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Energy Cost of Land and Shallow Water Walking in Females who are Overweight and Obese

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Abstract

Nineteen overweight or obese females completed three 10-minute experimental trials including a self-selected pace shallow water walking trial, a matched heart rate response land walking trial, and a self-selected pace land walking trial. Energy expenditure (kcal·min^{-1}) was computed from expired gases assessed via indirect calorimetry. Results showed energy expenditure was lower (*p= 0.046*) during shallow water walking (6.46 ± 1.38 kcal·min^{-1}) compared to matched heart rate response land walking trial (7.26 ± 1.29 kcal·min^{-1}), with no significant difference in between shallow water and self-selected pace land walking (6.92 ± 1.61 kcal·min^{-1}). The present study did not demonstrate superior energy cost of shallow water walking. However, results demonstrate that shallow water walking elicits an increase in energy expenditure, which may indicate that this form of activity is a reasonable alternative to land-based walking. Moreover, this form of activity may be particularly effective for individuals with mobility limitations during land-based exercise.

Keywords: energy expenditure, aquatic exercise, physical activity, obesity

Introduction

Overweight and obesity affect approximately 70 percent of adults in the United States (Fryar, Carroll, & Odgden). This is of significant public health concern because of the association between excess body weight with cardiovascular disease, diabetes, cancer, and musculoskeletal disorders (Jensen et al., 2014). Thus, intervention strategies that create a negative energy balance can be of particular importance for the treatment of obesity.

A key behavior that contributes to negative energy balance is physical activity, which may modestly contribute to weight loss (Foreyt & Goodrick, 1994). While land-based walking is typically prescribed as a form of physical activity within weight management programs, the American College of Sports Medicine also recommends other non-weight bearing activities for adults who are overweight or obese to minimize the potential musculoskeletal strain that may result with excess body weight (*ACSM's Guidelines for Exercise Testing and Prescription.*, 2017). One such non-weight bearing recommendation is for adults who are overweight or obese to engage in water-based activity. While typically thought of as swimming, there are other forms of activity that do not require the individual to be proficient with swimming to obtain the potential benefits of being active in water (Barker et al., 2015; Carroll, Volpe, Morris, Saunders, & Clifford, 2017; da Silva Rosa, Martinez, & Peyré-Tartaruga, 2017; Gomes et al., 2016; Kanitz et al., 2015; Kargarfard, Shariat, Ingle, Cleland, & Kargarfard, 2017; E. F. Nagle et al., 2007; E.F. Nagle, Sanders, & Franklin, 2017; Raffaelli, Milanese, Lanza, & Zamparo, 2016; Sanders, Islam, Naruse, Takeshima, & Rogers, 2016; Shono, Fujishima, Hotta, Ogaki, & Masumoto, 2001; Wang, Belza, Thompson, Whitney, & Bennett, 2007). These activities have typically adapted traditional land-based activities (i.e., walking, jogging, calisthenics, and additional locomotor/resistive movements) to a water medium (D'Acquisto, D'Acquisto, & Renne, 2001). Pertinent to this study is the potential appeal of shallow water walking, which does not require prior swimming skill (Shono et al., 2001), and may reduce the weight-bearing characteristics of traditional land-based walking (Di Prampero, 1986).

Despite the clinical recommendation for adults who are overweight or obese to consider water-based activity, such as shallow water walking, there is limited data on how this form of physical activity compares to land-based activity in this population group. Specifically, it is unknown whether shallow water walking provides a similar metabolic stimulus to land-based walking in adults who are overweight or obese. Previous research has reported reduced heart rates in the water compared to land based activity, potentially due to the hemodynamic changes that occur with immersion (Darby & Yaekle, 2000; Silvers, Rutledge, & Dolny, 2007). Moreover, it is unclear if adults who are overweight or obese have similar perceptual responses of exertion for land and water-based activities. These findings may have important clinical implications if water-based activity is shown to have a comparable or higher metabolic cost compared to land and if this is coupled with a similar or lower perceived exertion during water-based versus land-based activities.

