protocols were performed within 1 hour of arrival at the initial session and separated by a minimum of 48 hours. Each counterbalanced treatment order was assigned to participants randomly.

The continuous walking protocol consisted of 30 min of walking at a low-moderate intensity (3 METs; ~ 4.8 km/h) (1, 2), whereas the intermittent walking consisted of three 10-min bouts of low-moderate intensity walking separated by 20 min of rest. The interval walking protocols consisted of cycled work—active recovery bouts of high-moderate (5 METS; ~ 6.4 km/h) (1, 2) and low-moderate (3 METs; ~ 4.8 km/h) intensities separated by 20 min of rest. One intermittent interval walking protocol (IIW1) consisted of three 8-min bouts of cycled work with 30 s:60 s (5 METS:3 METS) of work:active recovery cycles. The second intermittent interval walking protocol (IIW2) consisted of three 8-min 40-s bouts of cycled work with 30 s:120 s (5

METS:3 METS) of work:active recovery cycles. Figure 1 provides a summary of the exercise protocols.

Pre-exercise $\dot{V}O_2$ was measured continuously in the supine position using a metabolic cart (TrueMax 2400, Parvo Medics, Sandy, UT) over 20 min while participants were supine; values were averaged every 30 s, and baseline $\dot{V}O_2$ was determined from averaging the final 5 min of 30-s averages (27). Exercising $\dot{V}O_2$ during each walking protocol was calculated as $\dot{V}O_2$ during walking minus $\dot{V}O_2$ at baseline. Heart rate (HR) was measured during and after walking in 5-min intervals and rating of perceived exertion (RPE) (6) was measured in 5-min intervals during walking. Following each bout of walking, EPOC over 20 min was determined by measuring $\dot{V}O_2$ on participants in the supine position (26).

Statistical Analyses

Accumulated O_2 uptake during exercise and EPOC (both in mL) were calculated from area-under-the-curve (20). These data, along with average HR and average RPE during and after exercise from each treatment were compared using one-way repeated measures analyses of variance (ANOVAs). Two-way repeated measures ANOVA (treatment × time) was used to analyze EPOC between trials and over time. When applicable, pairwise comparisons were analyzed using an bonferroni post-hoc procedure. Statistical Package for the Social Sciences v. 22 (SPSS; Armonk, NY) was used for all data analyses, and an alpha level of 0.05 was used for all hypothesis tests.

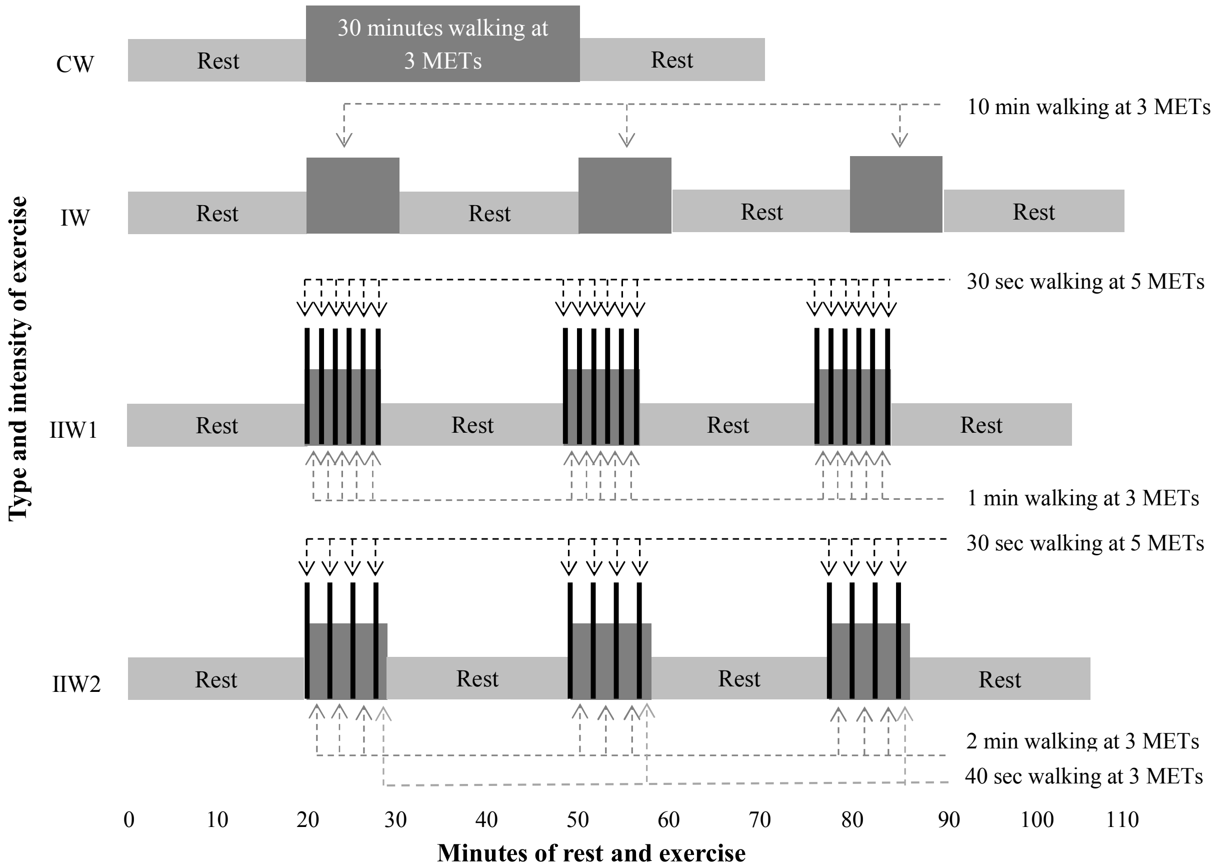
CW
Rest
30 minutes walking at 3 METs
Rest
10 min walking at 3 METs
IW
Rest
Rest
Rest
Rest
30 sec walking at 5 METs
IIW1
Rest
Rest
Rest
Rest
1 min walking at 3 METs
30 sec walking at 5 METs
IIW2
Rest
Rest
Rest
Rest
2 min walking at 3 METs
40 sec walking at 3 METs
Type and intensity of exercise
0 10 20 30 40 50 60 70 80 90 100 110
Minutes of rest and exercise

Figure Caption

Figure 1. Schematic representation of the four walking protocols.
CW = continuous walking; IW = intermittent walking; IIW1 = intermittent interval walking protocol 1; IIW2 = intermittent interval walking protocol 2.

