Effect of Exercise Duration and Intensity on Weight Loss in Overweight, Sedentary Women

A Randomized Trial

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Context A higher duration and intensity of exercise may improve long-term weight loss.

Objective To compare the effects of different durations and intensities of exercise on 12-month weight loss and cardiorespiratory fitness.

Design, Setting, and Participants Randomized trial conducted from January 2000 through December 2001 involving 201 sedentary women (mean [SD] age, 37.0 [5.7] years; mean [SD] body mass index, 32.6 [4.2]) in a university-based weight control program.

Intervention Participants were randomly assigned to 1 of 4 exercise groups (vigorous intensity/high duration; moderate intensity/high duration; moderate intensity/moderate duration; or vigorous intensity/moderate duration) based on estimated energy expenditure (1000 kcal/wk vs 2000 kcal/wk) and exercise intensity (moderate vs vigorous). All women were instructed to reduce intake of energy to between 1200 and 1500 kcal/d and dietary fat to between 20% and 30% of total energy intake.

Main Outcome Measures Body weight, cardiorespiratory fitness, and exercise participation.

Results After exclusions, 184 of 196 randomized participants completed 12 months of treatment (94%). In intention-to-treat analysis, mean (SD) weight loss following 12 months of treatment was statistically significant ($P < .001$) in all exercise groups (vigorous intensity/high duration = 8.9 [7.3] kg; moderate intensity/high duration = 8.2 [7.6] kg; moderate intensity/moderate duration = 6.3 [5.6] kg; vigorous intensity/moderate duration = 7.0 [6.4] kg), with no significant difference between groups. Mean (SD) cardiorespiratory fitness levels also increased significantly ($P = .04$) in all groups (vigorous intensity/high duration = 22.0% [19.9%]; moderate intensity/high duration = 14.9% [18.6%]; moderate intensity/moderate duration = 13.5% [16.9%]; vigorous intensity/moderate duration = 18.9% [16.9%]), with no difference between groups. Post hoc analysis revealed that percentage weight loss at 12 months was associated with the level of physical activity performed at 6 and 12 months. Women reporting less than 150 min/wk had a mean (SD) weight loss of 4.7% [6.0%]; inconsistent (other) pattern of physical activity, 7.0% [6.9%]; 150 min/wk or more, 9.5% [7.9%]; and 200 min/wk or more of exercise, 13.6% [7.8%].

Conclusions Significant weight loss and improved cardiorespiratory fitness were achieved through the combination of exercise and diet during 12 months, although no differences were found based on different exercise durations and intensities in this group of sedentary, overweight women.

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An estimated 60% to 65% of adults in the United States are overweight.[1] Obesity has been linked to an increase in the prevalence of chronic diseases such as cardiovascular disease, diabetes, and cancer.[2] Exercise is an important component of behavioral interventions targeting overweight and obese adults,[2] has been shown to be important for improving short-term weight loss when combined with changes in dietary intake,[2] and is one of the best predictors of long-term weight loss.[3] However, the optimal amount of exercise necessary to enhance long-term weight loss has not been established, leading to differing recommendations from leading health organizations. The Centers for Disease Control and Prevention and the American College of Sports Medicine recommend a minimum of 30 minutes of moderate-intensity activity on most days of the week to improve health (150 min/wk),[4] whereas the Institute of Medicine recommends a minimum of 60 min/d of exercise on most days of the week to control body weight.[5]

Although a recent study reported no significant difference between 30 vs 60

See also pp 1331 and 1377.

