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ORIGINAL ARTICLE

Comparison of energy expenditure, economy, and pedometer counts between normal weight and overweight or obese women during a walking and jogging activity

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Abstract This study compared energy expenditure (EE), economy of movement, and pedometer counts between normal weight and overweight or obese women during a treadmill walking and jogging activity. Participants were 13 normal weight (BMI 22.2 ± 2.0 kg m^{-2}) and 13 overweight or obese (BMI 27.2 ± 2.1 kg m^{-2}) women and all were non-smokers, not regularly active, and able to run 1.609 km continuously at 2.23 m s^{-1}. Each participant reported to the laboratory on three separate days within a 1-week period. During the first visit, tests for resting metabolic rate via indirect calorimetry, anthropometric measures, and $\dot{V}O_2$max were completed. On the subsequent two visits, participants were randomized to perform either a 1.609-km walk at 1.34 m s^{-1} or a 1.609-km jog at 2.23 m s^{-1}. During each physical activity trial, all participants wore a pedometer to assess steps taken. EE during the 1.609-km walk was 280 ± 29 kJ for the normal weight and 356 ± 42 kJ for the overweight/obese women and during the 1.609-km jog was 393 ± 46 kJ for the normal weight and 490 ± 59 kJ for the overweight/obese women. In both trials, EE was statistically greater in the overweight/obese women. Economy of movement was not statistically different between the normal weight and overweight/obese women during the walk or jog. In both groups, pedometer counts were lower during the jog than the walk ($P < 0.05$). These data indicate significant differences in EE between normal weight and overweight/obese women during both a walking and jogging activity.

Keywords Energy expenditure · Walking · Jogging · Obesity

Introduction

It is well established that the prevalence of overweight and obesity has increased worldwide (Filozof et al. 2001; Ford and Mokdad 2008; Martorell et al. 2000; Ogden et al. 2006; Yoon et al. 2006) and is associated with increased risk for multiple chronic and metabolic diseases, psychosocial problems, and orthopedic impairments (Frey and Zamora 2007; Ogden et al. 2006; Reeves et al. 2007; Stein and Colditz 2004). According to the National Heart, Lung, and Blood Institute, modest weight loss results in significant health benefits and is desirable for overweight and obese individuals; however, their minimum recommendation is to prevent further weight gain (NHLBI 1998). As there is a general trend for adults to gain weight each year, prevention of weight gain (i.e., weight maintenance) is important and may reduce the risk for chronic disease and assist in keeping lower-risk individuals from becoming high risk.

Weight maintenance results from balancing energy intake with energy expenditure (EE). Components of total

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daily EE include resting metabolic rate (RMR), thermic effect of food, and spontaneous and planned physical activity, which account for ~65–75%, 10%, and 15–25% of total daily EE, respectively (Ravussin and Bogardus 1992). Physical activity (PA) is known to be an important contributor for weight maintenance (Wing and Phelan 2005) and is the only component of EE that is easily modifiable from day to day. As a result, health professionals generally focus on the PA component as a means of increasing EE and to adjust for small imbalances in energy intake (Hill et al. 2003; Rodearmel et al. 2007). Recent guidelines have promoted moderate-intensity activities for five or more days per week or vigorous intensity activities for three or more days per week and have included suggestions to achieve these recommendations (Haskell et al. 2007). Additionally, there are promising behavioral tools, such as pedometers, that may enhance the likelihood of achieving current PA recommendations (Tudor-Locke and Bassett 2004).

Despite the known benefits of PA and exercise, there is evidence that EE during a given activity is often overestimated (Buchowski et al. 1999; Walsh et al. 2004) and as a result, the contribution of PA for weight management may be exaggerated by some individuals. Prediction equations, though useful, can be inconsistent tools to determine EE for walking and jogging activities (Hall et al. 2004) and common "rules of thumb", such as 1.609 km of walking equals 418 kJ, may not take into account important variables that affect EE. It is, therefore, useful to accurately assess the EE associated with common physical activities and for individuals to use that information for effective weight management.