RESULTS

Table 1 illustrates the physical characteristics of the study participants ($n = 10$). Figure 2 shows that participants expended more energy (as reflected by accumulated O_2 uptake) during three 10-min bouts of intermittent walking compared to 30 min of continuous walking ($p < 0.001$). Likewise, three 8-min bouts (IIW1) and three 8-min 40-s bouts (IIW2) of intermittent interval walking accumulated higher O_2 uptake during exercise compared to continuous walking of the same work volume (90 MET-min) ($p < 0.001$). Intermittent walking, IIW1, and IIW2 did not differ (all $p > 0.05$).

A similar pattern was observed for total EPOC. Intermittent walking (2,582 ± 339 mL), IIW1 (3,365 ± 507 mL), and IIW2 (3,083 ± 339 mL) elicited significantly higher cumulative total 20-min EPOC values than continuous walking (892 ± 73 mL; intermittent walking: $p = 0.002$; IIW1: $p = 0.003$; IIW2: $p < 0.001$). Intermittent walking did not differ from the intermittent interval walking protocols (IIW1: $p = 0.08$; IIW2: $p = 0.16$).

Figure 3 illustrates that in the first 5 min following exercise, intermittent walking, IIW1, and IIW2 elicited higher EPOC than continuous walking (intermittent walking and IIW2: $p < 0.001$; IIW1: $p = 0.001$) and did not differ from each other (all $p > 0.05$). After the first 5 min post-exercise, EPOC was not different among treatments (all $p > 0.05$).

IIW1 resulted in a higher overall average HR value during exercise compared to intermittent walking [HR = 105 ± 3 beats/min for IIW1 ($p = 0.02$), and 99± 2 beats/min]. Continuous walking (103 ± 3 beats/min), intermittent walking, and IIW2 (103± 3 beats/min) did not differ from each other (all $p > 0.05$). After exercise, average HR values did not differ among continuous walking (67 ± 3 beats/min), intermittent walking (64 ± 3 beats/min), IIW1 (64 ± 3 beats/min), and IIW2 (64 ± 2 beats/min) (all $p > 0.05$).

Despite different average HR during exercise among some of the treatments, overall average RPE was not different ($p = 0.17$). The mean RPEs for the walking protocols were 8 ± 0.55 (continuous walking), 8 ± 0.57 (intermittent walking), 8 ± 0.57 (IIW1), and 9 ± 0.71 (IIW2).

Table 1. Descriptive characteristics of participants (men: n = 6; women: n = 4).

Variable	Mean ± SD
Age (y)	24 ± 5
Height (cm)	171 ± 6.9
Body mass (kg)	77.3 ± 21.8
Waist circumference (cm)	78.1 ± 12.2
Hip circumference (cm)	99.3 ± 12.0
% body fat	10.7 ± 4.3
MET-min/wk	3804 ± 1847

Table 2. Descriptive characteristics of participants (men: n = 6).

Variable	Mean ± SD
Age (y)	24 ± 5
Male height (cm)	174.5 ± 4.5
Male body mass (kg)	85.0 ± 18.6
Male waist circumference (cm)	81.7 ± 11.7
Male hip circumference (cm)	100.7 ± 11.6
Male % body fat	10.4 ± 4.7
Male MET-min/wk	4750 ± 1666

Table 3. Descriptive characteristics of participants (women: n = 4).

Variable	Mean ± SD
Age (y)	24 ± 5
Female height (cm)	166.0 ± 7.0
Female body mass (kg)	65.9 ± 23.7
Female waist circumference (cm)	72.8 ± 12.4
Female hip circumference (cm)	97.2 ± 14.1
Female % body fat	11.2 ± 4.1
Female MET-min/wk	2385 ± 1065

