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The Impact of Body Composition on Energy Expenditure during Walking and Running in Young Adults

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ABSTRACT

Pauley A, Dixon CB, Rawson ES, McConnell TR, Andreacci JL. The Impact of Body Composition on Energy Expenditure during Walking and Running in Young Adults. **JEPonline** 2016;19(1):66-76. The purpose of this study was to examine the impact of body composition on energy expenditure (EE) of 164 young adults during a 1-mile walk and a 1-mile run on a treadmill. Segmental bioimpedance was used to measure body composition variables. The EE in men (108.3 ± 17.6 kcal) was greater than ($P<0.05$) women (80.3 ± 10.6 kcal) during the 1-mile walk, and the difference increased in magnitude during the 1-mile run (144.9 ± 23.2 kcal vs. 105.1 ± 14.9 kcal, respectively). When EE was expressed per unit of body mass, men and women were similar. However, women had a higher EE per unit of fat-free mass (FFM). Regardless of gender, running 1-mile resulted in a greater EE than walking 1-mile. In addition, men expended more absolute calories than women due to a higher body mass. When EE was examined relative to FFM, women were found to be less economical than men, which was most likely due to carrying larger amounts of inactive adipose tissue.

Key Words: 1-mile walk, 1-mile run, Fat-free mass, energy expenditure

INTRODUCTION

Increasing physical activity and making better nutritional choices will lead to better overall health, decrease the chances of becoming overweight, and promote weight loss (2,10). The American College of Sports Medicine (ACSM) recommends a minimum of 150 $min{\cdot}wk^{-1}$ of moderate-intensity physical activity for adults to improve health, with a more aggressive approach of 150 to 250 $min{\cdot}wk^{-1}$ for long-term weight loss (1,2). This increase in physical activity contributes to a daily caloric deficit of 300 to 500 $kcal{\cdot}d^{-1}$ that is recommended for safe and effective weight loss and management (10).

When beginning an exercise or weight management program, beginners may feel compelled to **engage in** an unsafe or unaccustomed physical activity (e.g., running) in order to increase energy expenditure (EE). However, when considering deconditioned individuals leading a sedentary lifestyle, lower-intensity exercise such as walking may be a more appropriate mode. In fact, walking at a brisk pace for 30 $min{\cdot}d^{-1}$ for 5 $d{\cdot}wk^{-1}$ enables a person to meet the ACSM recommendation while posing less orthopedic stress.

Several studies have reported consistent findings in EE during running and walking exercises (3,6,7,9,12). Running results in a higher EE than walking the same distance regardless of gender, and men have a higher EE than women regardless of the exercise mode. Although EE was often normalized to body mass (BM) in the aforementioned studies, few researchers examined the impact that body composition, specifically fat-free mass (FFM) on EE during running and walking.

Thus, the purpose of this study was to determine the effect of body composition on the EE of walking versus running 1-mile in men and women. Energy expenditure was expressed in total calories per mile ($kcal{\cdot}mi^{-1}$), calories per unit of BM ($kcal{\cdot}kg_{BM}^{-1}$) and calories per unit of FFM ($kcal{\cdot}kg_{FFM}^{-1}$).

METHODS

Subjects

A total of 164 subjects (81 men, 83 women) with an age range of 18 to 30 yrs participated in this study. The subjects were recruited from undergraduate and graduate courses at Bloomsburg University. Prior to testing, each subject completed a Physical Activity Readiness Questionnaire (PAR-Q) and an informed consent that was approved by the Bloomsburg University Institutional Review Board.

Body Composition

Height was taken for each subject using a wall-mounted stadiometer. Body mass and body composition were measured via segmental bioelectrical impedance analysis (SBIA); BC-418; (Tanita Corporation of America, Inc., Arlington Heights, IL) prior to testing. Each subject, wearing only a t-shirt and shorts, stood erect holding the hand electrodes with bare feet placed properly on the contact electrodes of the SBIA instrument.

Pre-testing guidelines were given to ensure the most accurate results when testing body composition. The guidelines included: (a) no physical exercise within 12 hrs of the scheduled test; (b) no eating or drinking within 2 hrs of the test; (c) empty the bladder within 30 min of the test; (d) no alcohol consumption within 48 hrs of the test; and (e) no diuretics within 7 days of the test.

