International Journal of Obesity (2002) 26, 1484–1493
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www.nature.com/ijo

PAPER

Dose–response effect of walking exercise on weight loss. How much is enough?

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OBJECTIVE: Exercise is the cornerstone of behavioral weight loss programs. The total volume of exercise needed to both promote weight loss and elicit health benefits has not been sufficiently investigated. The aim of this study was to examine the effects of two different volumes of walking 'metabolic fitness' exercise prescriptions, in combination with a low-fat, *ad libitum* diet (LFAL) on weight loss and additional modifiable health-related variables (HRV) in an ethnically diverse sample of overweight premenopausal women.
DESIGN: Clinical 12 week weight loss intervention study with a 5.0–5.8 MJ diet daily with (a) participants walking 30 min, 5 days per week (DEX1), (b) participants walking 60 min, five times per week (DEX2) or (c) a diet only control group (DO).
SUBJECTS: A mixed racial sample (predominantly Hispanic) of 56 subjects (mean BMI = 34.26 ± 6.61, mean age = 39.45 ± 7.34) completed the 12 week program.
MEASUREMENTS: Various body weight, body composition and fat distribution variables, dietary intake and additional HRV such as blood lipids, blood pressure and an estimate of cardiorespiratory fitness at baseline and after 3 months.
RESULTS: All groups showed similar and significant ($P < 0.001$) declines in body weight, percentage body fat, BMI, WHR, fat mass, fat-free mass and diastolic blood pressure following the program. In addition, total cholesterol, triacylglycerol and the TC:HDL ratio displayed a significant time effect ($P < 0.05$). Significant interactions ($P < 0.05$) were found for waist circumference, sagittal diameter, estimated VO_{2max} and LDL-C, with both exercise groups showing similar and significantly greater ($P < 0.05$) improvements than DO. Significant interactions ($P < 0.05$) were also observed for several dietary variables.
CONCLUSION: Our study showed no dose–response effect of walking exercise on weight loss over diet alone. Both lower and higher volume metabolic fitness prescriptions resulted in similar and significant beneficial changes in several HRV. This data suggests that 30 min of walking on most days of the week may be as beneficial as 60 min (in combination with diet) in promoting numerous additional healthful outcomes over diet alone following a 12 week weight loss program.

International Journal of Obesity (2002) **26,** 1484–1493. doi:10.1038/sj.ijo.0802133

Keywords: diet; overweight; obesity; body composition; premenopausal women

Introduction

In the USA, over half of the adult population is now considered overweight or obese.[1] Overweight is directly associated with an increased risk of mortality from all causes among middle-aged women.[2] The epidemic of obesity in this country coupled with the poor success rate of current treatments necessitates further study into treatment interventions. A review of the literature has demonstrated that an advantageous treatment approach combines a low fat *ad libitum* diet[3] with behavior modification[4,5] and aerobic exercise.[6,7] Recently, there has been substantial interest in the dose–response volume of aerobic exercise necessary to incur weight loss and additional health-related benefits. Investigators[8,9] have, in fact, focused on the new 'metabolic fitness' exercise recommendation as a method of using large volume, long-duration exercise such as walking to improve metabolic variables relevant to one's health as well as weight loss. This differs from the traditional cardiorespiratory fitness exercise prescription in that training intensity is lower (often performed at a self-selected pace) and duration of the exercise bout may be greater than that observed for the cardiorespiratory fitness exercise prescription. The scientific community, however, has not agreed upon the total daily energy expenditure (total volume of exercise) necessary to induce both weight loss and health-related benefits. The paucity of research data examining the concept of dose–response between volume of exercise and health benefits has recently been recognized.[10] Furthermore, it is imperative that scientists devise healthy weight loss intervention

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Received 16 January 2002; revised 6 May 2002; accepted 20 May 2002

strategies targeting minority groups since they show the highest obesity prevalence rates.[11] Thus, the primary purpose of this study was to investigate the effects of two different walking volumes in combination with a low-fat *ad libitum* diet (LFAL), compared to a diet only control group on weight loss and modifiable health-related variables (HRV) in an ethnically diverse sample of sedentary, overweight women.