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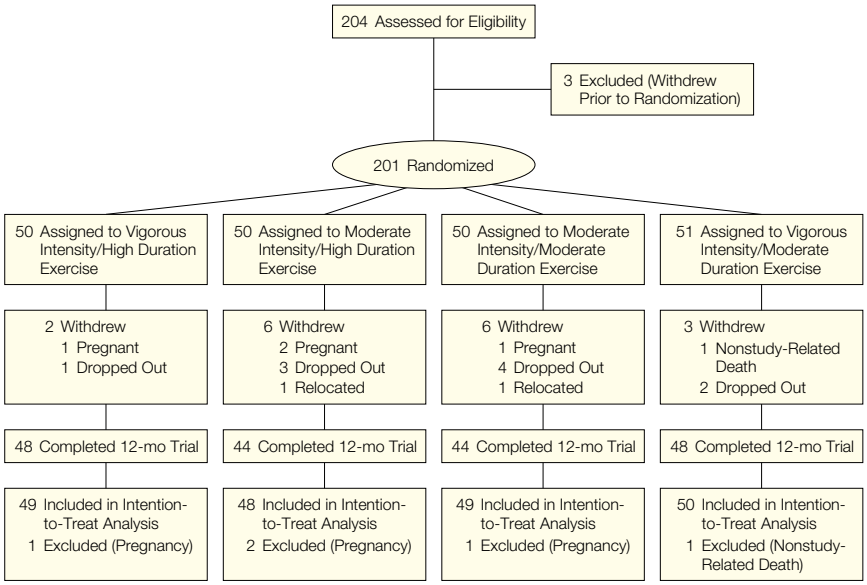
Figure 1. Participant Flow



minutes of exercise per day on weight loss over 12 weeks,[6] long-term data from randomized clinical trials examining the effect of different durations of exercise on weight loss are lacking. Moreover, while some evidence from short-term studies (<6 months) shows that energy expenditure rather than exercise intensity may have the greatest impact on body weight,[7] there are no data from long-term clinical trials to support these findings. The purpose of this study was to examine the effect of exercise of varying duration (moderate vs high) and intensity (moderate vs vigorous) on weight loss and cardiorespiratory fitness following 12 months of treatment in overweight women.

METHODS

Study Participants

A total of 201 women were randomized in this study (FIGURE 1). To be eligible for participation, baseline body mass index (BMI) had to be 27 to 40, with age ranging from 21 to 45 years. In addition, all participants were classified at baseline as *sedentary*, which was defined as reporting exercising less than 3 d/wk for less than 20 min/d over the previous 6 months. Participants were excluded if they met any of the following criteria: a history of myocardial infarction, taking medication that would alter the heart rate response during exercise (eg, β-blockers), taking medication that would affect metabolism or weight loss (eg, thyroid medication), being treated for psychological conditions, currently pregnant, pregnant within the previous 6 months, or planning to become pregnant during the intervention period, having any medical condition that could affect metabolism or body weight (eg, diabetes), or having a medical condition that would limit exercise participation.

Participants completed a detailed medical history and physical activity readiness questionnaire prior to entry into this study and provided permission from their personal physician indicating that the proposed intervention was not contraindicated. All participants provided written informed consent prior to initiating this study, and the protocol was approved by the institutional review board of the Miriam Hospital (Providence, RI).

Behavioral Weight Loss Intervention

All participants were enrolled into a standard behavioral weight loss intervention, which was based on social cognitive theory. The study was conducted from January 2000 through December 2001. Participants were scheduled to attend behavioral group meetings throughout the 12-month intervention period. Meetings were conducted weekly during the initial 24 weeks of treatment, and biweekly for the remainder of the study period. In addition to group meetings, participants received a biweekly telephone call from a member of the intervention team during months 7 through 12. These calls lasted approximately 10 minutes. All participants also were instructed to reduce energy intake to between 1200 and 1500 kcal/d, and to reduce intake of dietary fat to between 20% and 30% of total energy intake. Participants were provided with meal plans and were instructed to self-monitor dietary patterns in weekly food diaries.

Exercise Intervention

Participants were randomized to 1 of 4 exercise groups based on estimated energy expenditure (1000 kcal/wk vs 2000 kcal/wk) and exercise intensity (moderate vs vigorous). The targeted estimated energy expenditure of the exercise was converted to minutes per week based on the differences in exercise intensity that were prescribed. Thus, participants were randomized to (1) vigorous intensity/high duration, (2) moderate intensity/high duration, (3) moderate intensity/moderate duration, or (4) vigorous intensity/moderate duration (TABLE 1).