Thus, the purpose of this study is threefold: 1) to compare the energy cost of a bout of land walking performed at a self-selected pace to the energy cost of a bout of shallow water walking performed at a self-selected pace; 2) to compare the energy cost between a bout of shallow water walking performed at a self-selected pace, and a bout of land walking performed at a determined pace to elicit a matched heart rate response to that obtained during the bout of shallow water walking; 3) to investigate the influence of body weight and composition on energy expenditure during self-selected pace land and shallow water walking in adult females who are overweight or obese.

Methods

Participants

Nineteen healthy female adults who were overweight or obese (age: 42.11± 10.30 years; body mass index [BMI]: 30.92 ± 3.78 $kg \cdot m^{-2}$) volunteered to participate in this study. Subjects were recruited from research registries at the University of Pittsburgh, with community-posted fliers, and with online recruitment sites. Written informed consent was obtained from each individual. Exclusion criteria included BMI < 25.0 or > 44.9 $kg \cdot m^{-2}$, a history of heart disease, diabetes, orthopedic conditions that limited exercise, pulmonary diseases any other health problem that may interfere with exercise testing, and regular use of medication

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known to affect heart rate. To control for the influence of water depth on energy expenditure, subjects were excluded if they did not meet the height criteria of 154.9cm (61 inches) to 172.7cm (68 inches) (Alkurdi, Sadowski, Paul, & Dolny, 2010; Barbosa, Garrido, & Bragada, 2007). Additionally, all subjects underwent an orientation and assessment session to confirm eligibility and familiarize them with the experimental protocols and equipment. This study was approved by the University of Pittsburgh Institutional Review Board.

Study Design and Experimental Sessions

This study utilized a crossover design, with participants serving as their own control. Eligible participants reported for three separate experimental trials following the initial orientation and assessment session. Each of the experimental conditions were performed on separate days with the trials consisting of 1) a shallow water exercise trial, 2) a land-based exercise trial that was matched to the heart rate achieved during the shallow water exercise trial, or 3) a land-based self-selected pace exercise trial (as described below). Because the heart rate from shallow water exercise trial was used to establish the workloads in the land-based heart rate matched trial, the shallow water exercise always preceded the land-based heart rate matched trial. With this in mind, the order of the trials was otherwise randomized to minimize testing bias. Consistent with procedures of previous studies, the experimental trials were separated by at least 48 hours but not more than 7 days (Cassady & Nielsen, 1992; Phillips, Legge, & Jones, 2008; Whitley & Schoene, 1987). Prior to each experimental trial, participants were instructed to refrain from vigorous exercise and the use of alcohol and tobacco for 24 hours, and were instructed to abstain from food other than water for 4 hours. Compliance was confirmed by participants upon arrival to each experimental session. Upon arrival at the laboratory on each experimental day the subject was fitted with the necessary metabolic and heart rate monitor equipment, and then was seated for 5 minutes to allow for acclimatization.

Shallow Water Exercise Trial. The shallow water exercise trial was conducted in a large swimming pool at the University of Pittsburgh with a water depth of 1.07 meters, placing the water level approximately between the xiphoid and umbilicus for all subjects. Air temperature was maintained at approximately 27.5° Celsius. This session was 10 minutes in duration. Subjects were instructed to walk at a "comfortable brisk walking pace that they perceived could be sustained for the entire 10-minute period." During the initial 5 minutes, the subjects were prompted at 30-second intervals to adjust their pace (faster or slower) if they felt it necessary to do so in order to complete the entire 10-minute experimental session. After the initial 5-minute period the subjects were instructed to attempt to maintain their current pace throughout the remainder of the exercise session, which was later analyzed through video analysis of the water pace per length. Walking pace was not monitored in real time, and the investigators did not prompt the subjects to alter pace during final 5- minutes of the exercise trial.