Methods

Subjects and research design

Volunteer premenopausal overweight women were recruited from the Miami area from advertisements placed in local newspapers and a local television news station (Channel 4—WFOR, CBS Miami). A total of 88 overweight, premenopausal women met the eligibility requirements for participation in the program and were randomly assigned to one of three study groups: (1) diet only control group (DO), $n=30$; (2) diet plus a walking exercise prescription at 5 days/week, self-selected intensity, 30 min/day (DEX1), $n=29$; and (3) diet plus a walking exercise prescription at 5 days/week, self-selected intensity, 60 min/day (DEX2), $n=29$. Of the 88 women who completed baseline testing, 56 (64%) met the criteria for completion of the study. These criteria included baseline and post-testing as well as attending at least 85% of exercise sessions and dietary compliance. Thirty-two subjects (36%) did not meet criteria for completion of the study and were considered dropouts. The sample was a heterogeneous multi-ethnic group of Hispanic (50%), Caucasian (25%), African-American (21%), Indian (2%) and Asian (2%) individuals, reflective of recent Miami demographics.[12] Selection eligibility criteria included the following: apparently healthy women, body mass index (BMI) over 25 kg/m^2, premenopausal, non-smoking, sedentary prior to the start of the study and not having been on any recent weight reduction program (weight stable for the previous 4 months). Volunteers demonstrated a clear motivation to participate in the treatment program for the specified time period and deemed themselves physically capable of complying with all the training protocols. Women who had been previously diagnosed by their personal physician as having cardiovascular disease (CVD), pulmonary dysfunction, metabolic disease, an endocrine disorder, severe hypertension and/or on medication that may affect metabolic variables were excluded. The nature of the study was fully explained to all subjects before the study's onset and all participants were required to sign an informed consent prior to baseline testing. The study procedures were reviewed and approved by the University of Miami Review Board for Human Studies. The study had three phases: (1) a baseline testing phase; (2) a 12 week diet and exercise treatment program; and (3) a post-testing phase.

Baseline testing

All technicians measuring variables were blinded to group assignment. Initial testing consisted of height and weight measurements taken with participants clothed and without shoes. Body weight was measured to the nearest 0.25 lb on a calibrated clinical balance scale (Detecto Scales, Inc., Brooklyn, NY, USA). Subjects were required to be weighed at the baseline and post-treatment measurement periods on the same scale. Body height was measured to the nearest 0.25 in (without shoes) using a standard stadiometer. Body mass index (BMI; kg/m^2) was calculated from the weight in kilograms divided by the height in meters squared.

Body composition was determined by assessing body density using hydrodensitometry. The submersion tank was fitted with a scale attached to a force cell transducer and coupled with an integrated amplifier. This permitted instantaneous readings of underwater body weight and body density corrected for residual lung volume (estimated from each subject's vital capacity). Percentage body fat was calculated from body density using the Siri equation.[13] Fat mass was calculated by multiplying percentage body fat times body mass (kg). Fat-free mass was determined by subtracting fat mass (kg) from total body mass (kg). The average of triplicate hydrostatic weighing trials was reported. Subjects who were apprehensive about hydrostatic weighing with total head submersion performed the same procedure without head submersion (HWNS). Research has demonstrated that HWNS is a valid alternative to the conventional technique of hydrodensitometry to assess body composition in obese women.[14]

Sagittal diameter, waist circumference and the WHR were measured and calculated to assess changes in central obesity. Waist circumference and sagittal diameter measurements have been shown to be reliable anthropometric surrogates for predicting several health-related variables in overweight Caucasian and African-American women.[15] Sagittal diameter was measured in a reclining position using an anthropometer (model no. 01290, Lafayette Instrument Company, Lafayette, IN, USA) placed at the level of the umbilicus. Waist circumference was measured at the narrowest point of the trunk, using a standard spring-loaded measuring tape (Creative Health Products, Ann Arbor, MI, USA). Hip circumference was measured at the site of the greatest gluteal protrusion. Waist-to-hip ratio (WHR) was calculated as the ratio of waist girth to gluteal girth. All anthropometric measurements were taken by the same trained investigator, and recorded to the nearest 0.1 cm in duplicate and averaged. If differences between the two measurements were greater than 1 cm, a third measurement was taken and the average of the two closest values was recorded.

The subject's resting systolic and diastolic blood pressures (BP) were measured in duplicate to the nearest 2 mmHg (while sitting comfortably in a seated position). The right arm brachial artery pressure was determined after a 5 min rest period, using a mercury sphygmomanometer. The same trained registered nurse took all measurements. The mean of two measures was reported for baseline values. Heart rate was measured by palpation of the radial artery for 20 s and then multiplied by three to obtain a minute heart rate. Resting BP and heart rate were determined for all subjects before blood withdrawal and testing for estimated VO_{2max}.

Following testing and blood withdrawal at previous stations, subjects ate a light snack and were escorted to the University of Miami track. They were administered a one-mile field test supervised by trained exercise physiologists. Subjects were asked to walk as fast as possible four times around a standard tartan 440 yard track. Subjects received verbal encouragement to walk as quickly as possible. Heart rates were taken for 15 s and multiplied by four to obtain a minute heart rate immediately after completion of the one-mile walk. The time to complete the mile walk and the corresponding heart rate were subsequently entered into a valid ($r = 0.93$) and accurate (s.e.e. = 0.355) gender specific equation to calculate VO_{2max}.[16]

Blood collection and analyses

Blood was drawn from the antecubital vein and sampling was performed following an overnight fast (12 h). A trained phlebotomist collected 10 ml of venous blood from subjects while in a seated and quiet position for 5 min prior to blood sampling. Following centrifugation, serum was removed from the clot (to avoid metabolism of glucose by the cells) and analyzed using a Vitros DT 60 II System (Johnson & Johnson® Clinical Diagnostics, Rochester, NY, USA) for the following: total cholesterol (TC), high-density lipoproteins (HDL-C) and triacylglycerol (TG).