Walking and jogging are common modes of PA and are often utilized as part of a weight management program. Variables such as body mass, intensity, training level, and gender have been reported in the literature to influence the energy cost of walking and jogging activities. However, much of the literature utilizes a lean or trained subject population. In addition, available studies that compare normal weight and overweight/obese individuals for EE during a given PA (Browning and Kram 2005; Lafortuna et al. 2008; Lafortuna et al. 2006; Rutter 1994) rarely include both walking and jogging to account for the influence of intensity on EE.

Therefore, the purpose of this study was to augment existing literature by determining the extent that EE differed during a walking (1.609 km at 1.34 m s^{-1}) and jogging (1.609 km at 2.23 m s^{-1}) activity between normal weight and overweight/obese women. In addition, this study assessed net EE, economy of movement, and pedometer counts for each participant in order to provide objective and applicable data for women utilizing PA for weight management.

Materials and methods

Participants

This study received Institutional Review Board approval and each participant signed an informed consent prior to initiating the study. Thirteen overweight/obese women (BMI of $\geq$25 kg m^{-2}) and 13 normal weight women (BMI < 25 kg m^{-2}) were recruited. Participants were healthy and free of disease as determined by a physical activity readiness questionnaire (PAR-Q) and health history questionnaire. Participants were non-smokers, not on medications that affect metabolism (thyroid, hypertensive, antidepressant medications, etc.), pre-menopausal, 18–26 years of age, untrained (vigorous exercise <3 times/week), not pregnant or lactating, able to walk 1.609 km continuously at 1.34 m s^{-1} (3 mph), and able to jog 1.609 km continuously at 2.23 m s^{-1} (5 mph). Participants were recruited via campus email, fliers, and word of mouth.

Procedures

Participants reported to the Exercise Physiology Laboratory on three separate occasions, each separated by at least 24 h, and within a 7-day period (Tues, Thurs, Sat or Mon, Wed, Fri) at exactly the same time of morning and under the same conditions (6–9 a.m., no vigorous exercise for at least 24 h, no caffeine for 12 h, no energy consumption for 8 h). In addition, participants were asked to wear the exact same clothes and shoes during each visit and to continue to eat their regular diet. During each visit the laboratory was kept at approximately the same temperature and humidity.

During the first visit, participants were asked to void and were then measured for height using a Seca 214 Portable Height Rod (Itin Scale Co., Inc, Brooklyn, New York, USA) and body weight using a portable platform digital scale (Befour Inc, Saukville, WI.), both while barefoot and wearing a standardized hospital gown. Body mass index (BMI) was then calculated as kg m^{-2}. Abdominal circumference was measured using the umbilicus as a reference point and hip circumference was measured at the widest part of the gluteus maximus using a Gulick measuring tape (Fitness Wholesale, Stow, OH).

Resting metabolic rate (RMR) was then estimated using indirect calorimetry with a ParvoMedics TrueOne® 2400 metabolic measurement system (Sandy Lake, UT). The system was calibrated with 19.52% O_2 and 1.0% CO_2 from a compressed tank and a flow meter calibration was performed using a 3-L syringe with a flow rate between 40–50 L min^{-1} per stroke. During calibration and prior to RMR testing each participant sat quietly in a chair for 5 min. During RMR testing each participant lied comfortably in the supine position on an exam table in a private room, with a clear-colored ventilated hood fitted comfortably over the neck and head. A flexible plastic canopy draped over the anterior torso and tucked under the back was used to prevent unwanted flow in and out of the hood, which was connected to the metabolic cart with flexible tubing. In this way, oxygen consumption was captured in the hood and flowed through the hose to the metabolic cart for analysis and determination of RMR. Participants were asked to position themselves in a way that would keep them from fidgeting and were not allowed to talk or fall asleep during the test. After positioning the participant, flow was adjusted so room air (22–26°C) was drawn through the hood at a rate of 15–30 L min^{-1} while keeping expired CO_2 around 1.1 ± 0.1%. Data collection lasted for 30 min with the last 25 min averaged into an estimate of RMR.