Figure 2

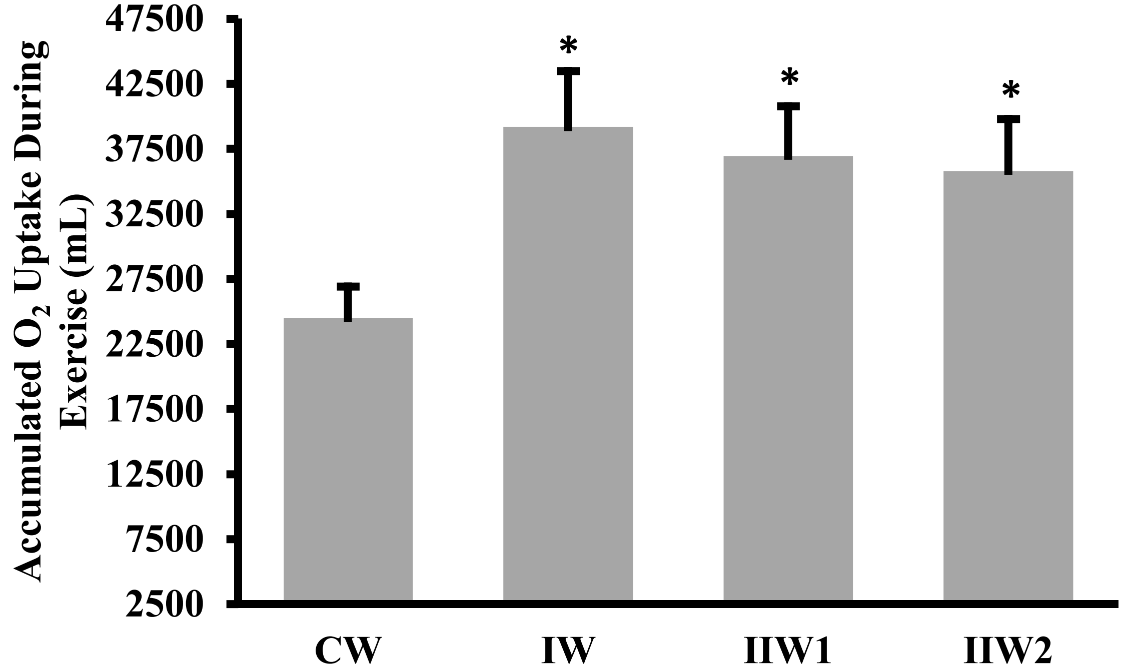

Figure 3

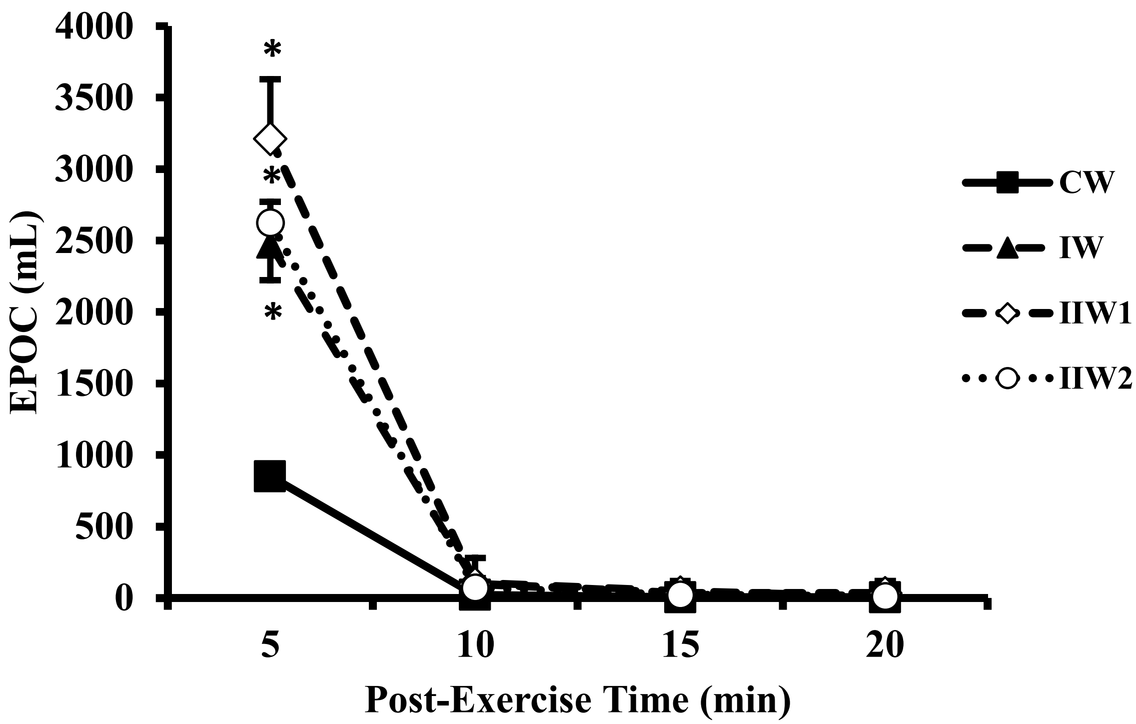

Figure Captions

Figure 2. Mean ± SD energy expenditure (reflected by Accumulated O_2 uptake) during continuous, intermittent, and intermittent interval walking for 90 MET-min. CW = continuous walking, IW = intermittent walking, IIW1 = intermittent interval walking protocol one and IIW2 = intermittent interval walking protocol two. * Significantly different from CW ($p < 0.05$).

Figure 3. Mean ± SD cumulative 5-min EPOC values during the 20-min recovery period following continuous, intermittent, and intermittent interval walking for 90 MET-min. CW = continuous walking, IW = intermittent walking, IIW1 = intermittent interval walking protocol one and IIW2 = intermittent interval walking protocol two. * Significantly different from CW ($p < 0.05$).

DISCUSSION

The purpose of this study was to compare accumulated O_2 uptake above baseline during exercise and EPOC between a continuous 30-min bout, three 8-min bouts of interval (IIW1), three 8-min 40-s bouts of interval (IIW2), and three 10-min walking bouts of the same volume. The primary finding was that intermittent exercises elicited higher accumulated during exercise $\dot{V}O_2$ and EPOC values than continuous walking. Another important finding was that multiple bouts of interval walking of various work-to-rest ratios of < 10 min result in elevated metabolic responses compared to continuous walking of a similar volume.

This study supports the observation that there is minimal sustained increase in $\dot{V}O_2$ after exercises of low exercise intensity (7) and that interval walking elicits greater EPOC than continuous walking of the same volume. The findings of this study are consistent with those of Gore and Withers (13) who calculated that exercise intensity explained five times more of EPOC than total work completed or exercise duration. Likewise, Phelain et al. (24) reported a significantly higher EPOC after cycling at 75% versus 50% $\dot{V}O_{2max}$ of equal work volume.

Research has indicated that intermittent exercises elicit higher cumulative EPOC values compared to continuous exercises. Similar to Potteiger et al. (26), our study found a significantly higher cumulative EPOC among the three 10-min bouts of walking compared to a 30-min bout of continuous walking, which is also consistent with the small but significantly higher cumulative EPOC noted by Lyons et al. (19) after three 10-min arm exercises compared to one 30-min bout of arm exercise of the same intensity.

We speculate that the reason for the higher metabolic rate during intermittent exercises in the current study was because intermittent walking, IIW1 and IIW2 reflect EPOCs from the previous bouts of exercises. Additionally, IIW1 and IIW2 accumulated additional EPOC following 30-s work bouts of high-moderate intensity walking which could have elevated the accumulated oxygen consumed both during and following exercise. These results indicate that the rapid component of EPOC was utilized at a greater capacity following intermittent exercise due to higher exercise intensities and thus greater disturbance to homeostasis. The significant but small EPOC values are similar to what Potteiger et al. found in females (26). Its contribution, however, may be less relevant than exercise energy expenditure in overall weight reduction.

The cumulative exercise kcal above baseline caloric energy expenditures for the entire exercise session (exercise + EPOC) were 127 kcal for continuous walking, 209 kcal for intermittent walking, 202 kcal for IIW1, and 194 kcal for IIW2. If an adult performed the walking protocols 5 days per week for 4 weeks they would accrue monthly walking kcal expenditures of 2,540 kcal (continuous walking), 4,176 kcal (intermittent walking), 4,032 kcal (IIW1), and 3,888 kcal (IIW2). Intermittent walking and IIW1 would have a similar monthly energy expenditure, followed by IIW2 and continuous walking. The hypothetical monthly energy expenditure illustrate that continuous, intermittent, and intermittent interval walking may provide adults with an exercise prescription to improve cardiovascular function.

Furthermore, lack of time has often been cited as a major barrier as to why many Americans do not meet the minimum physical activity guidelines (5); however, our research has indicated that multiple bouts of walking and interval walking ≤ 10 min can increase one's total exercising and post-exercise O_2 uptake relative to continuous walking. Shorter moderate-intensity exercises of ≤ 10 min may provide novice exercisers with a tolerable start to an exercise regimen. Interval walking of shorter durations may also address the "lack-of-time" barrier and possibly increase one's intention to exercise. Future studies should examine additional interval walking work-to-rest ratios $\leq$ 10 min and determine if similar exercising and post-exercise energy expenditures are evident in at-risk adults.