Controls were run daily for all tests and used to verify system performance and to help monitor accuracy and precision. VLDL-C was calculated by dividing TG by five and LDL-C concentration was calculated according to the method of Friedewald,[17] which subtracts HDL-C and VLDL-C from TC. The atherogenic index was calculated by assessing the TC to HDL-C ratio as indicated by Stampfer and colleagues.[18]

Twelve-week diet and exercise treatment program

Dietary program. The diet followed a modified version of the calorie exchange program of the American Dietetic Association and the American Diabetes Association Exchange Lists for Meal Planning booklet[19] in which subjects chose foods from different categories. Participants were instructed to follow a nutritionally balanced ‘heart healthy’ diet with the following guidelines: approximately 1200–1400 kcal daily intake, suggested maximum daily fat serving allowance (35 g/day), assignment of a suggested number of protein, dairy, fat and high-fiber complex carbohydrate exchanges and a minimum but no maximum number of fruit and vegetable exchanges. The diet is considered *ad libitum* as subjects were allowed unlimited access to high-fiber, low-fat and low-calorie foods. The unrestricted intake of fruit and vegetables did not significantly increase the approximate daily calorie intake above the recommended maximum. Subjects were asked to hand in weekly food diaries on several occasions which were reviewed by the registered dietitian to ensure similar dietary compliance across all three dietary intervention groups. Baseline and post-test 3 day food logs were analyzed with the Nutritionist V software program (First DataBank, Inc., San Bruno, California).

Exercise training protocols. All exercise sessions included a warm-up, pre-exercise stretches, an assigned walking period, a cool-down and post-exercise stretches supervised by two exercise physiologists. Subjects in training groups DEX1 and DEX2 were instructed to walk at a self-regulated intensity, as the goal of these exercise programs was to promote a pleasant exercise experience with the company of their friends and to enjoy the serene ambiance of a tropical park. The investigators chose not to emphasize training intensity and did not request heart rate monitoring or a rating of perceived exertion. The emphasis instead focused on attaining a high degree of calorie expenditure rather than cardiorespiratory fitness. Mental health researchers recommend self-selected exercise intensity for overweight subjects in an effort to make exercise a self-reinforced behavior.[20] After a 2 week familiarization phase designed to progressively increase subjects’ tolerance, participants walked either 30 min, 5 days per week, or 60 min, 5 days per week, (DEX1 and DEX2, respectively). The 30 min program was developed in accordance with national guidelines,[21–23] while the 60 min program followed additional recommendations by Ballor and Poehlman[24] and *Canada’s Physical Activity Guide*.[25] Members of the control (DO) group were directed to refrain from all exercise and maintain their usual sedentary lifestyle for the duration of the study. Control subjects were given advice from exercise physiologists regarding an exercise program at the completion of the study.

Based on previous research,[26] the dropout criterion for the walking groups was exercise compliance of less than 85%. Compliance with the exercise protocol was calculated as: the total number of sessions attended divided by the total number of exercise sessions provided multiplied by 100. Subjects were allowed to make-up missed exercise sessions which were logged into the attendance record form.

Post-testing. Post-testing consisted of repeating the same measurements performed in the same order as baseline testing. Following post-testing, statistical analyses were performed on all measured variables.

Statistical analyses

Univariate procedures were performed on all variables to describe the study sample, which included a number of descriptive statistics including the mean and standard deviation. Differences among groups were compared utilizing a Group by Time repeated measures General Linear Model. The main effects of Group and Time and the interaction effect of Group by Time were tested. A significant Group by Time interaction indicated that the change from baseline to post-testing was different depending upon the treatment group. All significant interactions were further examined using a repeated measures general linear model to contrast differences in time slopes, comparing two groups at a time. Additionally, in those variables showing a significant interaction, paired-samples *t*-tests were examined to determine significant baseline to post-test changes within each group. All statistical tests were considered significant at a $P \leq 0.05$ level. Data was analyzed using the Statistical Analysis System (SAS statistical software, SAS Institute, Cary, NC, USA).

Results

Statistical analyses of completers ($n = 56$) compared subject evaluations at baseline with those of dropouts ($n = 32$). There were no significant differences observed between dropouts and completers in any physiological and metabolic variables at baseline testing. Using chi-square analysis, it was determined that group affiliation was not associated with dropout rate ($\chi^2 = 2.388$; $P = 0.303$).

An ANOVA indicated no significant differences in any physical, dietary or health-related variables among the three groups ($n = 56$) at baseline. Furthermore, a chi-square analysis revealed no significant difference in ethnic distribution among the three groups ($\chi^2 = 5.478$; $P = 0.705$). Physical characteristics before and after the 12 week experimental period are presented in Table 1. With the exception of age and height, which did not change during the course of the program, each physical characteristic showed a significant main effect for time ($P \leq 0.05$), indicating similar and significant reductions in body mass (kg), BMI (kg/m^2), percentage body fat, total fat mass (kg) and fat-free body mass (kg), among all groups.