Subsequently, participants were measured for body composition using the BOD POD® (Life Measurements Inc, Concord, CA). The BOD POD® has been used in other studies as a valid and reliable body composition assessment technique (Fields et al. 2002; Levenhagen et al. 1999). Predicted lung volume was used, which has been shown to be as accurate as measured lung volume (Collins and McCarthy 2003; Demerath et al. 2002), and the Siri equation was applied to estimate percent body fat. Participants wore a tight bathing suit or skin-tight clothing, a skull cap to compress the hair, removed jewelry and glasses before measurements, and were asked to sit comfortably still while breathing normally during measurements.

Lastly, aerobic fitness ($V\text{O}_2$max) was assessed using the TrueOne® 2400 with a Quinton SR 60 motor driven treadmill (Bothel, WA, USA). Calibration of the metabolic measurement system for this test and the 1.609-km trials consisted of using a 16.0% O_2 and 4.0% CO_2 concentration gas, with flow calibrated using a 3-L syringe. Nose clips and a proper fitting mouthpiece connected to a one-way valve were used to ensure all expired air flowed into the metabolic cart. A Polar chest strap was fitted and interfaced with the metabolic cart for measurement of heart rate. The Bruce Protocol was used to elicit maximal oxygen consumption with an initial treadmill speed of 0.76 m s^{-1} (1.7 mph) on a 10% grade. At 3 min, metabolic data, HR, and RPE (Borg's 6–20 rating of perceived exertion) were recorded and the treadmill speed then increased to 1.12 m s^{-1} (2.5 mph) with a simultaneous increase to 12% grade. The test continued in this manner with increases in speed to 1.52 m s^{-1} (3.4 mph), 1.88 m s^{-1} (4.2 mph), 2.23 m s^{-1} (5.0 mph), and a 0.22 m s^{-1} (0.5 mph) increase thereafter with 2% increases in grade every 3 min until voluntary exhaustion. A cool-down consisted of walking on level grade at 1.12 m s^{-1} (2.5 mph) for 2 min. At least two of the following criteria were considered achievement of $V\text{O}_2$max: respiratory exchange ratio (RER) over 1.10, a leveling off in $V\text{O}_2$ consumption (a change no greater than 150 ml between stages), or ±10 beats of estimated maximum heart rate. At this time, the 1.609-km trials (walk or jog) were randomized and the second visit was scheduled.

Immediately before the second visit, participants were asked to void and then a DIGI-WALKER™ SW-701 pedometer (New Lifestyles, Lee's Summit, MO) was placed on the right waist along the front of the thigh for step counts during the 1.609-km trials. This pedometer was selected because it is frequently used in epidemiological and intervention studies due to its accuracy (Crouter et al. 2003; Schneider et al. 2004; Speck and Looney 2006). Participants then sat comfortably in a chair for 10 min at which time expired air was collected using the metabolic cart. After 10 min, the mouthpiece was removed and the participant completed a warm-up that consisted of walking for 5 min at 1.12 m s^{-1} (2.5 mph) on level grade. Upon conclusion of the warm-up, participants straddled the treadmill, the mouthpiece was again fitted, and the pedometer reset to zero. The treadmill was brought up to either 1.34 m s^{-1} (3 mph) or 2.23 m s^{-1} (5 mph), both on 0% grade, and participants began to walk or jog after 1 min of completing the warm-up. Participants were allowed to use the handrails only while mounting the treadmill. The walking speed of 1.34 m s^{-1} (3 mph) was chosen as it falls within a moderate-intensity walking pace (3–6 METs)(Haskell et al. 2007) and the jogging speed of 2.23 m s^{-1} (5 mph) was chosen as it is considered a vigorous intensity (6 METs or greater) (Haskell et al. 2007) but not so intense as to decrease the likelihood that overweight or obese individuals could complete a continuous 1.609-km jog. At exactly 1.609 km, the participants immediately straddled the treadmill, the mouthpiece was removed, RPE was recorded, and step counts from the pedometer were recorded. Oxygen consumption was measured during each of the trials and used to determine gross EE. The third visit was conducted in the same manner as the second with only the speed of locomotion changed during the 1.609-km trial.