Participants were instructed to exercise 5 d/wk with walking encouraged as the primary mode of exercise. Exercise intensity was prescribed both in terms of percentage of age-predicted maximal heart rate and rating of perceived exertion based on the Borg Scale.[8] The exercise was to occur in bouts of at least 10 minutes.[9] Exercise was not supervised on site, but motorized treadmills were provided to all participants, which has been shown to be an effective behavioral strategy for enhancing exercise participation.[9] Participants received no other incentives (eg, payments) for participation in this 12-month study. Partici-

Table 1. Exercise Prescription Based on Intervention Group

	Intervention Group			
	Vigorous Intensity/ High Duration	Moderate Intensity/ High Duration	Moderate Intensity/ Moderate Duration	Vigorous Intensity/ Moderate Duration
Intensity, rate of perceived exertion				
Weeks 1-12	10-12	10-12	10-12	10-12
Weeks 13-24	13-15	10-12	10-12	13-15
Weeks 25-52	13-15	10-12	10-12	13-15
Duration, min/d (min/wk)				
Weeks 1-4	20 (100)	20 (100)	20 (100)	20 (100)
Weeks 5-8	30 (150)	30 (150)	30 (150)	30 (150)
Weeks 9-12	40 (200)	40 (200)	40 (200)	30 (150)
Weeks 13-16	40 (200)	50 (250)	40 (200)	30 (150)
Weeks 17-20	40 (200)	60 (300)	40 (200)	30 (150)
Weeks 21-52	40 (200)	60 (300)	40 (200)	30 (150)

pants were instructed to record their weekly exercise in a log that was returned to the intervention team, and feedback was provided to the participant.

Assessments

Outcomes of this study were assessed at 0, 6, and 12 months. Height was measured with a wall-mounted stadiometer to the nearest 0.1 cm. Weight was measured on a calibrated balance beam scale to the nearest 0.25 lb and then converted to kilograms. Participants were weighed in undergarments while wearing a cloth hospital gown. Body mass index was calculated as weight in kilograms divided by the square of height in meters.

A submaximal graded exercise treadmill test was used to assess cardiorespiratory fitness. The speed of the treadmill was constant at 80.4 m/min, with grade beginning at 0% and progressing by 2.5% at 3-minute intervals until 85% of age-predicted maximal heart rate (computed as 220 minus age) was achieved. Heart rate was measured using a 12-lead electrocardiogram at 1-minute intervals and at the point of termination. A calibrated SensorMedics Vmax metabolic cart (Yorba Linda, Calif) was used to assess breath-by-breath oxygen consumption, and data were averaged in 20-second intervals.

Data on exercise participation were obtained from the exercise logs and included minutes, intensity, and type of exercise. These data were used as a process measure to assess adoption and maintenance of the prescribed duration and intensity of exercise.

Leisure-time physical activity was assessed using 7-day physical activity recall and was completed using a structured interview.[10] Total duration of leisure-time physical activity classified as at least moderate intensity was computed and used for data analysis.

The 1998 version of the food frequency questionnaire developed by Block et al[11] was used to assess energy intake. This type of food frequency questionnaire has previously been validated.[11]

Statistical Analysis

Power calculations were computed based on expected changes in body weight based on a 3-factor design (intensity × duration × time), with time as the repeated measure. We estimated moderate intraclass correlations (0.40-0.60) among the repeated measures for the major dependent variable (body weight). Using a conservative and moderate effect size (0.50), and taking into consideration moderate intraclass correlations among the repeated measures (0.40-0.60), we estimated that 40 participants per group would provide at least 70% statistical power at an α level of .05. To allow for the potential for a 15% to 20% attrition rate, 50 women were randomized to each treatment group.

Based on the study design, a priori analyses were performed to assess differences in the outcome variables based on randomization group. Additional analyses were performed based on post hoc grouping of participants according to duration of reported physical activity participation.

Mixed-effects models were used to examine the significant group, time, and group-time interaction effects for the primary outcomes. Five participants were not followed up for the 12-month period because of pregnancy (n=4) and a nonstudy-related death (n=1) and were excluded from all analyses. Other participants with missing data for the primary outcome variables were included in intention-to-treat analyses using baseline values carried forward. Least-square means were obtained from the models and differences between groups were tested with Bonferroni adjustment. Statistical analyses were performed using SAS (version 8, SAS Institute Inc, Cary, NC). $P \leq .05$ (2-tailed) was used to identify statistical significance.