Dietary intake data for the three experimental groups before and after the 12-week program is presented in Table 2. Repeated measures ANOVAs revealed significant Group by Time interaction effects for percentage of total calories from carbohydrate, fat, protein and dietary fiber ($P \leq 0.05$). The DEX2 group increased their consumption of carbohydrates to a greater extent than either the DO ($P = 0.0171$) or the DEX1 group ($P = 0.0003$). A paired Student's *t*-test, however, showed a significant increase in percent of energy intake from carbohydrate in both the DO and DEX2 groups ($t(15) = -5.43$, $P = 0.0001$ for DO and $t(18) = -9.24$, $P = 0.001$ for DEX2). The DEX2 group decreased percent of total calories from fat more so than either the DO group ($P = 0.0099$) or the DEX1 group ($P = 0.0048$). A paired Student's *t*-test also revealed a significant decrease in the percentage of total calories from fat in each group ($t(15) = 9.4$, $P = 0.0001$ for DO, $t(20) = 8.8$, $P = 0.0001$ for DEX1, and $t(18) = 11.9$, $P = 0.0001$ for DEX2). The DEX2 group increased dietary fiber intake to a greater extent than either the DO group ($P = 0.0319$) or the DEX1 group ($P = 0.0103$). A Student's *t*-test for paired samples indicated that at post-testing the DEX2 group only showed a significant increase in their consumption of dietary fiber ($t(18) = -6.7$, $P = 0.0001$). Although no significant Group by Time interactions were observed for total calorie intake, saturated fat and cholesterol intake, there was a similar and significant decrease in consumption of each nutrient as indicated by the significant main effect for time observed in these variables ($P = 0.0001$). No significant main effect for group was found for any dietary variable.

Table 1 Physical characteristics of study groups before and after a 12 week weight loss program

Variable	*DO (n = 16)*	*DEX1 (n = 21)*	*DEX2 (n = 19)*
Age (y)	40.13 ± 1.49	38.67 ± 1.64	39.74 ± 1.94
Height (m)	1.66 m ± 0.02	1.63 m ± 0.02	1.62 m ± 0.01
Body mass (kg)[a]			
Pre	90.17 ± 4.48	93.57 ± 4.59	88.40 ± 3.74
Post	86.04 ± 4.01	87.82 ± 4.16	82.55 ± 3.43
Body mass index (kg/m^2)[a]			
Pre	32.79 ± 1.48	35.27 ± 1.76	33.76 ± 1.37
Post	31.29 ± 1.31	33.11 ± 1.61	31.49 ± 1.25
Body fat (%)[a]			
Pre	40.40 ± 1.50	41.6 ± 1.37	41.2 ± 1.48
Post	39.38 ± 1.31	40.4 ± 1.50	38.9 ± 1.22
Fat mass (kg)[a]			
Pre	37.09 ± 2.82	39.91 ± 3.15	37.19 ± 2.58
Post	34.46 ± 2.51	36.38 ± 2.91	32.78 ± 2.19
Fat-free mass (kg)[a]			
Pre	53.08 ± 2.10	53.66 ± 1.75	51.21 ± 1.51
Post	51.58 ± 1.83	51.45 ± 1.65	49.77 ± 1.38

Values are means ± s.e.m.
[a] Significant time effect between baseline and post values determined by an *F*-test ($P \leq 0.05$).

Table 2 A comparison of dietary intake among study groups over time, before and after a 12 week weight-loss program

Variable	*DO* (n = *16*)	*DEX1* (n = *21*)	*DEX2* (n = *19*)	F	P-*values*[a]
Energy (kJ)					
Pre	9429.4 ± 449.9 (2252.6 kcal)	9380.4 ± 576.4 (2240.9 kcal)	8479.6 ± 578.3 (2025.7 kcal)		
Post	5596.3 ± 187.4 (1336.9 kcal)	507608 ± 190.3 (1212.8 kcal)	5410.8 ± 169.9 (1292.6 kcal)	1.28	0.2863
Energy from carbohydrate (%)					
Pre	47.63 ± 1.76	46.67 ± 1.21	43.16 ± 1.40		
Post	59.81 ± 1.73	54.29 ± 2.57	63.11 ± 1.58†	9.00	0.0005
Energy from fat (%)					
Pre	37.38 ± 2.09	37.29 ± 1.22	39.47 ± 0.99		
Post	23.81 ± 1.78	24.24 ± 1.53	19.79 ± 1.47†	5.83	0.0051
Energy from protein (%)					
Pre	16.13 ± 0.94	15.20 ± 0.77	16.32 ± 0.74		
Post	18.81 ± 0.74	23.05 ± 1.15*	19.89 ± 0.57‡	5.26	0.0083
Saturated fat intake (g)					
Pre	30.7 ± 2.72	31.02 ± 2.43	29.43 ± 2.07		
Post	10.04 ± 1.02	9.41 ± 0.88	8.03 ± 0.80	0.03	0.9682
Cholesterol intake (mg)					
Pre	291.66 ± 33.21	345.81 ± 31.98	303.66 ± 36.74		
Post	130.12 ± 14.00	145.40 ± 13.81	121.16 ± 13.11	0.29	0.7515
Dietary fiber (g)					
Pre	17.93 ± 2.20	15.09 ± 1.66	12.72 ± 1.40		
Post	22.66 ± 1.86	18.57 ± 1.50	23.48 ± 1.71†	3.87	0.0271