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CHAPTER IV

EXCESS POST-EXERCISE OXYGEN CONSUMPTION FOLLOWING SELF-PACED CONTINUOUS AND INTERMITTENT WALKING

ABSTRACT

Purpose: The purpose of this study was to investigate the acute changes associated with exercise oxygen uptake ($\dot{V}O_2$) and excess post-exercise oxygen consumption (EPOC) following self-paced intermittent interval walking. Methods: Ten participants (6 men and 4 women) completed one continuous, one intermittent, and one intermittent interval walking (IIW) protocol. Each protocol intensity was self-regulated in a moderate rating of perceived exertion (RPE) range (RPE 12-13) and 30 min in duration. Intermittent walking and IIW consisted of three 10-min bouts of walking, while continuous walking consisted of 30-min of walking. Pre-exercise $\dot{V}O_2$ was measured prior to each walking protocol for 20 min and intermittent bouts of walking were separated by 20 min of rest. Results: Accumulated O_2 uptake during exercise and EPOC values were significantly higher with intermittent walking (43,204 ± 4,685 mL and 3,676 ± 443 mL for accumulated O_2 uptake during exercise and EPOC, respectively) and IIW (42,958 ± 4,327 mL and 3,422 ± 244 mL for accumulated O_2 uptake during exercise and EPOC, respectively) than continuous walking (19,521 ± 1,992 mL and 1,412 ± 159 mL for accumulated O_2 uptake during exercise and EPOC, respectively; all $p < 0.05$). Conclusion: Intermittent exercises of self-paced, moderate-intensity elicited significantly higher accumulated O_2 uptake and EPOC values than continuous walking of the same overall duration.

Key Words: Interval walking, Aerobic exercise, Self-selected intensity, Body composition

INTRODUCTION

It is well recognized that regular physical activity can decrease one's risk of chronic disease; however, only approximately half of Americans meet the recommended physical activity guidelines (1). Based on these guidelines, a person should accumulate a minimum of 150 minutes of moderate intensity aerobic exercise each week. This can be achieved using multiple exercise training bouts $\geq$ 10 min throughout the day (14) which can attenuate the deleterious physiological effects that occur from extended inactivity (16).

Lack of time is cited as a major barrier as to why many Americans do not meet the current minimum physical activity guidelines (6). Adults who meet physical recommendations, however, commonly report walking as their preferred mode of physical activity (29). Interval training, an effective time-efficient method of exercise, is composed of multiple bouts of exercise of various intensities separated by rest periods. Interval training can elicit greater or similar benefits as continuous training in a shorter amount of time (8, 9, 23).

Interval training has typically referred to high-intensity bouts, but interval walking training is a form of interval training with lower intensities than traditional running or jogging and traditionally consists of cycled work and active rest intensities of 3 minutes each. Interval walking training is a preventive approach to reduce lifestyle-associated diseases (19, 21, 28) and mitigates age-related reduction of peak oxygen uptake ($\dot{V}O_{2peak}$) and muscular strength in older individuals (30), and may address the lack of time barrier. Interval training, although shorter in duration than traditional training methods has been shown to elicit greater excess post-exercise oxygen consumption (EPOC) than continuous training.

EPOC, defined as the elevated oxygen consumption above resting levels following exercise, is affected by both exercise duration and intensity (10), and may contribute to fat loss in adults. A study conducted by Darling et al. (11) examined both exercising and post-exercise oxygen consumption related to a 30-min continuous bout and three intermittent 10-min bouts of exercise at a constant intensity of 70% maximal oxygen uptake ($\dot{V}O_{2max}$). A 22.2 kcal higher EPOC value was elicited from three 15-min periods of recovery associated with the intermittent exercise compared to the continuous walking protocol. Kaminsky et al. (18) found that the combined EPOC magnitude of two 25-min runs at 70% of $\dot{V}O_{2peak}$ was higher than a 50-min continuous run at the same intensity (13.9 vs. 6.4 kcal).

Previous research has focused on the effect of high-intensity interval training on EPOC; however, further investigation is needed on lower intensity interval training deemed safe for most adults. Extended exercise duration is not necessary to cause an increase in post-exercise metabolism (25); therefore, intermittent interval walking may safely provide interval training at lower intensities without the physiological stress associated with traditional high-intensity interval training.

Intermittent interval walking's impact on energy expenditure during and following exercise is unknown. The purpose of this study, therefore, was to investigate the acute metabolic responses during and post-exercise associated with self-paced intermittent and intermittent interval versus self-paced continuous walking over a constant duration of 30 min. It was hypothesized that intermittent interval walking (IIW) would elicit higher exercise $\dot{V}O_2$ and EPOC values than intermittent and continuous walking.

METHODS

Study participants

Based on an a priori power analysis, ten adults were necessary to observe a low-moderate effect (effect size = 0.3, $\alpha = 0.05$, power = 80%, noncentrality parameter = 12.15, critical F = 3.63). The variance used in this analysis was determined from Peterson et al. (24). All participants completed a Physical Activity Readiness Questionnaire and medical history questionnaire to screen for health risks prior to beginning any study procedures. The sample consisted of four women and six men aged 19-40, without diagnosed metabolic, pulmonary, or cardiovascular disease (15). Eligible participants read and signed an informed consent approved by the local Institutional Review Board prior to participation.

The International Physical Activity Questionnaire (short version) (12) and modified Balke-Ware Treadmill Protocol (5) were administered to evaluate participants' current physical activity and fitness levels, respectively, during the initial visit. Anthropometric measurements (for descriptive purposes) of height (Seca, Gayamills, WI), weight (Tanita BWB-800, Japan), hip and waist circumferences (Gulick II Measuring Tape, Gaysmills, WI), and percent body fat via sum of skinfolds (17, 26) were obtained from participants prior to initial testing. Each participant was informed to refrain from consumption of any food or calorie-containing beverages two hours prior to testing and avoid moderate to vigorous exercise for at least 24 hours prior to each visit. Adherences to the guidelines were verified based on responses to a 24-hour history form.

Experimental Design

Each participant completed three counterbalanced trials. All protocols (1 trial of continuous walking, 1 trial of intermittent walking, 1 trial of intermittent interval walking) were

30 min duration each, and separated by a minimum of 48 hours. Walking protocols were performed on a treadmill (Quinton, Seattle, WA) at 0% grade in a room temperature environment (~22-23 °C), and scheduled within 1 hour of the same time of the day as the initial session. Exercise intensities for each walking protocol were self-selected by participants during specific time points in each session. Participants were not able to view the display for speed.

Each participant's baseline $\dot{V}O_2$ was measured during a 20-minute rest period while in a supine position before each exercise session. $\dot{V}O_2$ was measured breath-by-breath and averaged over 30 s using a metabolic cart (TrueOne 2400, Parvo Medics, Sandy, UT). The final 5 minutes of $\dot{V}O_2$during rest was considered baseline (31). Heart rate (HR; Polar, Lake Success, NY) was measured during each bout of walking and rest at 5 min intervals and rating of perceived exertion (RPE) was measured every 5 minutes during exercise. $\dot{V}O_2$ during exercise was calculated as $\dot{V}O_2$ while walking minus baseline $\dot{V}O_2$. Post-exercise $\dot{V}O_2$ was measured with participants in the supine position for 20 min following each bout of continuous, intermittent, and intermittent interval walking.