Experimental Protocol

The walk and run tests occurred during the same session, which lasted approximately 60 min. The walk preceded the run for all subjects, as to cause minimal disruption in EE. Prior to the run test, an approximate 10-min rest period was given to ensure that all physiological values returned to baseline. All tests were performed on a Quinton Q-Stress Treadmill (Cardiac Science Corporation, Bothell, WA).

Oxygen uptake (VO_2) and respiratory exchange ratio (RER) were determined by indirect calorimetry using a Parvo Medics TrueOne 2400 Metabolic Measurement System (ParvoMedics, Sandy, Utah), which was also used to calculate EE (kilocalories). Heart rate was recorded at the end of every minute using a Polar Heart Rate Monitor (Polar Electro, Inc., Lake Success, NY).

There was a 3-min warm-up period during which the subjects walked at 1.7 $mi \cdot hr^{-1}$ at 0% grade. Then, the speed was increased to the subjects' self-selected speed. The respiratory exchange ratio was monitored to insure a value of ≤1.0 to maintain a submaximal level of exercise intensity during the exercise session. The average speed for the walk was 3.1 ± 0.3 $mi \cdot hr^{-1}$. The average speed for the run was 5.4 ± 0.5 $mi \cdot hr^{-1}$. Ratings of perceived exertion were monitored throughout the walk and run using the OMNI Rating of Perceived Exertion (RPE) scale (11).

Statistical Analysis

The data were analyzed using SPSS 22.0 for Windows (SPSS, Inc., Chicago, IL) and Sigma-Plot 12.5 (Systat Software, Inc., San Jose, CA). A repeated-measures two-way analysis of variance (ANOVA) was used to determine if significant differences occurred between independent variables [speed (walk and run) and gender (men and women)] and if any interaction occurred between independent variables. The level of significance was set at $P \leq 0.05$. All results are reported as the mean ± SD. In addition, correlation coefficients were used to determine the relationship between BM, FFM, and EE.

RESULTS

General characteristics showed that the men were taller, had greater BM and FFM, and a higher BMI when compared to women. The women had a greater %BF and FM (Table 1). The 1-mile walk and run treadmill speeds and completion times were similar between the men and women (Table 2). As expected, steady state VO_2, RER, heart rate, and RPE were greater ($P<0.001$) during the run when compared to the walk for both men and women (Table 2). During the 1-mile run, the men demonstrated higher mean VO_2 values whereas the women had higher heart rate values (Table 2).

Table 1. Participant Characteristics.

	Women (n = 83)		Men (n = 81)	
	Mean ± SD	**Range**	**Mean ± SD**	**Range**
Age (yrs)	20.6 ± 1.5	18 - 27	20.9 ± 1.5	18 - 24
Height (cm)	161.2 ± 12.8	60.9 - 177	175.7 ± 13.4*	71 - 199
Body Mass (kg)	61.1 ± 8.1	43.3 - 83.8	81.3 ± 10.6*	62.3 - 113.1
BMI ($kg \cdot m^{-2}$)	23.1 ± 2.5	17.8 - 29.4	26.1 ± 3.6*	20 - 44.7
Body Fat (%)	23.9 ± 5.5	10.3 - 35.8	15.1 ± 5.2*	4.7 - 36.1
Fat Mass (kg)	14.9 ± 4.9	4.7 - 28.9	12.6 ± 5.8	3.2 - 40.8
Fat-Free Mass (kg)	46.2 ± 4.5	37.2 - 59.1	68.7 ± 7.1*	53.3 - 90.2

All values are mean ± SD. *Significant (P<0.001) when compared to women.

Table 2. Exercise Data during Walking and Running.

	Treadmill Speed $mi \cdot hr^{-1}$	Time min	VO_2 $ml \cdot kg^{-1} \cdot min^{-1}$	RER	HR $beats \cdot min^{-1}$	OMNI RPE Overall
Women (n = 83)						
1-Mile Walk	3.1 ± 0.3	19:22 ± 1:42	14.0 ± 2.6	.84 ± .05	117 ± 15	1.2 ± 1.1
1-Mile Run	5.4 ± 0.5*	11:13 ± 1:00*	31.6 ± 4.1*	.92 ± .05*	173 ± 15*	3.6 ± 2.2*
Men (n = 81)						
1-Mile Walk	3.2 ± 0.4	18:57 ± 2:03	14.9 ± 3.2	.86 ± 06	114 ± 17	1.5 ± 1.3
1-Mile Run	5.4 ± 0.5*	11:17 ± 0.58*	34.0 ± 3.9*#	.92 ± .04*	165 ± 17*#	3.5 ± 1.8*

All values are mean ± SD. VO_2, oxygen consumption; RER, respiratory exchange ratio, HR, Heart Rate. *Significantly (P<0.001) different when compared to 1-mile walk; #Significantly (P<0.05) different when compared to women.