Statistical analysis

PC-SAS (version 8.2, SAS Institute, Inc., Cary, NC) was used for all descriptive statistics (mean, standard deviation, etc.) and unpaired *t* tests were used to statistically determine differences between the normal weight and overweight/obese women for all outcomes reported. An alpha level of $P < 0.05$ was used to determine significance for all statistical analyses. In order to determine the actual EE cost of just exercise, net EE (EE above RMR) was determined by subtracting RMR per minute of exercise (20 min for walk and 12 min for jog) from the gross EE. Economy of movement (energy requirement of a given velocity of movement) was reported as the average relative oxygen consumption (ml kg^{-1} min^{-1}) during the walk and jog. In order to determine exercise intensity, the average relative oxygen consumption during the walk or jog was divided by VO_2max (ml kg^{-1} min^{-1}) and multiplied by 100. Pearson correlation coefficients were used to determine relationships between descriptive characteristics and pedometer counts. Where appropriate, body mass and fat-free mass (FFM) were added to the statistical models as control variables.

Results

Participants were 26 women (13 normal weight and 13 overweight/obese), young, and primarily Caucasian (88%), while the remaining 12% were 2 African-Americans and 1 Asian-American. There was no difference in age or height between the normal weight and overweight/obese women ($P > 0.05$). The overweight/obese participants averaged a BMI that was 5 kg m^{-2} higher and a body weight that was 15.6 kg heavier than the normal weight participants. In addition, abdominal and hip circumference were significantly higher in the overweight/obese individuals ($P < 0.05$). Body fat percentage tended to be higher in the overweight/obese participants ($P = 0.07$) and FFM percentage tended to be lower in the overweight/obese participants compared to the normal weight participants ($P = 0.07$). However, when expressed in kg, both fat mass and FFM were higher in the overweight/obese individuals ($P < 0.05$) (Table 1).

Resting metabolic rate was 13% higher in the overweight/obese participants compared to the normal weight participants ($P < 0.05$). When RMR was adjusted for body mass and FFM, there was no longer a difference in RMR ($P > 0.05$). VO_2max (ml kg^{-1} min^{-1}) was significantly greater in the normal weight women though both groups, on average, tended to possess a poor to fair level of fitness (Heyward 2006). HRmax, RPEmax, and RERmax during the VO_2max test were not statistically different between the normal weight and overweight/obese participants. Time to exhaustion (min) during the VO_2max test was significantly shorter in the overweight/obese participants compared to the normal weight participants (Table 2).

Table 1 Demographic and body composition characteristics

	Normal weight ($n = 13$)	Overweight/ obese ($n = 13$)	P
Age (years)	21.2 ± 1.5	20.2 ± 1.4	0.12
Weight (kg)	59.8 ± 6.1	75.4 ± 5.7	<0.00
Height (cm)	164.1 ± 4.8	166.6 ± 5.1	0.23
BMI (kg m^{-2})	22.2 ± 2.0	27.2 ± 2.1	<0.00
Body fat (%)	27.3 ± 7.0	32.3 ± 3.2	0.07
Fat mass (kg)	16.6 ± 5.7	24.4 ± 5.7	<0.00
Fat-free mass (%)	72.7 ± 7.0	67.7 ± 6.3	0.07
Fat-free mass (kg)	43.2 ± 3.8	50.7 ± 5.1	<0.00
Abdominal (cm)	76.0 ± 5.3	89.4 ± 8.0	<0.00
Hip (cm)	93.5 ± 4.4	106.9 ± 4.0	<0.00