Land-Based Heart Rate Matched Exercise Trial. Subjects completed a land-based trial that involved walking on a treadmill at a workload that was matched to the heart rate response of the shallow water exercise trial. The heart rate was matched to the average heart rate obtained during the last 5 minutes of the shallow water exercise trial, with the target heart rate being within ± 5 beats per minute of this average heart rate. The treadmill was set at an initial speed of 1.0 mph and 0% incline, with the speed increased at 0.5 mph until the target heart rate was achieved. After the initial 5 minutes, speed was adjusted by ± 0.1 mph at 1-minute intervals as needed to maintain the heart rate within the target range throughout the test. Throughout the walking session the subject was kept blinded to their actual walking speed.

Land-Based Self-Selected Pace Exercise Trial. Subjects completed a land-based trial that involved walking on a treadmill at a self-selected walking pace. The self-selected walking pace was described to the subject as the "comfortable brisk walking pace that they felt could be sustained for 10 minutes." The treadmill was set at an initial speed of 1.0 mph and 0% incline. During the initial 5 minutes, at 30 second intervals the subject indicated whether they wanted to increase, decrease, or maintain the current speed to elicit their perceived brisk walking pace, with adjustments made at 0.5 mph increments. The speed of the treadmill achieved at the conclusion of the initial 5 minutes was maintained through the remainder of the experimental session. Throughout the walking session the subject was kept blinded to their actual walking speed.

Instrumentation and Procedures

Indirect Calorimetry. Oxygen consumption, carbon dioxide production, respiratory exchange ratio (RER) and expired volume were measured during the shallow water walking and land trials using the portable Cosmed $K4b^2$ metabolic unit and Aquatrainer mask attachment (Chicago, IL), allowing for an in-pool measure of expired gas volume and concentrations. The validity and reliability of the device has been previously established for land and water use (Baldari et al., 2012). The Aquatrainer attachment was used during the shallow water walking trial and a facemask attachment was used during the land trials. All data, including heart rate detected by a Polar monitor (Kempele, Finland) were transmitted by telemetry from the Cosmed $K4b^2$ portable unit to a personal computer and collected in real time. Participants breathed into a fitted mouthpiece with the nose clipped off for the duration of each exercise test. Expired volume concentrations of oxygen and carbon dioxide were analyzed by open circuit spirometry in 15-second intervals. The primary outcome was energy expenditure per minute ($kcal \cdot min^{-1}$) of the last 5 minutes of each trial, which was determined from oxygen consumption ($L \cdot min^{-1}$) using the non-protein caloric equivalent based on RER to adjust for energy substrate utilization. Energy expenditure relative to body weight ($kcal \cdot min^{-1} \cdot kg^{-1}$) utilizing the assumed resting value ($3.5\ mL \cdot kg^{-1} \cdot min^{-1}$), were calculated by the Cosmed K4b^2 (Parr, Strath, Bassett, & Howley, 2001).

Rating of Perceived Exertion (RPE). The Borg 15-category rating scale of perceived exertion was used to measure perceived effort immediately following each 10-minute exercise bout. Prior to testing, the scale was described to the participant to ensure their understanding using a standardized script (Borg, 1982).

Anthropometric Measurements. Measures of body dimensions and composition were assessed. Height and weight were collected using a free-standing stadiometer and digital scale, and were utilized to calculate BMI (kg/m^2) to classify overweight or obesity status. Body composition was assessed utilizing a Tanita bioelectrical impedance analyzer (Arlington Height, IL). Circumference measurements of the waist (measured horizontally at the iliac crest), the hip (measured horizontally at the widest part of the hip), and the thigh (measured midway between the inguinal crease and the proximal border of the patella, perpendicular to the long axis) were measured utilizing standardized procedures (*ACSM's Guidelines for Exercise Testing and Prescription.*, 2017). Leg length was measured vertically from the greater trochanter to the base of the lateral malleolus (*ACSM's Guidelines for Exercise Testing and Prescription.*, 2017).