Values are means ± s.e.m.
Dietary intake was calculated from three-day food logs obtained from each subject.
Percentages are based on total energy intake. Energy in kilojoules (1 kcal = 4.186 kJ).
[a] Determined from a repeated-measures analysis of variance performed among groups over time.
*Significantly different from the DO group using an *F*-test ($P \leq 0.05$).
†Significantly different from the DO and DEX1 groups using an *F*-test ($P \leq 0.05$).
‡Significantly different from the DEX1 group using an *F*-test ($P \leq 0.05$).

Shown in Table 3 are the repeated measures ANOVA's for modifiable HRV. The VO$_{2\text{max}}$ (expressed in relative terms in ml/kg/min) showed a significant Group by Time interaction ($P = 0.007$) with a significant increase in VO$_{2\text{max}}$ in both the DEX1 group ($P = 0.0017$) and DEX2 group ($P = 0.0340$) above that of the DO group. The control group exhibited a negative slope (decline in VO$_{2\text{max}}$ over time) as compared with a positive slope in both exercise groups. The interaction for VO$_{2\text{max}}$ is depicted graphically in Figure 1. A significant Group × Time interaction was also observed for waist circumference ($P = 0.038$) and sagittal diameter ($P = 0.016$). For waist circumference, *post hoc* analysis revealed a greater reduction in waist circumference for the DEX1 ($P = 0.0435$) and DEX2 groups ($P = 0.0197$) compared with the DO group (see Figure 1), with no significant difference detected between the two walking groups. For sagittal diameter, *post hoc* analysis revealed a greater decrease in sagittal diameter in both the DEX1 ($P = 0.0231$) and DEX2 groups ($P = 0.0024$) compared with the DO group with no significant difference between the two walking groups. The interaction of waist circumference and sagittal diameter is displayed graphically in Figure 1. A paired Student's *t*-test revealed a significant decrease in both waist circumference ($t(15) = 5.4$, $P = 0.0001$ for DO, $t(20) = 9.7$, $P = 0.0001$ for DEX1, and $t(18) = 8.7$, $P = 0.0001$ for DEX2) and sagittal diameter measurements ($t(15) = 4.1$, $P = 0.001$ for DO, $t(20) = 6.2$, $P = 0.0001$ for DEX1, and $t(18) = 8.3$, $P = 0.0001$ for DEX2) between baseline and post values for each group.

Low-density-lipoprotein cholesterol (LDL-C) was the only metabolic variable to display a significant Group by Time interaction ($P = 0.004$). Shown in Figure 1 is the significantly greater reduction in LDL-C for both the DEX1 ($P = 0.0099$) and DEX2 ($P = 0.0011$) groups compared with the DO group. There were no significant differences between the DEX1 and DEX2 groups with regard to the magnitude of the decrease in LDL-C. A Student's paired *t*-test revealed that the exercise groups only, showed a statistically significant ($t(20) = 2.89$; $P = 0.010$ for DEX1 and $t(18) = 4.0$; $P = 0.001$ for DEX2) drop in LDL-C from baseline to post-testing.

There was no other significant Group by Time interaction for any of the other variables presented in Table 3. There were, however, numerous health-related variables exhibiting a significant main effect for time. Resting diastolic blood pressure displayed a statistically significant decrease (main effect for time) for all groups ($P = 0.0027$). A significant main effect for time was also detected in WHR ($P \leq 0.05$), which indicates a similar and significant reduction in these values within each group at post-testing. There was also a similar

Table 3 A comparison of modifiable health-related variables among study groups over time, before and after a 12-week weight-loss program