Energy expenditure data for women and men during the walk and the run are shown in Table 3. Running a mile resulted in a higher total EE (kcal·mi^{-1}) and EE (kcal·min^{-1}) for the women (24.9 kcal and 5.2 kcal·min^{-1}) and men (36.5 kcal and 7.1 kcal·min^{-1}) when compared to walking. When EE was expressed relative to BM and FFM, running still resulted in greater caloric expenditure than walking. Interestingly, the mean difference in EE between walking and running when expressed relative to BM or FFM was the same for both genders (~0.5 kcal·kg^{-1}). The difference between women and men for total EE for the walk was 28.0 ± 7.0 kcal and 39.8 ± 8.3 kcal for the run (Table 3). The difference between women and men for EE for the walk was 1.5 ± 1.4 kcal·min^{-1}and 3.6 ± 8.9 kcal·min^{-1} for the run (Table 3). When EE was expressed relative to FFM, women expended more (P<0.05) calories than men during both walking and running (Table 3).

Table 3. Comparison of Energy Expenditure (EE) Data for Women and Men.

	1-Mile Walk	1-Mile Run	Difference
Women (n = 83)			
TEE (kcal·mi^{-1})	80.3 ± 10.6	105.1 ± 14.9*	24.8 ± 4.3
EE (kcal·min^{-1})	4.3 ± 1.0	9.4 ± 1.4*	5.1 ± 0.4
EE$_{BM}$ (kcal·kg$_{BM}^{-1}$)	1.33 ± 0.17	1.72 ± 0.15*	0.4 ± 0.02
EE$_{FFM}$ (kcal·kg$_{FFM}^{-1}$)	1.74 ± 0.20	2.28 ± 0.25*	0.5 ± 0.05
Men (n = 81)			
TEE (kcal·mi^{-1})	108.3 ± 17.6$^{\#}$	144.9 ± 23.2*$^{\#}$	36.6 ± 5.6
EE (kcal·min^{-1})	5.8 ± 1.4$^{\#}$	12.9 ± 2.2*$^{\#}$	7.1 ± 0.08
EE$_{BM}$ (kcal·kg$_{BM}^{-1}$)	1.34 ± 0.16	1.79 ± 0.20*$^{\#}$	0.5 ± 0.04
EE$_{FFM}$ (kcal·kg$_{FFM}^{-1}$)	1.57 ± 0.19$^{\#}$	2.10 ± 0.24*$^{\#}$	0.5 ± 0.05

All values are mean ± SD. TEE = Total Energy Expenditure; BM = Body Mass; FFM = Fat-Free Mass. *Significant (P<0.001) different when compared to 1-mile walk; $^{\#}$Significantly (P<0.05) different when compared to women.

The correlation between BM and the total EE for walking and running 1-mile were significant (P<0.001) for both men (r = 0.71 and 0.80, respectively) and women (r = 0.58 and 0.79, respectively, Figure 1a and 1b). The correlation between FFM and the total EE (kcal) for walking and running 1-mile were significant (P<0.001) for both men (r = 0.69 and 0.68, respectively) and women (r = 0.55 and 0.63, respectively, Figure 2a and 2b).