Statistical Analysis

Statistical analyses were performed using SPSS version 21.0. Statistical significance was set at $p<0.05$. Normality of the data was assessed using a Shapiro-Wilk test. Descriptive analyses were performed for age, height, weight, BMI, percent body fat, waist circumference, hip circumference, thigh girth, and leg length. One-way repeated measures analysis of variance (ANOVA) was performed for all physiological and perceptual variables across exercise trials. Only the final 5-minutes of the test were used for data analysis to allow the participant to establish a comfortable and maintainable walking pace, as well as steady state. When appropriate, post-hoc comparisons (dependent t-tests) were made using the Bonferonni adjustment to determine which conditions were significantly different.

To examine the relationship between obesity status (BMI), body composition (percent body fat), and the difference in energy cost between land and water, correlations coefficients were computed. First, the difference in relative energy expenditure ($kcal \cdot min^{-1} \cdot kg^{-1}$) was calculated by subtracting the energy expenditure during the shallow water walking trial from the land trial (i.e., Land Exercise Trial minus Shallow Water Exercise Trial). Thus, a positive number would indicate greater energy expenditure during the land trial while a negative number would indicate greater energy expenditure during the shallow water walking trial. The correlation between this difference in energy expenditure and both BMI and percent body fat were computed. The nonparametric equivalent of the Spearman correlation was utilized for non-normal data, including the difference in relative energy expenditure between shallow water walking and the matched heart rate response land exercise trial ($W = 0.824$, $p = 0.018$).

Results

Participant Characteristics

Table 1 represents the physical characteristics of the female participants. Of the 19 participants, 7 were classified as overweight (BMI 25.0 to <30.0 $kg \cdot m^{-2}$), 10 participants were classified as Class I Obese (BMI 30.0 to <35.0 $kg \cdot m^{-2}$), 1 participant was classified as Class II Obese (BMI 35.0 to <40.0 $kg \cdot m^{-2}$), and 1 participant was classified as Class III Obese (BMI $\geq$ 40.0 $kg \cdot m^{-2}$) at the time of the physical assessment.

Table 1. Demographic and anthropometric physical characteristics of participants (N= 19)

	Mean ± SD	**Range**
Age (years)	42.11 ± 10.30	21-55
Height (cm)	163.70 ± 4.55	156.10-171.10
Weight (kg)	83.25 ± 13.70	63.30-118.50
BMI ($kg \cdot m^{-2}$)	30.91 ± 3.78	25.80-40.50
Percent Body Fat (%)	39.54 ± 6.37	26.20-48.50
Waist Circumference (cm)	99.17 ± 9.13	86.05-122.35
Hip Circumference (cm)	112.74 ± 8.16	98.80-133.00
Waist-to-Hip Ratio (cm)	0.88 ± 0.06	0.76-0.99
Thigh Circumference (cm)	55.29 ± 5.44	47.75-67.90
Leg Length (cm)	84.08 ± 4.72	75.20-92.00

Walking Pace

Data were analyzed to determine whether the walking pace during the last 5 minutes of the shallow water exercise trial was maintained per protocol (Table 2). Video of the shallow water walking to determine walking pace was available for 14 of the 19 subjects. The walking pace during the final 5 minutes of the shallow water exercise trial was 0.58 ± 0.06 $m \cdot sec^{-1}$. Subjects fluctuated their walking pace by 0.06 ± 0.01 $m \cdot sec^{-1}$ throughout this period (range: 0.08-0.04 $m \cdot sec^{-1}$). The walking pace was significantly lower during shallow water walking compared to both land-based walking trials.

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Physiological and Perceptual Variables

Physiological and perceptual variables are presented in Table 2. Heart rate did not differ significantly between the three experimental sessions (*p= 0.860*). However, during the matched heart rate response land exercise trial, 3 participants were unable to achieve the target heart rate during the last 5 minutes of the test with two participants falling below and one falling above the target heart rate range. When excluded from the analysis, the results remained unchanged and were therefore included in the final analysis. Additionally, participants achieved approximately 71% of their age-predicted maximal heart rate (APMHR) during the shallow water walking trial, and 72% of APMHR during the land trials, with no difference between trials *(p= 0.825).*

RPE did not differ significantly between the experimental conditions (*p= 0.439*). Expired volume was significantly lower during the shallow water walking trial compared to the heart rate matched land trial (difference= 5.61 ± 6.05 $L \cdot min^{-1}$; *p=0.001*), with no significant differences for other trial comparisons. RER was significantly lower in the shallow water walking trial (0.85 ± 0.07) compared to both the heart rate matched land trial (0.90 ± 0.07*; p=0.001*) and the self-paced land trial (0.88 ± 0.07; *p=0.014*).