Variable	*DO* (n = *16*)	*DEX1* (n = *21*)	*DEX2* (n = *19*)	F	P-*values*[a]
VO$_{2max}$ (ml/kg/min)					
Pre	30.43 ± 2.46	26.02 ± 1.81	27.69 ± 1.46		
Post	27.61 ± 1.79	29.08 ± 1.53*	29.52 ± 1.18*	5.58	0.007
Resting SBP (mmHg)					
Pre	122.50 ± 5.53	130.10 ± 4.85	126.47 ± 4.41		
Post	121.53 ± 4.68	124.62 ± 3.84	122.21 ± 3.22	0.63	0.5365
Resting DBP (mmHg)					
Pre	80.69 ± 3.45	84.53 ± 2.85	87.79 ± 3.05		
Post	78.33 ± 3.06	79.05 ± 2.43	80.11 ± 1.94	1.17	0.3198
Waist (cm)					
Pre	93.86 ± 3.67	96.99 ± 3.93	95.00 ± 3.03		
Post	88.27 ± 3.56	88.61 ± 3.46*	85.76 ± 2.28*	3.48	0.0381
SD (cm)					
Pre	22.63 ± 1.12	23.55 ± 0.99	23.58 ± 0.99		
Post	21.21 ± 1.07	20.69 ± 0.90*	20.53 ± 0.93*	4.52	0.0155
WHR					
Pre	0.80 ± 0.02	0.80 ± 0.02	0.80 ± 0.01		
Post	0.79 ± 0.02	0.78 ± 0.02	0.77 ± 0.01	1.90	0.1590
TC (mg/dl)					
Pre	194.69 ± 7.48	179.57 ± 5.46	184.84 ± 7.00		
Post	187.13 ± 7.59	167.00 ± 5.53	170.32 ± 5.96	0.60	0.5541
TG (mg/dl)					
Pre	145.47 ± 22.10	97.19 ± 12.49	104.79 ± 11.52		
Post	102.00 ± 18.66	84.76 ± 11.36	106.95 ± 12.21	2.13	0.1295
HDL-C (mg/dl)					
Pre	40.19 ± 2.11	42.90 ± 3.00	42.68 ± 2.82		
Post	40.56 ± 2.63	40.62 ± 2.15	40.95 ± 1.99	0.13	0.8792
LDL-C (mg/dl)					
Pre	121.69 ± 5.84	117.38 ± 4.19	121.16 ± 5.54		
Post	124.31 ± 6.48	108.53 ± 5.89*	107.95 ± 5.51*	6.25	0.0039
TC:HDL ratio					
Pre	5.09 ± 0.38	4.61 ± 0.36	4.63 ± 0.31		
Post	4.91 ± 0.37	4.28 ± 0.25	4.33 ± 0.26	0.05	0.9511

Systolic blood pressure (SBP); diastolic blood pressure (DBP); sagittal diameter (SD); waist-to-hip ratio (WHR); total cholesterol (TC); triacylglycerol (TG).

Values are means ± s.e.m.

[a] Determined from a repeated measures analysis of variance performed among groups over time.

*Significantly different from the DO group using an *F*-test ($P \leq 0.05$).

and statistically significant decrease in TC ($P = 0.0001$), TG ($P = 0.0200$) and TC/HDL ratio ($P = 0.0264$) among all groups. There was no significant main effect for group in any of the health-related variables tested. Furthermore, a Student's *t*-test for independent samples revealed no significant difference in total number of exercise sessions attended between DEX1 and DEX2 ($t(38) = -1.29$, $P = 0.20$).

Discussion

The dose–response issue of walking volume over the short-term has been examined and a more precise quantification of how much exercise is enough to promote weight loss and other health benefits has been provided. Furthermore, our data is the first to compare two different volumes of walking exercise combined with diet in a large sample of overweight, sedentary women of largely Hispanic and African-American descent.

We did not find a volume–outcome dose–response between 30 and 60 min of physical activity per day with regard to weight loss over diet alone. In fact, the addition of exercise did not enhance the magnitude of weight loss at all. All subjects, regardless of group, lost approximately 6% of their body weight (DO lost 9 lb, DEX1 lost 13 lb and DEX2 lost 13 lb, respectively). This finding is in accordance with previous research[5,27] examining the additional effect of exercise on weight loss over the short-term. In a review of randomized controlled clinical trials, Stefanick[28] reported no greater weight loss with diet plus exercise compared to diet alone. Wing[29] has suggested that the discrepancy may be due to small sample sizes and short treatment periods, two limitations that certainly could have led to the lack of