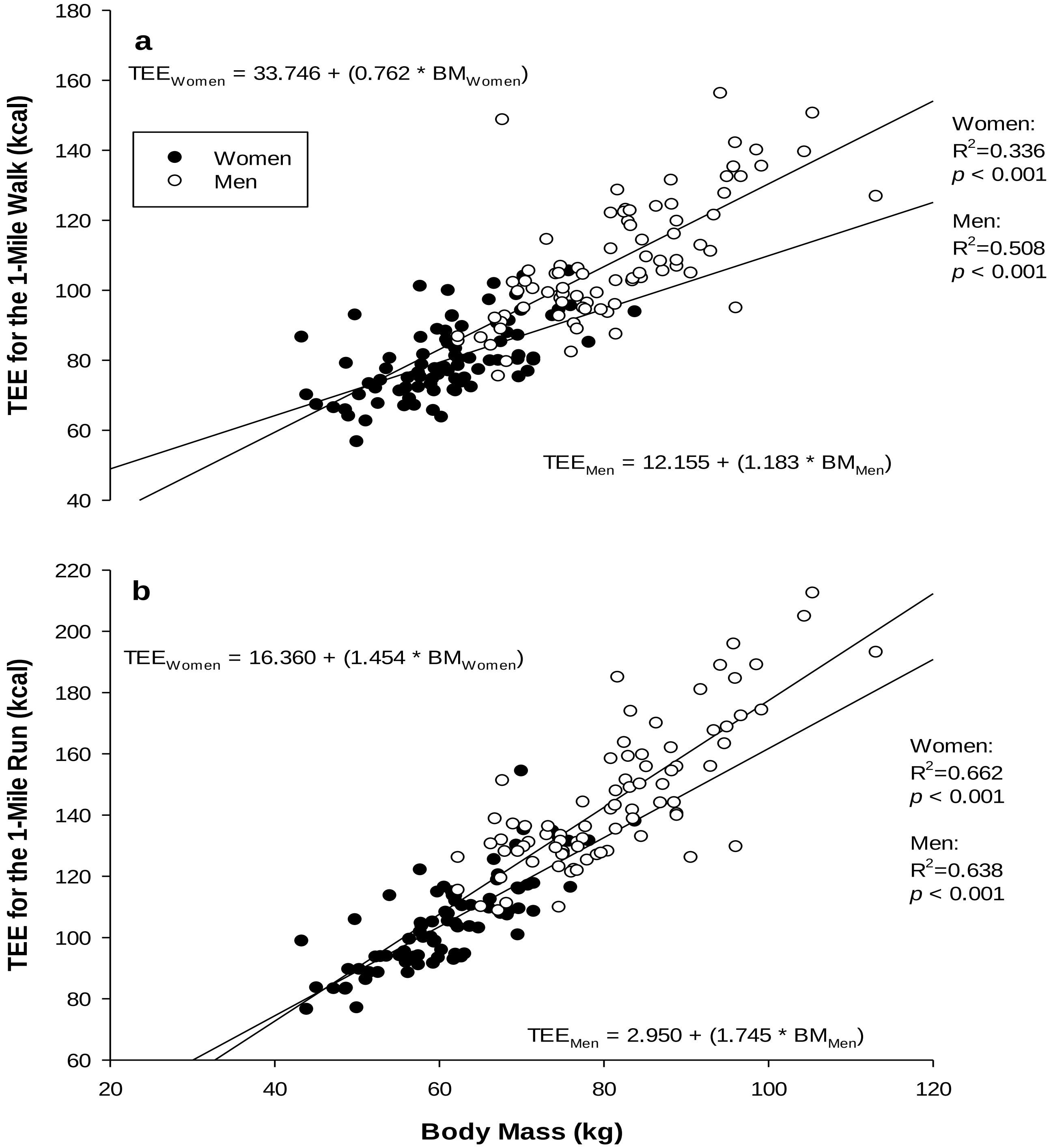

Figure 1. The Relationship Between Total Energy Expenditure (TEE) and Body Mass (BM) for the (a) 1-Mile Walk; and (b) 1-Mile Run in Women (●) and Men (○).