Participants walked for 30 min without stopping during the continuous walking bout whereas during the intermittent and IIW bouts they completed three 10-min periods of walking each separated by 20 min of rest (27) in a supine position. Prior to each exercise bout, participants were blinded to the initial low-moderate intensity (3 metabolic equivalents) (~ 4.8 km/h) (2, 3) set by a test administrator. Participants were allowed to adjust the exercise intensity by adjusting speed over a 50-s period every 5 min during exercise.

Prior to the start of the continuous and intermittent walking protocols, each person was instructed to set an initial preferred fairly light intensity (RPE = 12; low-moderate intensity) within 50-s and additional 50-s fairly light intensity adjustments every five minutes thereafter

(13). Participants were not allowed to make additional intensity adjustments following the cessation of the 50-s adjustment to ensure steady-state exercise. The continuous walking bout consisted of six 50-s intensity adjustment periods (0 min, 5 min, 10 min, 15 min, 20 min, 25 min) whereas bouts of intermittent walking consisted of only two adjustments (0 min, 5 min). IIW, however, consisted of cycled work bouts of 30 s (somewhat hard; RPE-13; high-moderate intensity) followed by active recovery bouts of 120 s (fairly light; RPE-12; low-moderate intensity). Participants were instructed to make 5-s work bout and 20-s active recovery bout intensity adjustments during each 30 s work bout and 120 s active recovery bout, respectively, of IIW. Each IIW bout consisted of eight intensity adjustments (0 min, 0.5 min, 2.5 min, 3 min, 5 min, 5.5 min, 7.5 min, 8 min). Borg's RPE scale (7) was used to define fairly light (RPE = 12; low-moderate) and somewhat hard (RPE = 13; high-moderate) intensities prior to each pre-walking $\dot{V}O_2$ and exercising $\dot{V}O_2$ measures. The exercise protocol is summarized in Figure 1.

Statistical Analyses

Accumulated O_2 uptake during exercise and EPOC were calculated as area-under-the-curve (20). Repeated measures analysis of variance (ANOVA) was used to compare treatments for accumulated O_2 uptake during exercise and EPOC. Heart rate and RPE were averaged during exercise and post-exercise and were also compared among treatments using repeated measures ANOVA. Cumulative EPOC was calculated every 5 min, and two-way repeated measures ANOVA was utilized compare treatments over time (treatment × time). In the event of significant omnibus effects, post-hoc bonferroni was performed to test for individual differences. An alpha level of 0.05 was used for all hypothesis tests.

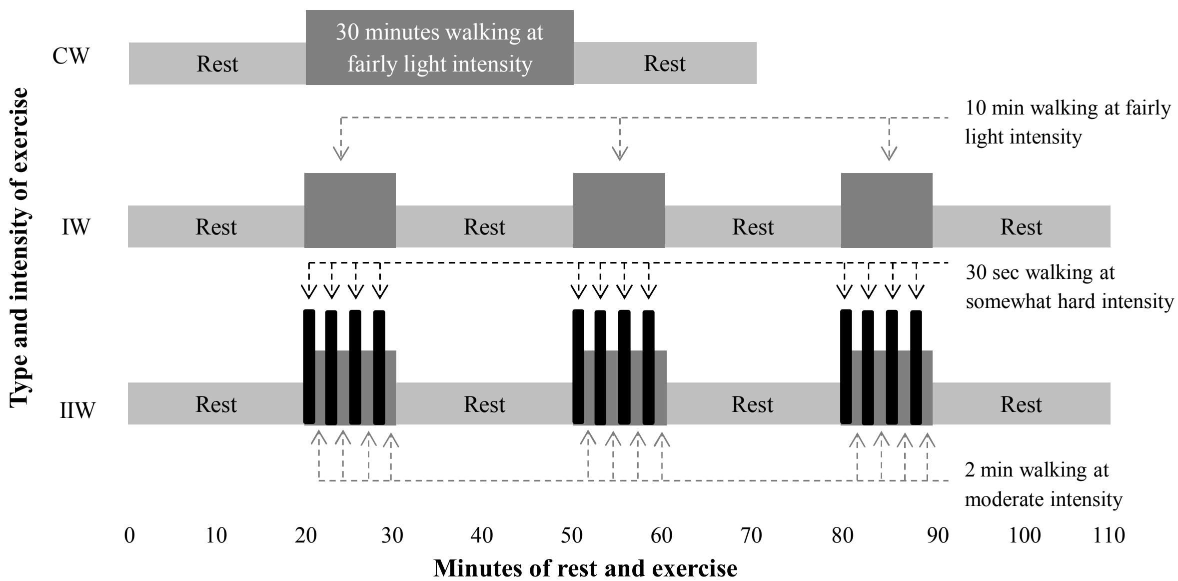
CW
Rest
30 minutes walking at fairly light intensity
Rest
10 min walking at fairly light intensity
IW
Rest
Rest
Rest
Rest
30 sec walking at somewhat hard intensity
IIW
Rest
Rest
Rest
Rest
2 min walking at moderate intensity
Type and intensity of exercise
0
10
20
30
40
50
60
70
80
90
100
110
Minutes of rest and exercise

Figure Caption

Figure 1. Schematic representation of the three self-paced walking intensity protocols. CW = continuous walking, IW = intermittent walking, IIW = intermittent interval walking.

RESULTS

Study participants' physical characteristics are portrayed in Table 1. Accumulated O_2 uptake above baseline was significantly higher during intermittent walking (43,204 ± 4,685 mL) and IIW (42,958 ± 4,327 mL) compared to continuous walking (19,521 ± 1,992 mL; both $p < 0.001$) of the same work duration (Figure 2). Intermittent and IIW accumulated O_2 uptake during exercise did not differ from each other.

A comparison of cumulative total 20-min EPOC for the three walking protocols showed a significant difference between continuous walking (1,412 ± 159 mL), IW (3,676 ± 443 mL), and IIW (3,422 ± 244 mL). Continuous walking produced a significantly lower EPOC value than intermittent walking ($p < 0.001$) and IW1 ($p < 0.001$). IIW and intermittent walking had similar cumulative total 20-min EPOCs.

5 min following exercise, intermittent walking (3,364 ± 329 mL) and IIW (3,263 ± 210 mL) elicited cumulative 5-min EPOC values that were significantly higher than continuous walking (1,124 ± 75 mL; both $p < 0.001$) (Figure 3). A rapid decline in EPOC near baseline was noted after the initial 5 min post-exercise (all $p > 0.05$).