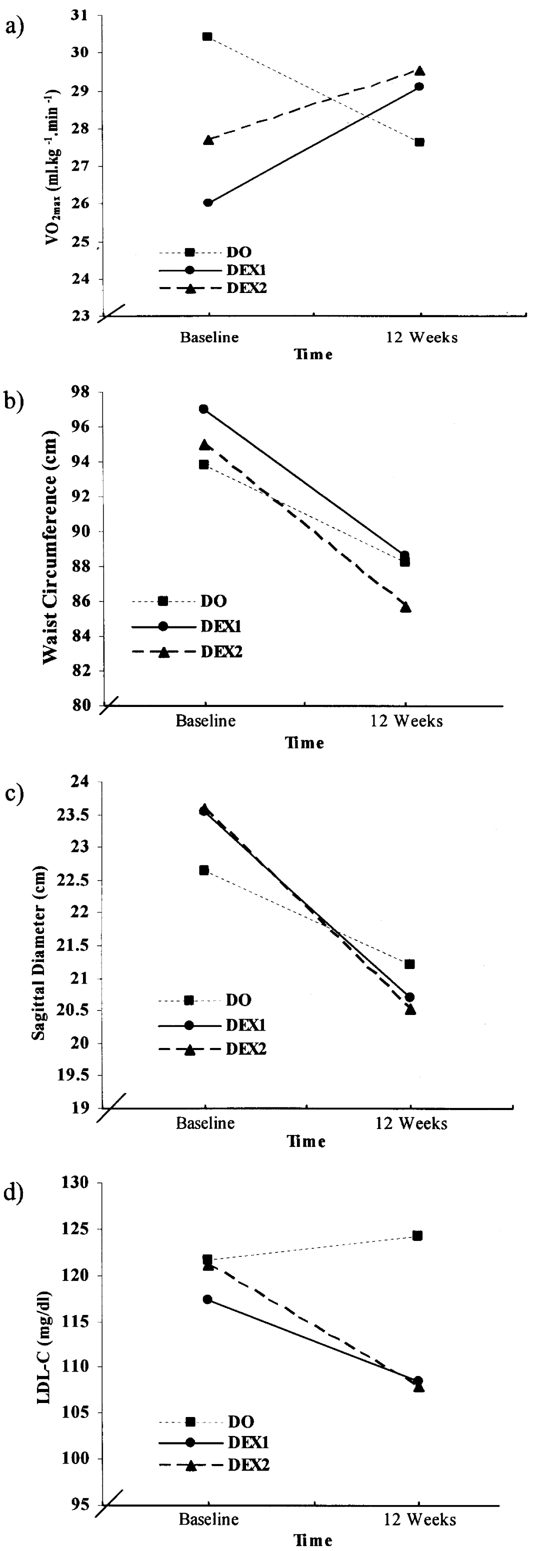

Figure 1 Repeated measures analysis of variance of (a) estimated VO_{2max}, (b) waist circumference, (c) sagittal diameter and (d) LDL-cholesterol for diet-only group (DO, $n = 16$), 30 min walkers (DEX1, $n = 21$) and 60 min walkers (DEX2, $n = 19$).

significant differences in weight loss among groups shown in our study. Nevertheless, calorie intake appears to be the most powerful component of weight loss,[5] with even large volumes of almost daily aerobic exercise showing no statistically significant increase in weight loss above diet alone (over the short-term).

A meta-analysis has shown that exercise training preserves FFM during diet-induced weight loss.[43] Surprisingly, the percentage of total weight loss attributed to fat-free mass (FFM) was high (approximately 33%) among all groups. Thus the addition of walking failed to attenuate the loss of FFM commonly associated with low-calorie dieting. Loss of FFM of this magnitude has been previously reported as a consequence of either a LFAL diet or a low-fat/low-calorie dietary regimen in obese subjects.[30] However, the percentage of FFM lost in the present study is considerably more than that reported by Hammer *et al*,[31] where subjects placed on a similar LFAL diet displayed only a 1% total weight loss from FFM. The significant loss of FFM observed in the present study, across all groups, may have been attributed to the subjects' failure to eat the recommended minimum calorie intake of 1200 calories/day, as it appears that highly restrictive dieting promotes higher losses of FFM. Furthermore, obese individuals have larger hearts, livers, kidneys and muscle mass than leaner individuals.[32] It is known that, as weight loss occurs, there is a decrease in the size of body organs typically enlarged by obesity. Perhaps the higher BMI of the subjects in this study (hence a higher amount of viscera and muscle mass) at the outset contributed to the greater loss of FFM than that observed in the research by Hammer *et al*[31] and Kraemer *et al.*[33] Both aforementioned studies utilized subjects with a considerably lower mean percentage body fat (38.5 and 37.4%, respectively) as opposed to 41.07% in this study.

The addition of physical activity to diet did produce several positive health outcomes that were not observed in the DO group. Both exercise groups, regardless of the volume of walking performed, displayed a significantly greater decline in waist and sagittal diameter variables than the DO group. Interestingly, no significant difference was detected between walking groups with regard to the magnitude of loss. The present finding of a decline in central adiposity in both exercise groups is consistent with results of previous research[27,34] reporting a preferential loss of central adipose tissue following a diet and aerobic exercise training program. Although some studies have shown the potential for ethnic differences in response to weight loss programs,[35,36] others have not.[37] Considering the equal distribution of ethnic groups among DO, DEX1 and DEX2 in the present study, any possible ethnic differences should not have significantly influenced the overall findings. The fact that sagittal diameter and waist circumference were significantly reduced in both walking groups above the DO group attests to the importance of exercise in reducing central fat distribution; a key finding since this pattern of distribution is highly correlated with CVD risk.[38] Furthermore, since there were no significant differences between the DEX1 and DEX2 groups, walking 30 min, 5 days a week was shown to be as beneficial in reducing central adipose tissue as walking 60 min, 5 days per week.