Values are mean ± SD

Gross EE was 27% higher in the overweight/obese participants compared to the normal weight participants during the 1.609-km walk (356 vs. 280 kJ, respectively) ($P < 0.05$). Net EE during the 1.609-km walk was also higher (31%) in the overweight/obese individuals compared to the normal weight individuals (259 vs. 197 kJ, respectively) ($P < 0.05$). Gross EE was 25% higher in the overweight/obese group compared to the normal weight group during the 1.609-km jog (490 vs. 393 kJ, respectively) ($P < 0.05$). Likewise, net EE during the 1.609-km jog was 28% higher in the overweight/obese individuals compared to the normal weight individuals (431 vs. 338 kJ, respectively) ($P < 0.05$). When expressed per unit of FFM (kg) or body mass (kg), or when FFM or body mass was statistically controlled for, there was no difference between the normal weight and overweight/obese participants for gross or net EE during the walk or jog ($P > 0.05$).

The overweight/obese participants tended to have higher HR, RPE, and average RER during both the 1.609-km walk and jog compared to the normal weight participants; however, only HR and average RER during the 1.609-km jog were statistically significant. When intensity was expressed as a percentage of VO_2max (ml kg^{-1} min^{-1}), the overweight/obese women worked at a higher relative intensity than the normal weight women for both the walk and the

Table 2 Resting metabolic rate and maximal oxygen consumption

	Normal weight ($n = 13$)	Overweight/ obese ($n = 13$)	P
RMR [kJ day (kcal day)]	6,113 ± 678 (1,461 ± 162)	6912 ± 515 (1,652 ± 123)	<0.00
RMR·FFM (kg)$^{-1}$ (kJ day)	141.7 ± 10.2	137.5 ± 15.9	0.43
Resting RER	0.84 ± 0.03	0.83 ± 0.04	0.84
VO_2max (ml kg^{-1} min^{-1})	38.5 ± 5.6	31.9 ± 3.2	<0.00
HRmax (bpm)	181 ± 13	186 ± 9	0.30
RPEmax	16.8 ± 2.9	17.7 ± 1.4	0.36
RERmax	1.13 ± 0.07	1.15 ± 0.06	0.45
Time to Exhaustion (min)	10.7 ± 1.9	9.3 ± 1.0	0.03

Values are mean ± SD

RMR resting metabolic rate, *kJ day* kilojoules per day, *kcal day* kilocalories per day, *HR* heart rate, *RPE* rating of perceived exertion (Borg's 6–20 scale), *RER* respiratory exchange ratio jog ($P < 0.05$). Economy of movement, as expressed by average VO_2, during either the walk or jog (Morgan et al. 1989) was not statistically different between BMI groups (Table 3).

During the 1.609-km walk there was no difference in pedometer counts between the overweight/obese individuals (2,365 ± 272) and the normal weight individuals (2,339 ± 85) ($P > 0.05$). Similarly, during the 1.609-km jog, there was no difference in pedometer counts between the 2 groups (1,902 ± 103 vs. 1,862 ± 153 for overweight/obese and normal weight individuals, respectively) ($P > 0.05$). However, within each group, the 1.609-km walk resulted in approximately 25% more pedometer counts than the 1.609-km jog ($P < 0.05$) (Fig. 1). Controlling for height did not change the difference in pedometer steps during the walk or jog, between or within groups. Correlation analysis revealed that height was indirectly related to pedometer steps during the walk ($r = -0.417$, $P < 0.05$) but not jog ($r = -0.17$, $P > 0.05$). When the relationship between height and pedometer steps was analyzed by BMI group, height was moderately and negatively associated with walking ($r = -0.657$, $P < 0.05$) and jogging ($r = -0.554$ $P < 0.05$) counts in the overweight/obese but not normal weight participants.