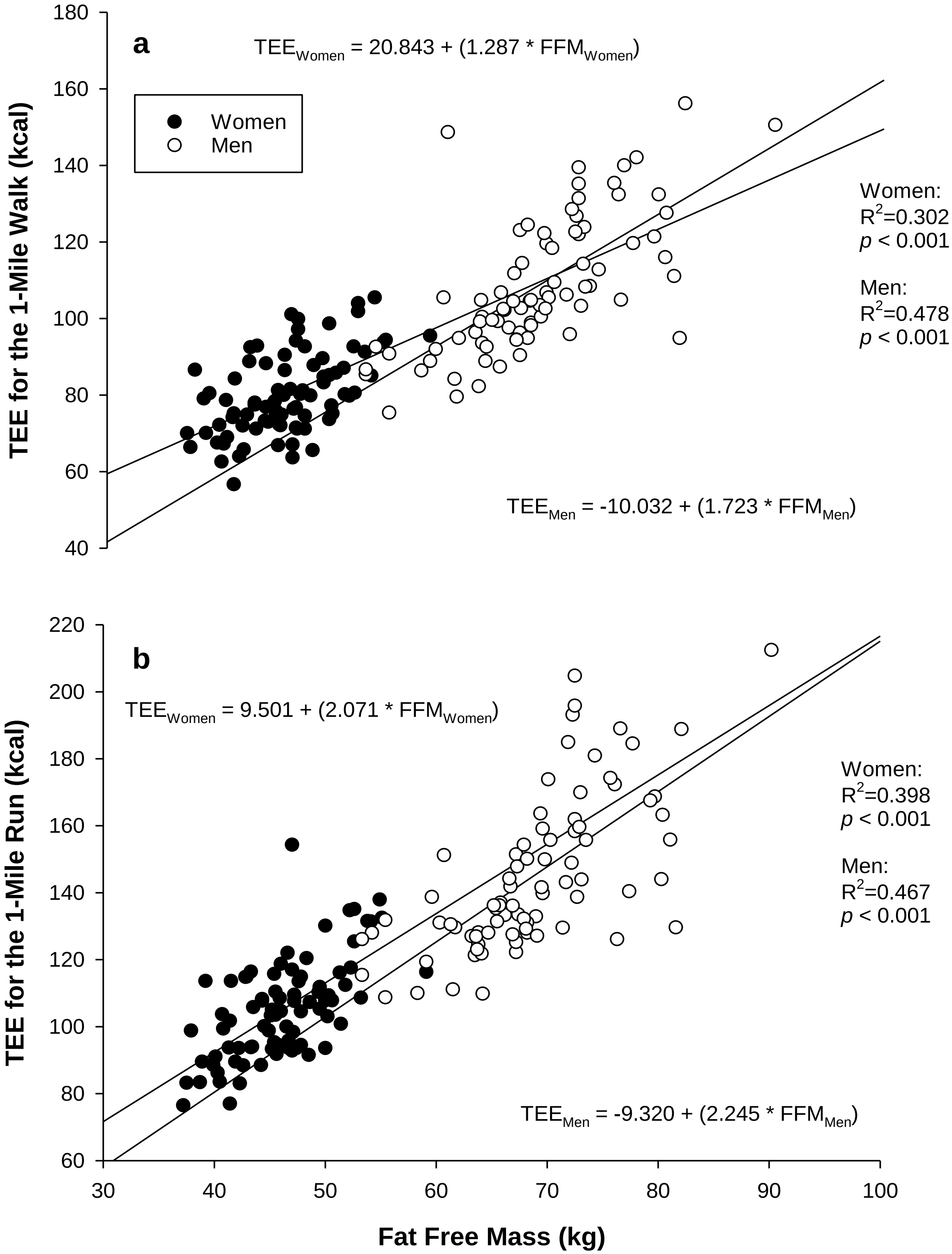

Figure 2. The Relationship Between Total Energy Expenditure (TEE) and Fat-Free Mass (FFM) for the (a) 1-Mile Walk; and (b) 1-Mile Run in Women (●) and Men (○).

DISCUSSION

The purpose of this study was to determine the effect of body composition on the EE of walking versus running 1-mile in men and women. In agreement with previous research (3-5,7,9,12), our data confirms that running 1-mile results in a higher EE than walking for both men (+36.5 kcal) and women (+24.9 kcal).

The ACSM has published prediction equations for the determination of EE during walking and running (1). Using mean speeds, times, and BM from this study, predicted EE values for walking and running for men and women were calculated for comparison. The walking equations predicted EE for women to be 69 $kcal \cdot mi^{-1}$ and for men 93 $kcal \cdot mi^{-1}$ compared to the current values of 80.3 ± 10.6 $kcal \cdot mi^{-1}$ and 108.3 ± 17.6 $kcal \cdot mi^{-1}$. Loftin and colleagues (9) reported mean 1-mile walk EE values of 103.1 kcal in 11 normal weight men and 81.1 kcal in 8 normal weight women. In addition, similar mean 1-mile walking EE values in men and women of 88.6 ± 13.9 kcal and 81.3 ± 4.2 kcal have also been previously reported in the literature, when converted from kJ (12).