Oxygen Consumption and Energy Cost

Oxygen consumption ($mL \cdot kg^{-1} \cdot min^{-1}$) was not significantly different between the experimental sessions (*p= 0.077*). However, energy expenditure ($kcal \cdot min^{-1}$) was significantly lower (difference = 0.8 $kcal \cdot min^{-1}$; *p=0.001*) for the shallow water walking trial (6.46 ± 1.38) compared with the heart rate matched land trial (7.26 ± 1.29), but not compared to the self-paced walking trial (6.92 ± 1.61).

Energy Cost and Body Weight and Composition

To examine the influence of body weight and composition on energy cost, the association between the difference in energy expenditure between each of the land-based exercises and shallow water walking (difference computed as land-based minus shallow water walking), and measures of body composition (BMI and percent body fat), were examined using correlation coefficients (Table 3, Figure 1). BMI (ρ= 0.551; *p= 0.014*) and percent body fat (ρ= 0.556; *p= 0.013*) were significantly correlated with the difference in energy expenditure between the matched heart rate response land trial and shallow water walking trial. These results indicate that as BMI or percent body fat increase, the difference between the energy expenditure during the water and land exercise became smaller, such that individuals with higher levels of obesity and/or body fatness may produce similar caloric expenditure during shallow water and land-based walking. Correlations between BMI and percent body fat and the difference in energy expenditure between the self-selected pace land trial and the shallow water walking trial were not statistically significant.

Table 2 Walking pace, physiological, and perceptual responses during trials.

	Shallow Water Trial (Mean ± SD)	Matched Heart Rate Response Land Trial (Mean ± SD)	Self-Selected Pace Land Trial (Mean ± SD)	P-Value*
Average Walking Pace ($m \cdot s^{-1}$) ***	0.58 ± 0.06	1.48 ± 0.33	1.45 ± 0.35	<0.001
Difference with Shallow Water Exercise Trial	---	-0.90 ± 0.29 *(p= <0.001)***	-0.87 ± 0.31 *(p <0.001)***	
Difference with Matched Heart Rate Response Land Exercise Trial	---	---	-0.02 ± 0.21 *(p = 0.743)*	
Heart Rate ($beats \cdot min^{-1}$)***	125.25 ± 14.66	125.84 ± 13.80	126.97 ± 15.60	0.860
Difference with Shallow Water Exercise Trial	---	-0.59 ± 4.38	-1.79 ± 16.00	
Difference with Matched Heart Rate Response Land Exercise Trial	---	---	-0.90 ± 15.35	
Rating of Perceived Exertion (RPE)****	11.84 ± 1.09	12.21 ± 1.84	11.68 ± 1.60	0.439
Difference with Shallow Water Exercise Trial	---	-0.37 ±2.11	0.16 ± 1.57	
Difference with Matched Heart Rate Response Land Exercise Trial	---	---	0.53 ± 1.71	
Expired Volume ($L \cdot min^{-1}$)***	37.61 ± 9.91	43.22 ± 10.07	40.39 ± 11.42	0.027
Difference with Shallow Water Exercise Trial	---	-5.61 ± 6.05 *(p = 0.001)***	-2.79 ± 10.23 *(p = 0.251)*	
Difference with Matched Heart Rate Response Land Exercise Trial	---	---	2.82 ± 9.09 *(p = 0.193)*	
Respiratory Exchange Ratio (RER)***	0.85 ± 0.07	0.90 ± 0.07	0.88 ± 0.07	0.001