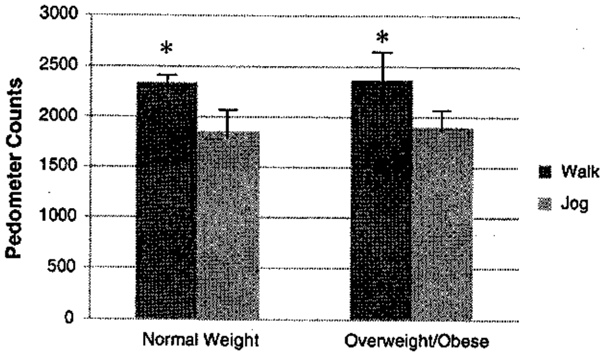

Fig. 1 Pedometer counts during the 1.609-km walk and 1.609-km jog. *Asterisk* indicates significant difference between walk and jog within each group. Walking counts were not different ($P = 0.75$) nor were jogging counts different ($P = 0.44$) between the normal weight and overweight/obese women

Table 3 Energy expenditure during the 1.609-km walk and 1.609-km jog

	Normal weight ($n = 13$)	Overweight/ obese ($n = 13$)	P
1.609-km walk			
Gross EE [kJ (kcal)]	280 ± 29 (67 ± 7)	356 ± 42 (85 ± 10)	<0.00
Net EE [kJ (kcal)]	197 ± 21 (47 ± 5)	259 ± 38 (62 ± 9)	0.04
Ending HR (bpm)	100 ± 9.0	107 ± 12	0.11
Ending RPE	9.4 ± 1.9	10.5 ± 1.4	0.09
Intensity (%VO_2max)	31.2 ± 4.7	35.8 ± 3.9	0.01
Average RER	0.85 ± 0.04	0.86 ± 0.02	0.44
EE kg^{-1} min^{-1}	0.24 ± 0.02	0.24 ± 0.01	0.98
EE FFM $(kg)^{-1}$ min^{-1}	0.33 ± 0.03	0.35 ± 0.05	0.10
VO_2 (ml kg^{-1} min^{-1})	11.8 ± 0.9	11.3 ± 0.4	0.10
1.609-km jog			
Gross EE [kJ (kcal)]	393 ± 46 (94 ± 11)	490 ± 59 (117 ± 14)	<0.00
Net EE [kJ (kcal)]	338 ± 46 (82 ± 11)	431 ± 59 (103 ± 14)	<0.00
Ending HR (bpm)	160 ± 18	176 ± 20.5	0.05
Ending RPE	13.0 ± 2.2	15.1 ± 3.0	0.06
Intensity (%VO_2max)	70.6 ± 9.1	80.8 ± 10.7	0.01
Average RER	0.91 ± 0.04	0.96 ± 0.06	0.02
EE kg^{-1} min^{-1}	0.55 ± 0.04	0.54 ± 0.04	0.50
EE FFM $(kg)^{-1}$ min^{-1}	0.77 ± 0.09	0.80 ± 0.09	0.25
VO_2 (ml kg^{-1} min^{-1})	26.7 ± 1.9	25.4 ± 1.6	0.08

Values are mean ± SD

Gross EE total energy expenditure during the trial, *net EE* total energy expenditure during the trial minus resting metabolic rate, *EE* kg^{-1} min^{-1} energy expenditure (kJ) per kilogram of body weight, *EE FFM(kg)* $^{-1}$ min^{-1} energy expenditure (kJ) per kilogram of fat-free mass