Although significant $\dot{V}O_2$ above baseline differences were found during and post-exercise, mean exercise and post-exercise HR were similar. The walking protocols elicited average exercising HR of 109 ± 3 beats/min (continuous walking), 108 ± 4 beats/min (intermittent walking), and 110 ± 5 beats/min (IIW) and mean post-exercise HR of 67 ± 2 beats/min (continuous walking), 68 ± 3 beats/min (intermittent walking), and 66 ± 2 beats/min (IIW) (all $p > 0.05$). Continuous walking (11 ± 0.47), intermittent walking (11 ± 0.49), and IIW (12 ± 0.32) also elicited similar RPE during exercise.

Table 1. Descriptive characteristics of participants (men: n = 6; women: n = 4).

Variable	Mean ± SD
Age (y)	24 ± 5
Height (cm)	171 ± 6.9
Body mass (kg)	77.3 ± 21.8
Waist circumference (cm)	78.1 ± 12.2
Hip circumference (cm)	99.3 ± 12.0
% body fat	10.7 ± 4.3
MET-min/wk	3804 ± 1847

Table 2. Descriptive characteristics of participants (men: n = 6).

Variable	Mean ± SD
Age (y)	24 ± 5
Male height (cm)	174.5 ± 4.5
Male body mass (kg)	85.0 ± 18.6
Male waist circumference (cm)	81.7 ± 11.7
Male hip circumference (cm)	100.7 ± 11.6
Male % body fat	10.4 ± 4.7
Male MET-min/wk	4750 ± 1666

Table 3. Descriptive characteristics of participants (women: n = 4).

Variable	Mean ± SD
Age (y)	24 ± 5
Female height (cm)	166.0 ± 7.0
Female body mass (kg)	65.9 ± 23.7
Female waist circumference (cm)	72.8 ± 12.4
Female hip circumference (cm)	97.2 ± 14.1
Female % body fat	11.2 ± 4.1
Female MET-min/wk	2385 ± 1065

Figure 2

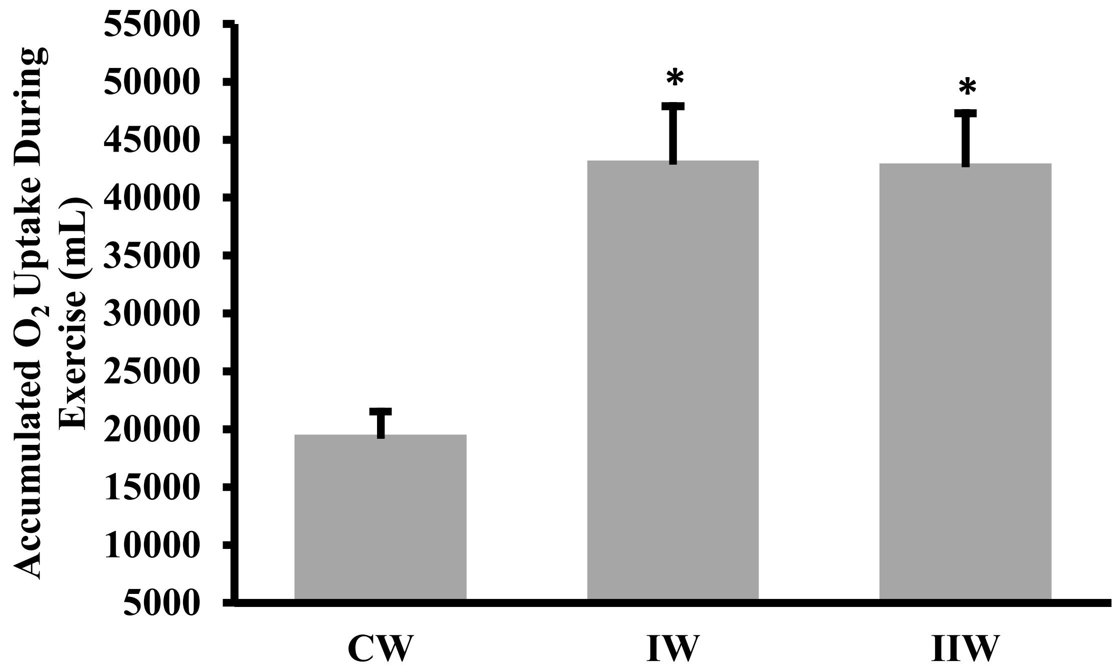

Figure 3

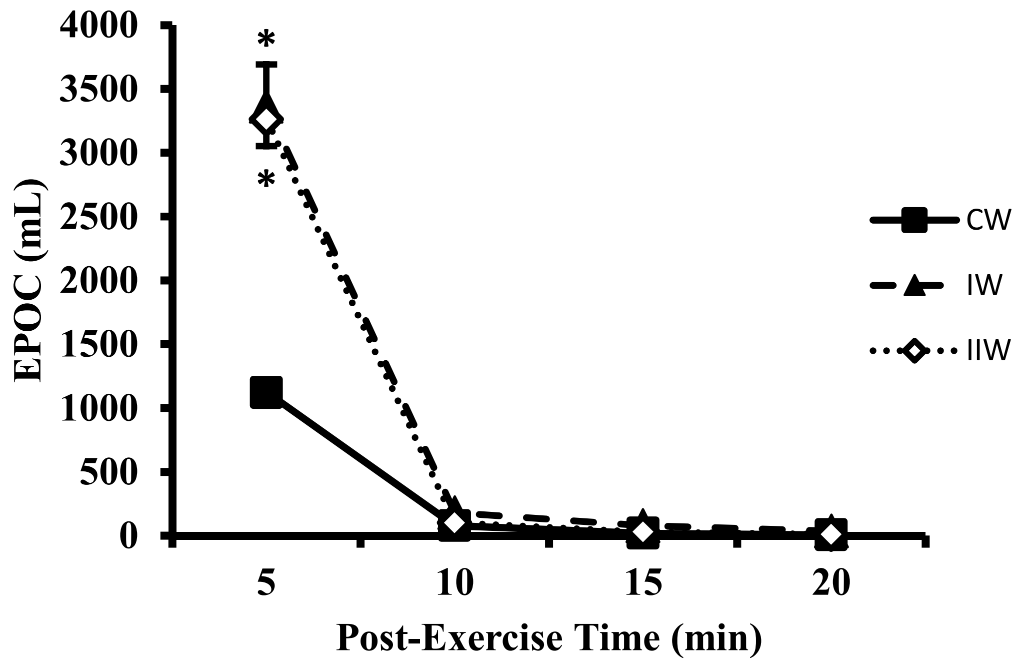

Figure Captions

Figure 2. Mean ± SD energy expenditure (reflected by accumulated O_2 uptake) during continuous, intermittent, and intermittent interval walking of 30 min total duration. CW = continuous walking, IW = intermittent walking, IIW = intermittent interval walking. * Significantly different from CW ($p < 0.05$).