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Difference with Shallow Water Exercise Trial	---	-0.05 ± 0.06 ($p = 0.001$)**	-0.03 ± 0.05 ($p = 0.014$) **	
Difference with Matched Heart Rate Response Land Exercise Trial	---	---	0.01 ± 0.04 ($p = 0.152$)	
Oxygen Consumption (mL·kg^{-1}·min^{-1})* **	16.28 ± 3.31	18.13 ± 3.96	17.40 ± 4.83	0.077
Difference with Shallow Water Exercise Trial	---	-1.85 ± 2.60	-1.12 ± 3.77	
Difference with Matched Heart Rate Response Land Exercise Trial	---	---	0.73 ± 3.87	
Energy Expenditure (kcal·min^{-1})* **	6.46 ± 1.38	7.26 ± 1.29	6.92 ± 1.61	0.046
Difference with Shallow Water Exercise Trial	---	0.80 ± 0.93 ($p = 0.001$)**	0.46 ± 1.48 ($p=0.192$)	
Difference with Matched Heart Rate Response Land Exercise Trial	---	---	0.34 ± 1.56 ($p = 0.354$)	

**P-value represents comparison of experimental conditions using a one-way analysis of variance.*
***Significant difference between experimental sessions with the critical p-value adjusted for multiple comparisons using the Bonferroni procedure ($p<0.0167$).*
****Based on the mean for minutes 6-10 of the experimental session.*
*****Measured at the completion of the experimental session.*

Discussion

The present study compared energy expenditure in shallow water walking and land walking in a sample of women who were overweight or obese. Results showed that when physiologically matched based on heart rate, the energy expenditure during shallow water walking is lower compared to land-based treadmill walking (difference = 0.80 ± 0.93 kcal·min^{-1}). When the walking pace during land-based on a treadmill is self-selected, there is a similar pattern observed with the energy expenditure being lower in the shallow water walking (difference = 0.46 ± 1.48 kcal·min^{-1}), although not statistically significant. Thus, the results do not support the findings of prior research that suggested the water environment would result in higher levels of energy expenditure relative to comparable land-based exercise (Campbell, D'Acquisto, D'Acquisto, & Cline, 2003; Darby & Yaekle, 2000).

Table 3 Correlations coefficients between differences in energy expenditure across exercise conditions and both BMI and percent body fat. (N=19)

	Correlation	P-Value
BMI vs. Difference* in Energy Expenditure between Shallow Water Walking and:		
Matched Heart Rate Response Land Walking	ρ= -0.551	0.014
Self-Selected Land Walking	r= -0.293	0.224
Body fat % vs. Difference* in Energy Expenditure between Shallow Water Walking and:		
Matched Heart Rate Response Land Walking	ρ= -0.556	0.013
Self-Selected Land Walking	r= - 0.405	0.085

**Difference in energy expenditure computed as land walking minus shallow water walking.*

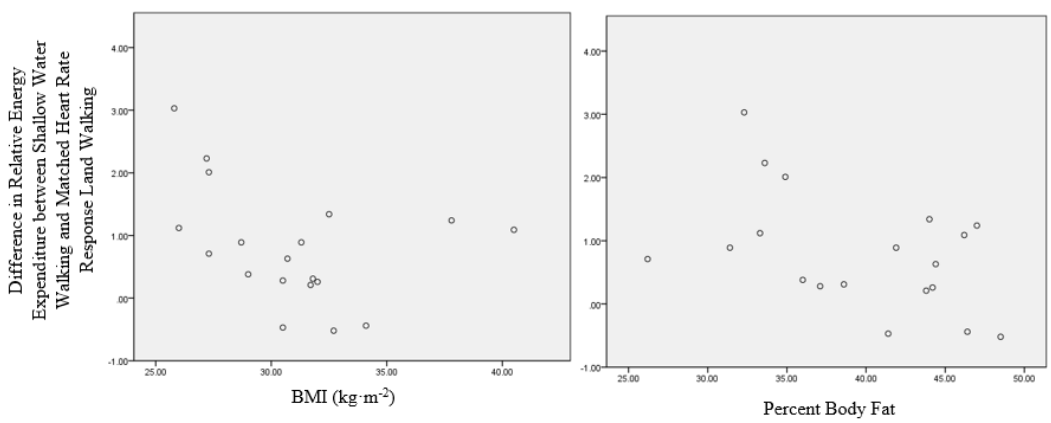

Figure 1. Correlation between BMI, percent body fat and differences in energy expenditure between shallow water walking and matched heart rate response land walking