Discussion

This study compared EE in normal weight and overweight/obese women during a walking and jogging activity to provide valid and quantitative data for women utilizing PA for weight management. This study supports existing literature that body mass significantly impacts RMR and EE during a given PA (Browning et al. 2006; Browning and Kram 2005; Freyschuss and Melcher 1978; Lafortuna et al. 2008), and the intensity of the PA significantly influences EE (Greiwe and Kohrt 2000; Hall et al. 2004). While differences in EE during the walk and jog disappeared for both BMI groups when adjusting for body mass and FFM, gross EE remained approximately 25% higher for the overweight/obese women during the walk and jog. This study is unique in that the overweight/obese participants were untrained but able to run continuously for 1.609 km; whereas, other studies have typically used trained individuals or cycling as the mode of exercise when comparing normal weight and overweight individuals (Hulens et al. 2001; Lafortuna et al. 2008). In addition, we quantified EE objectively using indirect calorimetry as opposed to prediction equations or PA questionnaires. Further, a female population was used to control for potential gender differences in EE (Browning et al. 2006).

The effect of walking and jogging activities has received considerable attention in the literature. Based upon previous research, the EE of walking versus speed for a given distance resembles a U-shaped curve (Bastien et al. 2005; Browning and Kram 2005; Ralston 1958) with the walking speed that elicits the minimum EE at approximately 1.3–1.4 m s^{-1} (Alexander 2005; Bastien et al. 2005; Martin et al. 1992; Zarrugh et al. 1974). Slower walking has been associated with increased EE (Browning and Kram 2005), while walking at greater speed for a given distance increases EE in a curvilinear fashion (Bastien et al. 2005; Browning and Kram 2005). Furthermore, previous studies have indicated that the walking speed associated with the minimum EE (1.3–1.4 m $s^{-1)}$ to be approximately equal to preferred speed of walking for normal weight individuals (Browning and Kram 2005). While previous reports indicate obese individuals tend to prefer a slower speed of walking than normal weight adults, Browning and Kram recently reported similar preferred speeds of walking (Browning and Kram 2005). Thus, while variations in walking speed result in differences in EE for a given distance, the speed of walking utilized in the present study (1.34 m s^{-1}) and the associated EE likely generalizes well to normal weight and overweight/obese individuals as it may be comparable to their preferred speed of walking utilized for exercise.

There appears to be a point in which fast walking costs more energy than jogging at the same speed (Falls and Humphrey 1976). This crossover point tends to be the speed in which there is a spontaneous transition from walking to jogging and is associated with jogging speeds of 2.2–2.5 m s^{-1} (McArdle et al. 2007; Menier and Pugh 1968). In addition, EE during jogging and running activities appears to be independent of speed for a given a distance, incline, and person. For example, a woman jogging 2.23 m s^{-1} for 1.609 km results in similar EE as running 3.6 m s^{-1} for 1.609 km at the same grade; only the time to completion differs (McArdle et al. 2007). In the present study, the speed of 2.23 m s^{-1} was chosen because it represents "vigorous" intensity activity, it was a feasible jogging speed for some larger individuals, and it corresponds well to the speed of spontaneous jogging rather than fast walking. As a jogging speed of 2.23 m s^{-1} for 1.609 km is not likely to be a typical speed for fast walking and also scales similarly to higher intensity jogging/running speeds, the data from the present study provides a good estimation of EE for both normal weight and overweight/obese individuals jogging for 1.609 km.

As expected, increasing intensity over 1.609 km resulted in significantly higher EE in both the normal weight and overweight/obese women. The role of intensity, therefore, appears important to consider when utilizing PA for weight management. Jogging at 2.23 m s^{-1} for 1.609 km equated to approximately 40% more EE than walking at 1.34 m s^{-1} over the same distance in both groups of women. In the normal weight women, this equated to 113 kJ per 1.609 km more during jogging than walking and in the overweight/obese women 134 kJ per 1.609 km more during jogging than walking. Hypothetically, if these women were to jog 16.09 km per week at 2.23 m s^{-1} instead of walking 16.09 km per week at 1.34 m s^{-1}, the difference in EE would be equivalent to 58,760 kJ per year or almost 2 kg of body fat for the normal weight women and 69,680 kJ per year or 2+ kg of body fat for the overweight/obese women.