The ACSM equations for running predicted EE of 109 $kcal \cdot mi^{-1}$ for women and 145 $kcal \cdot mi^{-1}$ for men were similar to the currently measured 105.1 ± 14.9 $kcal \cdot mi^{-1}$ for women and 144.9 ± 23.2 $kcal \cdot mi^{-1}$ for men. Loftin and colleagues (9) reported that 10 women marathon runners expended 91.7 kcal and 10 men marathon runners expended 106.9 kcal when running 1-mile. Similarly, Wilkin and colleagues (12), reported that in 30 participants (15 women and 15 men) during a 1-mile run, women expended 96.6 ± 13.6 $kcal \cdot mi^{-1}$ and men expended 128.6 ± 21.6 $kcal \cdot mi^{-1}$, when converted from kJ, respectively.

When compared to the women, the men had a greater EE per mile even though the treadmill speeds and exercise durations were similar between the groups. More specifically, the total EE for the men exceeded the women by 28 kcal for the walk and 40 kcal for the run. On average, the men were 20 kg heavier than the women in this study. Clearly, the additional BM of the men required a greater absolute EE regardless of whether they were walking or running. Interestingly, the women in this study would have had to walk an additional 6:30 min or run an additional 4:12 min in order to equal the 1-mile EE of the men. When EE was expressed relative to BM, the gender differences were mitigated for the walk (1.34 ± 0.17 vs. 1.33 ± 0.17 $kcal \cdot kg_{BM}^{-1}$, $P>0.05$) and the run (1.79 ± 0.20 vs. 1.72 ± 0.15 $kcal \cdot kg_{BM}^{-1}$, $P = 0.017$) for the men and women, respectively.

In order to examine the effect of body composition, we further examined EE relative to the FFM (EE_{FFM}) of each subject. The women demonstrated a greater EE_{FFM} when compared to men, regardless of intensity (walk: 1.74 ± 0.2 $kcal \cdot kg_{BM}^{-1}$ vs. 1.57 ± 0.19 $kcal \cdot kg_{BM}^{-1}$ and run: 2.28 ± 0.25 $kcal \cdot kg_{BM}^{-1}$ vs. 2.10 ± 0.24 $kcal \cdot kg_{BM}^{-1}$). Similarly, Loftin and colleagues (9) reported that following a 1-mile walk, EE_{FFM} values of 1.64 $kcal \cdot kg_{BM}^{-1}$ and 1.82 $kcal \cdot kg_{BM}^{-1}$ in men and women, respectively. In the present study, the men were lean with an average body fat of 15% while the women averaged 24%. While covering the 1-mile, the men transported less non-metabolic tissue (i.e., FM) and were more economical as demonstrated by the lower EE_{FFM} when compared to the women.

For health maintenance it is recommended that adults expend approximately 1000 kcal·wk^{-1} in moderate intensity exercise and approximately 2200 kcal·wk^{-1} for weight loss and maintenance (10). According to our data, to meet the 1000 kcal·wk^{-1} recommendation, women would need to perform 246:01 ± 42:4 min and men 179:90 ± 38:4 min of walking. To expend 2200 kcal, women would need to walk 541:10 ± 93:20 min and men would need to walk 395:45 ± 84:30 min. In order to equal the same EE as the 1-mile run, our subjects would be required to walk approximately 6 additional min (women = 5:46 min, men = 6:18 min) beyond their 1-mile walk time.

It has been previously shown **(4-6,9,12)** and supported by our data that individuals with a greater BM expend more energy when walking or running 1-mile, regardless of gender and body composition. From a weight management standpoint, it is important for health and fitness professionals to recognize that the EE required for a given distance of exercise will decrease as an individual loses BM. As such, when using the same mode and intensity of exercise, clients will be required to walk or run a greater distance to achieve the same caloric expenditure as when they were heavier.

Furthermore, a positive relation between FFM and EE was found in the present study. Previous research has shown that a significant portion of the overall BM reduction observed following diet and endurance exercise programs is FFM (8). Of concern, as demonstrated in Figure 2, is that reductions in FFM negatively impact EE during walking and running. Kraemer et al. (8) found that when resistance exercise was combined with dietary restriction, the subjects retained FFM and lost almost exclusively fat. As such, resistance exercise should be considered an integral part of a weight loss program in order to maintain the valuable metabolically-active FFM tissue.

CONCLUSIONS

The findings in the present study indicate that both men and women expend more energy during running 1-mile than when walking 1-mile. In addition, men expend more calories than the women due to their higher BM values. When EE is examined relative to FFM, women are less economical than the men (e.g., higher kcal·kg_{BM}^{-1}) since, on average, they are carrying larger amounts of inactive adipose tissue. Overall, these findings provide important information for health and fitness professionals involved in supervising weight management programs.

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