The difference in findings compared to prior studies may be partially explained by methodological differences. Darby and Yaekle (2000) reported that at a comparable heart rate, performing various exercises in water elicited 2-6 $mL \cdot kg^{-1} \cdot min^{-1}$ greater oxygen consumption than when performing similar exercises on land (Darby & Yaekle, 2000). However, this investigation included callisthenic exercises that isolated the legs only or combined arm and leg activities that were performed at various cadences, whereas the current study relied solely on walking as the mode of exercise. However, Nagle and colleagues (2013) report energy cost ranging from 4.0- 8.4 $kcal \cdot min^{-1}$ for a variety of shallow water aquatic exercise activities, eliciting an average of 6.3 $kcal \cdot min^{-1}$ during a 40-minute exercise session (E.F. Nagle et al., 2013), Although the previous study utilized both cardiorespiratory and muscular endurance training activities, similar to that of a typical aquatics exercise session, the average energy cost observed was similar to that of shallow water walking in the present study.

A finding of this study was that shallow water walking elicited an energy expenditure similar to that of land-based treadmill walking at a self-selected pace. The self-selected land-based walking pace was 1.4 $m \cdot sec^{-1}$, which is similar to previously reported walking speeds of normal weight adults (1.4 $m \cdot sec^{-1}$) and slightly faster than observed walking speeds in obese women with a BMI above 35.0 $kg \cdot m^{-2}$ (1.2 $m \cdot sec^{-1}$) (Di Prampero, 1986; Margaria, 1976; Ralston, 1958; Zarrugh, Todd, & Ralston, 1974). However, despite the self-selected pace of shallow water walking being slower than the pace of land-based walking (0.58 ± 0.06 $m \cdot sec^{-1}$ vs. 1.45 ± 0.35 $m \cdot sec^{-1}$), the energy expenditure was comparable. This confirms the finding reported by both Migita et al. and Shono et al., which showed that a slower walking pace in water was required to elicit a similar oxygen consumption to what was observed with land-based walking (Migita et al., 1994; Shono et al., 2001). These findings may have implications for individuals with mobility limitations that limit the pace at which they can walk, suggesting that a shallow water environment for walking, with increased buoyancy and drag forces, may be beneficial for eliciting an oxygen consumption and energy expenditure that would be comparable to land-based treadmill walking.

While this study compared land-based treadmill walking to shallow water walking that involved completing laps in a pool, other studies have used an aquatic treadmill with varying speeds to examine energy expenditure. These studies showed a greater oxygen consumption when walking on an aquatic treadmill compared to a treadmill on land (Darby & Yaekle, 2000; Hall, Macdonald, Maddison, & O'hare, 1998; Masumoto, Shono, Hotta, & Fujishima, 2008; Migita et al., 1994; Shono et al., 2001; Silvers et al., 2007). Hall and colleagues compared water and land-based treadmill walking at three speeds (3.5, 4.5, and 5.5 $km \cdot h^{-1}$) and found that oxygen consumption was similar when walking at 3.5 $km \cdot h^{-1}$, but was significantly higher in the shallow water at 4.5 and 5.5 $km \cdot h^{-1}$ (Hall et al., 1998). Masumoto et al. also observed significantly higher oxygen consumption with walking at 2.4 $km \cdot h^{-1}$ in water versus land (Masumoto et al., 2008). By comparison, the self-selected pace of shallow water walking in this current study was (0.58 ± 0.06 $m \cdot sec^{-1}$ or 2.0 $km \cdot h^{-1}$), and this resulted in a similar oxygen consumption but lower energy expenditure compared to land-based treadmill walking at the same heart rate (see Table 2). Walking across the pool in this current study likely resulted in increased drag forces, which resulted in a slower walking pace but with a higher oxygen consumption than what would have been achieved with an aquatic treadmill. For example, Gleim and Nicholas reported oxygen consumption of 8.6 ± 0.4 $mL \cdot kg^{-1} \cdot min^{-1}$ with subjects walking at approximately 0.67 $m \cdot sec^{-1}$ on an aquatic treadmill, while the current study showed that at a comparable walking pace (0.58 ± 0.06 $m \cdot sec^{-1}$) in water without an aquatic treadmill the oxygen consumption was 16.28 ± 3.31 $mL \cdot kg^{-1} \cdot min^{-1}$ (Gleim & Nicholas, 1989). These differences in experimental methods may partially explain the difference in findings in the current study compared to prior studies.