We recognize that some individuals have orthopedic issues or other physical limitations that prevent jogging or other high impact activities. Fortunately, recent scientific evidence shows moderate-intensity walking to be associated with beneficial weight management outcomes in active individuals (Mougios et al. 2006) as well as in those who begin an exercise program (Williams and Thompson 2006). Nevertheless, findings from the present study highlight the potentially meaningful difference increasing intensity can have on EE and potentially on body weight over time. Thus, appropriately adding intensity is worth consideration when prescribing or beginning an exercise program.

In the present study, economy of movement, typically defined as the steady-state VO_2 needed to maintain a given velocity of movement (Morgan et al. 1989), was not statistically different between BMI groups after normalizing for body mass (kg). There may be biomechanical and body mass distribution differences between normal weight and obese individuals that result in differences in EE (Browning et al. 2006) and movement economy (Hulens et al. 2001). Further, increased recruitment of muscle fibers, increased power output, high braking forces, and high mediolateral forces have all been postulated as variables affecting economy that increase EE during exercise (Kyrolainen et al. 2001). As our study did not assess these variables, we are unable determine their effect on economy of movement. Nevertheless, the lack of statistical difference in economy of movement was not surprising as all participants were untrained. In addition, our participants were overweight or class 1 obese. It is possible that more severely obese individuals would exhibit more distinct characteristics that result in declining economy of movement compared to overweight or normal weight individuals and would have altered the results; however, this is speculative.

When comparing normal weight and overweight/obese individuals for pedometer counts, there was no difference while walking or jogging 1.609 km, but jogging resulted in fewer counts than walking. This finding is in agreement with other researchers (Welk et al. 2000) and is expected since the increase in speed during the jog more than likely elicited a longer stride length that resulted in fewer counts over the 1.609-km trial. This study did not assess nor factor in stride length when comparing jogging and walking trials and this represents a limitation in the interpretation of the results. However, height was used as an indirect measure of stride length to determine its effect on pedometer counts during the walk and jog. It is noteworthy that when analyzed by BMI group, height was significantly and indirectly correlated with pedometer counts only in the overweight/obese individuals during both the walk and jog trials. Interpretation of this finding is difficult without stride length data to determine if stride length or height is the more important factor in this association. It has been suggested that a more sensitive pedometer be used with overweight and obese adults, such as a piezo-electric pedometer (Melanson et al. 2004), since a spring-levered pedometer may be affected by its tilt due to increased BMI and waist circumference often seen in overweight and obese adults (Crouter et al. 2005). Additionally, caution should be used with spring-levered pedometers since some tend to be less accurate at speeds faster than a brisk walk (Crouter et al. 2003). Finally, many pedometer models have a function that allows the user to input his or her stride length to estimate distance walked. Whether or not this function is used, it is important for the user to understand that fewer steps will be taken while jogging compared to running and that this does not necessarily translate to lower EE.

In summary, this study indicates that women with larger body mass expend more energy at rest and during walking and jogging. In addition to the public health guidelines to regularly obtain moderate-intensity activity for health benefits, progressively adding intensity may be a strategy to increase EE and prevent small imbalances in energy intake. While orthopedic considerations may exist for some heavier individuals preventing intense or high impact treadmill exercise, increasing intensity using lower impact modes should be considered. It is also noteworthy that moderate-intensity walking may elicit significantly less EE than the traditional 418 kJ (100 kcal) per 1.609 km (1 mile) but this "rule of thumb" may more accurately quantify jogging 1.609 km in some normal and overweight women. Lastly, 2,000 steps may accurately predict 1.609 km (1 mile) of walking but may significantly under-predict steps during jogging or running activities and should be considered when evaluating the health and weight management benefits of attaining 10,000 steps per day.

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