Fasting serum TG concentration typically increases following adherence to a low-fat diet.[39] Surprisingly, our data showed a significant decline in fasting TG concentrations. These results mirror those of similar low-fat diet and aerobic exercise programs in which TG levels declined in both diet only and diet plus exercise groups.[40,41] All groups lost weight and exhibited reductions in TG regardless of the addition of exercise. Thus, it appears that weight loss is the factor that may reverse the TG-raising effect of a low-fat diet.

Despite a decline in TG in diet only and diet plus exercise groups in the above-mentioned research,[40] it was the addition of exercise to diet that promoted a significant decrease in LDL-C in the combination groups compared with diet alone. Additionally, a significant reduction in LDL-C was observed by Kramer *et al*[33] in their diet and aerobic exercise combination group when compared to the diet only and control (no exercise and no diet) groups. Our study also found that the addition of walking exercise to a LFAL diet resulted in a significant drop in LDL-C in both exercise groups with no change observed in the DO group. Thus the exercise component of diet and exercise combination programs appears to strongly target LDL-C metabolism. Recent research has demonstrated that a 3 month program of aerobic exercise alone (without diet or weight loss) significantly lowers LDL-C.[42] One potential mechanism through which exercise could affect LDL-C metabolism is by promoting fat utilization as a substrate and creating a physiologic state conducive to enhanced lipid metabolism. No dose – response effect of exercise volume was observed regarding LDL-C changes. This finding suggests that as with anthropometric measures of central adiposity, 30 min of walking per day/5 days a week is as effective as 60 min in eliciting a statistically similar decline in LDL-C. The data provided from this research therefore reinforces the notion that either volume of walking exercise combined with a LFAL diet is effective in conferring greater health benefits than diet alone regarding LDL-C and the CVD risk profile.

It should be noted that the DO group exhibited a decline in estimated VO_{2max} which was significantly different from the increase in estimated VO_{2max} displayed by both walking groups. A small but significant increase in VO_{2max} was also observed by Duncan, Gordon and Scott[26] in research using low-intensity walking exercise in previously sedentary, premenopausal women. Thus our data adds to the body of research suggesting that walking at a self-selected intensity is beneficial for improving cardiorespiratory fitness during diet-induced weight loss. This has important public health implications since low cardiorespiratory fitness is a strong and independent predictor of CVD and all-cause mortality.[43] Furthermore, these results further support the concept of self-regulated exercise as a promoter of ‘metabolic fitness’ and as a means to attain significant health-related benefits.

Unexpected was the fact that the DEX2 group demonstrated a significantly healthier nutrient intake profile than either the DEX1 or DO groups. Diet composition is known to influence the risk of CVD. Fiber intake for example, has a strong inverse association with CVD risk factors.[44] One explanation for the improved dietary intake pattern observed in the DEX2 group is that the longer duration exercise prescription may have differentially affected mood and imparted a psychological effect that supports better compliance to dietary recommendations. Another possibility is that long-duration aerobic activity is known to deplete glycogen stores, which may have promoted a higher preference for carbohydrate as a means of replenishing glycogen stores.[45] Few studies have addressed this issue, as the literature is unclear as to whether chronic exercise training can preferentially alter macronutrient selection in obese individuals.[46] Finally, the improved nutrient intake in the DEX2 group may have implications for long-term maintenance. Given their positive changes in diet, it is entirely plausible that the DEX2 group would be better able to maintain their weight loss and associated health-related improvements in the long term. Several researchers[47,48] have suggested that a higher volume of exercise is necessary to maintain weight loss and associated health-related variables. Future studies should examine the dose – response role of exercise volume on weight loss and additional health outcomes over the longer term, such as one year.

Our analyses showed no significant difference in exercise attendance between DEX1 and DEX2. Thus, empirical evidence has been provided suggesting that 30 min per day of walking is similar in its ability to reduce waist circumference, sagittal diameter and LDL-C to the 60 min exercise prescription. Future research comparing different volumes of walking and incorporating larger sample sizes would be helpful in more clearly understanding if in fact a dose – response relationship does exist regarding walking and beneficial changes in metabolic variable outcomes. The present research has given some insight regarding how much exercise is enough to promote health-related benefits. The fact that the addition of walking to diet did not elicit significantly greater weight loss suggests that the emphasis should focus on exercise as a means to attain health-related benefits rather than purely as a means to enhance weight loss.

In conclusion, the current findings provide evidence that: (1) neither 30 nor 60 min of walking, 5 days per week contributed to a significantly greater weight loss above diet alone, suggesting that diet is the most powerful factor in promoting weight loss within this time frame; (2) the addition of walking exercise to diet results in more beneficial changes in several HRV above diet alone. Regarding the dose – response effect of walking on HRV, it was found that 30 min of walking exercise combined with diet and performed on most days of the week is as beneficial as 60 min a day of walking exercise in achieving these additional health-related benefits in accordance with the ‘metabolic fitness’ paradigm; (3) it was shown that a large number of overweight women of Hispanic and African-American descent responded favorably to a metabolic fitness and LFAL diet program that promotes a healthy lifestyle. This finding warrants additional obesity intervention programs targeting this population.

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