A strength of this study is the standardization of methods during the shallow water walking trial. Prior studies have suggested that oxygen consumption of aquatic exercise is influenced by both buoyancy and drag forces added by the water (Kato, Onishi, & Kitagawa, 2001). For example, when buoyancy is inadequate to provide substantial limb unloading of weight, as is typically seen in water levels below the waist, drag forces imposed by fluid resistance substantially elevate the metabolic cost (Gleim & Nicholas, 1989; Pohl & Mcnaughton, 2003). Additionally, the influence of buoyancy is dependent on water depth. Alkurdi and colleagues reported that shallower water depths (10 cm below the xiphoid process) elicited higher amounts of energy expenditure than both land walking and deeper water depths (10 cm above the xiphoid process) (Alkurdi et al., 2010). Therefore, these factors may have contributed to the energy expenditure in shallow water observed in the current study (Di Prampero, 1986; Evans, Cureton, & Purvis, 1978). Thus, the current study attempted to control for the influence of water depth, which would influence buoyancy and drag forces, by setting standardizing the height of study subjects between 154.9 cm (61 inches) to 172.7 cm (68 inches). This limited height range, however, limits the generalizability of the results to individuals with height lesser or greater than this range. Moreover, while this study included subjects with a wide range of BMI and percent body fat, few subjects were included that would be categorized with Class II or III obesity, which may limit the ability of this study to determine the influence of the broad range of BMI and body fatness on the results of this study. The correlations shown in Table 3 and Figure 1, however, suggest that at a higher BMI or percent body fat the energy expenditure between shallow water walking and a heart rate matched land-based treadmill walking session

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approach similar values. This study also examined responses to a 10-minute bout of exercise, and future studies are needed to determine if exercise of longer duration would elicit similar is different physiological responses.

Physical activity is an important lifestyle behavior that contributes to body weight regulation, and therefore may be important for both prevention and treatment of overweight and obesity, as previous studies have demonstrated (Baena-Beato et al., 2014; E. F. Nagle et al., 2007). While the current investigation did not demonstrate that shallow water walking was superior to land-based treadmill walking, the findings of the present study have practical significance. Of note, the results of this study indicate that shallow water walking at a self-selected pace, as would be the case in typical physical activity intervention, results in a similar energy expenditure compared to a land-based treadmill walking, when performed at a self-selected pace. Additionally, the results of the current investigation show that during the shallow water walking bout and the land walking bout respectively, participants achieved approximately 71% and 72% of their age-predicted maximal heart rate and 12 on the RPE scale. Based on recommendation set forth by the American College of Sports Medicine (64-76% HR_{max} and 12-13 RPE), these parameters for both modes of exercise meet the criteria of moderate intensity exercise (Garber et al., 2011).

Therefore, a significant finding of this study is that while not superior to land-based treadmill walking, shallow water walking may be a reasonable alternative to land-based walking for eliciting an increase in energy expenditure, meeting ACSM criteria for moderate intensity exercise. While not specifically examined in this study, the added benefits of buoyancy unloading the weight on the limbs while increasing resistance through drag forces, may shallow water walking be particularly effective for individuals with weight related mobility limitations during land-based exercise, and warrants further investigation.

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