Figure 3. Mean ± SD cumulative 5-min EPOC values during the 20-min recovery period following continuous, intermittent, and intermittent interval walking of 30 min total duration. CW = continuous walking, IW = intermittent walking, IIW = intermittent interval walking. A significant treatment × time interaction was found ($p < 0.001$). * Significantly different from CW ($p < 0.05$).

DISCUSSION

The primary purpose of the present investigation was to examine the acute metabolic effects of self-paced moderate-intensity intermittent and intermittent interval walking protocols on exercising $\dot{V}O_2$ and EPOC compared to continuous walking of the same overall duration. The primary finding was that both intermittent walking and IIW resulted in significantly higher energy expenditure (as reflected by accumulated O_2 uptake) during exercise and cumulative total 20-min EPOC than continuous walking. Given a constant total duration, college-aged adults may self-select higher exercise intensities during intermittent walking compared to continuous walking, yet these higher intensities will be perceived as similar to that during lower-intensity continuous walking (as reflected by similar RPE values during exercise).

Total exercise session kcal (exercise + 20-min EPOC) for each protocol were 105 (continuous walking), 234 (intermittent walking), and 216 kcal (IIW). The monthly (5 days a week for 4 weeks) kcal for each protocol were for continuous walking 2,094 kcal, for intermittent walking 4,672 kcal, and for IIW 4,638 kcal. Assuming the total kcal intake did not change over a monthly period, intermittent walking and IIW could account for caloric deficits resulting in a similar monthly weight loss of 1.3 pounds compared to a continuous walking monthly weight loss of 0.60 pounds.

Similar to a previous study conducted by Potteiger et al. (27) of constant intensity, the present findings suggest that acute self-paced moderate-intensity intermittent walking results in a higher EPOC value than continuous walking. Similarly, a study conducted by Almuzaini et al. (4) found that intermittent cycling (two, 15-min periods) bouts elicited a cumulative 20-min EPOC significantly larger than that from a single continuous 30-min bout of cycling of the same relative intensity.

Although the present findings suggest that intermittent walking resulted in significantly higher walking energy expenditure than continuous walking, a prior study found the opposite. Peterson et al. (24) found that no differences between one 30-min and three 10-min bouts of walking of the same intensity were evident during exercise. That previous study, however, used imposed exercise intensities on unfit men aged 40-49 years, which may explain the discrepant results.

Mechanisims that might explain the higher values associated with intermittent and intermittent interval walking are that during exercise $\dot{V}O_2$ reflect EPOCs from previous bouts of exercise. Similarly, accumulated mini EPOCs following 30-s work bouts of high-moderate walking could have increased the overall during and post-exercise $\dot{V}O_2$ of the participants.

Self-paced intensities selected by the participants seem to be higher in the intermittent exercises. This higher selected intensity would further explain the higher exercise and EPOC values of the study—higher intensity exercises utilize greater phosphocreatine and thus increase the amount of oxygen during recovery to replenish the energy stores. Additionally, the single 30 min bout of continuous walking may have deterred participants from selecting higher intensities comparable to the three 10-min bouts of intermittent and intermittent interval walking.

Future studies should examine the metabolic responses associated with intermittent walking and intermittent interval walking in middle-aged and older adults. Affective responses to these exercises should also be examined in this population.

As a response to reduced compliance of meeting the minimum physical activity recommendations of 150 min/week, greater emphasis should be placed on walking to promote physical activity due to its safety and effectiveness in promoting health. Williams and Raynor (32) noted that greater perceived choice was evident when participants freely choose their physical activity intensity versus having it imposed on them. Additionally, in a study conducted outside of our laboratory, we found that self-paced continuous and interval walking protocols of 20 min duration did not alter adult females pre-, during-, and post- exercise enjoyment. Therefore, allowing participants to self-regulate the intensity of walking sessions in a moderate RPE range (RPE 12-13) may increase feelings of positive affect states which contribute to better exercise adherence.

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APPENDIX A: IRB APPROVAL LETTER

Office for Research

Institutional Review Board for the Protection of Human Subjects

THE UNIVERSITY OF ALABAMA RESEARCH

July 14, 2014

Jermaine Mitchell, MAED, CSCS
Department of Kinesiology
College of Education
The University of Alabama
Box 870312

Re: IRB # 14-OR-219-ME "Impact of Increase Intensity Walking Training on Physiological and Perceptual Responses"

Dear Mr. Mitchell:

The University of Alabama Institutional Review Board has reviewed the revision to your previously approved expedited protocol. The board has approved the change in your protocol.

Please remember that your approval period expires one year from the date of your original approval, June 10, 2014, not the date of this revision approval.

Should you need to submit any further correspondence regarding this proposal, please include the assigned IRB application number. Changes in this study cannot be initiated without IRB approval, except when necessary to eliminate apparent immediate hazards to participants.

Good luck with your research.

Sincerely,

Director & Research Compliance Officer
Office for Research Compliance
The University of Alabama

358 Rose Administration Building
Box 870127
Tuscaloosa, Alabama 35487-0127
(205) 348-8461
FAX (205) 348-7189
TOLL FREE (877) 820-3066

Office for Research

Institutional Review Board for the
Protection of Human Subjects

THE UNIVERSITY OF
ALABAMA
RESEARCH

July 14, 2014

Jermaine Mitchell, MAED, CSCS
Department of Kinesiology
College of Education
The University of Alabama
Box 870312

Re: IRB # 14-OR-220-ME "Physiological and Perceptual Responses to Continuous Walking vs. Two Fractionalized Walking Protocols"

Dear Mr. Mitchell:

The University of Alabama Institutional Review Board has reviewed the revision to your previously approved expedited protocol. The board has approved the change in your protocol.

Please remember that your approval period expires one year from the date of your original approval, June 10, 2014, not the date of this revision approval.

Should you need to submit any further correspondence regarding this proposal, please include the assigned IRB application number. Changes in this study cannot be initiated without IRB approval, except when necessary to eliminate apparent immediate hazards to participants.

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APPENDIX B: RPE SCALE

Rating	Perceived Exertion
6	No exertion
7	Extremely light
8	
9	Very light
10	
11	Light
12	
13	Somewhat hard
14	
15	Hard
16	
17	Very hard
18	
19	Extremely hard
20	Maximal exertion

The Borg Rating of Perceived Exertion Scale

Gunnar Borg 1985

APPENDIX C: 24-HOUR HISTORY QUESTIONNAIRE

ID ______________
Date ______________
Time ______________

1. How many hours of sleep did you get last night? __________

2. How many hours of sleep do you normally get? ___________

3. How many hours has it been since your last meal or snack? _____________

4. When did you last have:
   · a cup of coffee, tea, or caffeine? ____________________________

   · cigarettes? ____________________________

   · drugs (including aspirin)? ____________________________

   · alcohol? ____________________________

   · herbal/dietary supplements? ____________________________

5. How many glasses of water or other beverages have you consumed in the last 24 hours?

6. When did you last consume water or another beverage? _____________How much? ________ (glasses)

7. What sort of physical activity did you perform yesterday?

8. What sort of physical activity have you performed today?

9. What day are you in your menstrual cycle? _______________

10. How many days does your menstrual cycle typically last? ___________________

11. Describe your general feelings by checking one of the following:

______excellent
______very, very good
______very good
______good
______neither good nor bad
______bad
______very bad
______very, very bad
______terrible

APPENDIX D: HEALTH SCREENING QUESTIONNAIRE

Date ________________

Name

____

______

Last First MI

Address

____

_____

Street Apt #

____

____

City State Zip Code

Contact

____

____

Home Phone Cell Phone Email

Date of Birth___________________ Age___________ Sex________ Ht______ Wt________

MM/DD/YYYY

Occupation

____

__

Emergency Contact

____

Name Relationship Phone

List any medicines, drugs, and herbal products or dietary supplements you are now taking:

____

____

____

____

____

Explain any other significant medical problems you consider it important for us to know:

____

____

____

____

____

(continued on next page)

Adapted from AHA/ACSM Health/Fitness Facility Preparticipation Screening Questionnaire as shown in: Preparticipation Health Screening. In: *ACSM's Guidelines for Exercise Testing and Prescription*, edited by L. S. Pescatello, R. Arena, D. Riebe, and P.D. Thompson. Philadelphia, PA: Wolters Kluwer; Lippincott Williams & Wilkins, 2014, p. 19-38.
Assess your health status by marking all *true* statements:

History

You have had:
_____ a heart attack
_____ heart surgery
_____ cardiac catheterization
_____ coronary angioplasty (PTCA)
_____ pacemaker/implantable cardiac defibrillator/rhythm disturbance
_____ heart valve disease
_____ heart failure
_____ heart transplantation
_____ congenital heart disease

Symptoms

_____ You experience chest discomfort with exertion
_____ You experience unreasonable breathlessness
_____ You experience dizziness, fainting, or blackouts
_____ You experience ankle swelling
_____ You experience unpleasant awareness of a forceful or rapid heart rate
_____ You take heart medications

Other health issues

_____You have diabetes
_____You have asthma or other lung disease
_____You have burning or cramping sensation in your lower legs when walking short distances
_____ You have musculoskeletal problems that limit your physical activity
_____ You have concerns about the safety of exercise
_____ You take prescription medications
_____ You are pregnant

Cardiovascular Risk Factors

_____ You are a man ≥ 45 years
_____ You are a woman ≥ 55 years
_____ You smoke or quit smoking within the previous 6 months
_____ Your blood pressure is > 140/90 mm Hg
_____ You do not know your blood pressure
_____ You take blood pressure medication
_____ Your blood cholesterol level is ≥ 200 mg/dL
_____ You do not know your cholesterol level
_____ You have a close blood relative who had a heart attack or heart surgery before age 55 (father or brother) or age

65 (mother or sister)
_____ You are physically inactive (i.e., you get < 30 minutes of physical activity on at least 3 days per week)
_____ You have a body mass index ≥ 30 kg/m2
_____ You have prediabetes
_____ You do not know if you have prediabetes
_____ None of the above

APPENDIX E: PHYSICAL ACTIVITY READINESS QUESTIONNAIRE (PAR-Q)

Physical Activity Readiness Questionnaire - PAR-Q (revised 2002)

PAR-Q & YOU

(A Questionnaire for People Aged 15 to 69)

Regular physical activity is fun and healthy, and increasingly more people are starting to become more active every day. Being more active is very safe for most people. However, some people should check with their doctor before they start becoming much more physically active.

If you are planning to become much more physically active than you are now, start by answering the seven questions in the box below. If you are between the ages of 15 and 69, the PAR-Q will tell you if you should check with your doctor before you start. If you are over 69 years of age, and you are not used to being very active, check with your doctor.

Common sense is your best guide when you answer these questions. Please read the questions carefully and answer each one honestly: check YES or NO.

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

If you answered

YES to one or more questions

Talk with your doctor by phone or in person BEFORE you start becoming much more physically active or BEFORE you have a fitness appraisal. Tell your doctor about the PAR-Q and which questions you answered YES.

- You may be able to do any activity you want — as long as you start slowly and build up gradually. Or, you may need to restrict your activities to those which are safe for you. Talk with your doctor about the kinds of activities you wish to participate in and follow his/her advice.
- Find out which community programs are safe and helpful for you.

NO to all questions

If you answered NO honestly to all PAR-Q questions, you can be reasonably sure that you can:

- start becoming much more physically active – begin slowly and build up gradually. This is the safest and easiest way to go.
- take part in a fitness appraisal – this is an excellent way to determine your basic fitness so that you can plan the best way for you to live actively. It is also highly recommended that you have your blood pressure evaluated. If your reading is over 144/94, talk with your doctor before you start becoming much more physically active.

DELAY BECOMING MUCH MORE ACTIVE:

- if you are not feeling well because of a temporary illness such as a cold or a fever – wait until you feel better; or
- if you are or may be pregnant – talk to your doctor before you start becoming more active.

PLEASE NOTE: If your health changes so that you then answer YES to any of the above questions, tell your fitness or health professional. Ask whether you should change your physical activity plan.

Informed Use of the PAR-Q: The Canadian Society for Exercise Physiology, Health Canada, and their agents assume no liability for persons who undertake physical activity, and if in doubt after completing this questionnaire, consult your doctor prior to physical activity.

No changes permitted. You are encouraged to photocopy the PAR-Q but only if you use the entire form.

NOTE: If the PAR-Q is being given to a person before he or she participates in a physical activity program or a fitness appraisal, this section may be used for legal or administrative purposes.

"I have read, understood and completed this questionnaire. Any questions I had were answered to my full satisfaction."

NAME ________________________________

SIGNATURE ________________________________ DATE ________________________________

SIGNATURE OF PARENT ________________________________ WITNESS ________________________________
or GUARDIAN (for participants under the age of majority)

Note: This physical activity clearance is valid for a maximum of 12 months from the date it is completed and becomes invalid if your condition changes so that you would answer YES to any of the seven questions.

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APPENDIX G: INTERNATIONAL PHYSICAL ACTIVITY QUESTIONNAIRE (IPAQ)

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 have done 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

This is the end of the questionnaire, thank you for participating.

SHORT LAST 7 DAYS SELF-ADMINISTERED version of the IPAQ. Revised August 2002.