RESULTS

Demographic characteristics of participants are shown in TABLE 2. There were no significant differences in baseline characteristics between women randomly assigned to each of the 4 exercise groups. Excluding the 5 participants who became pregnant or had a nonstudy-related death, 184 (94%) of 196 randomized participants completed the study. χ^2 Analysis showed no significant difference in completion rates between groups (vigorous intensity/high duration=96%; moderate intensity/high duration=88%; moderate intensity/moderate duration=88%; vigorous

intensity/moderate duration=94%). The reasons for attrition are shown in Figure 1. There was no significant difference in baseline age, weight, BMI, or cardiorespiratory fitness between participants who completed or dropped out of this study (data not shown).

Attendance, Exercise, and Energy Intake

Study participants attended a mean (SD) of 79.2% (19.2%) of group sessions for months 0 through 6, with an attendance of 71.4% (21.1%) over the entire 12-month period. The telephone intervention was implemented during months 7 through 12 and 75.1% (27.2%) of telephone calls were completed. There were no significant differences between groups for percentage of group sessions attended or telephone calls completed.

Exercise participation data are presented in TABLE 3 and are based on exercise logs for months 0 through 6 and months 7 through 12. There was a significant exercise duration effect ($P=.048$), indicating that the minutes of exercise were greater in the vigorous intensity/high duration and moderate intensity/high duration groups compared with the moderate intensity/moderate duration and vigorous intensity/moderate duration groups. For rating of perceived exertion, there was a significant exercise intensity effect ($P<.001$ for 0-6 and 7-12 months) and exercise intensity × time ($P=.04$ for 0-6 months and $P=.02$ for 7-12 months). These results indicate that the rating of perceived exertion was greater in the vigorous intensity/moderate duration and vigorous intensity/high duration groups compared with

Table 2. Characteristics of Participants at Baseline

	Intervention Group				
	Vigorous Intensity/ High Duration (n = 50)	Moderate Intensity/ High Duration (n = 50)	Moderate Intensity/ Moderate Duration (n = 50)	Vigorous Intensity/ Moderate Duration (n = 51)	Total (N = 201)
Age, mean (SD), y	38.3 (5.4)	36.8 (5.3)	36.8 (6.0)	35.9 (5.7)	37.0 (5.7)
Weight, mean (SD), kg	87.3 (11.2)	86.8 (14.6)	87.2 (13.1)	88.1 (14.6)	87.4 (13.3)
Body mass index, mean (SD)*	32.8 (3.9)	32.2 (3.9)	32.8 (4.3)	32.8 (4.6)	32.6 (4.2)
Level of education, No. (%)					
High school	11 (22)	6 (12)	7 (14)	7 (14)	31 (15)
Vocational training	1 (2)	4 (8)	3 (6)	2 (4)	10 (5)
Some college	17 (34)	19 (38)	21 (42)	22 (43)	79 (39)
College degree	14 (28)	14 (28)	12 (24)	14 (27)	54 (27)
Graduate/professional education	7 (14)	7 (14)	7 (14)	6 (12)	27 (13)
Employment status, No. (%)					
Professional	19 (38)	22 (44)	20 (40)	22 (43)	83 (41)
Clerical/technical	16 (32)	23 (46)	13 (26)	19 (37)	71 (35)
Service/laborer	4 (8)	1 (2)	4 (8)	3 (6)	12 (6)
Homemaker	5 (10)	2 (4)	4 (8)	2 (4)	13 (7)
Student	1 (2)	1 (2)	0	1 (2)	3 (2)
Unemployed	0	0	2 (4)	0	2 (1)
Other	5 (10)	1 (2)	7 (14)	4 (8)	17 (8)
Race/ethnicity, No. (%)					
American Indian or Alaska Native	1 (2)	0	0	0	1 (1)
Asian	0	0	0	0	0
Black	3 (6)	3 (6)	8 (16)	2 (4)	16 (8)
Hispanic, Latino, Portuguese, or Cape Verdean	1 (2)	1 (2)	6 (12)	9 (18)	17 (9)
Native Hawaiian or other Pacific Islander	0	1 (2)	0	0	1 (0)
White	44 (88)	45 (90)	35 (70)	39 (76)	163 (81)
Mixed	0	0	1 (2)	1 (2)	2 (1)
Not specified	1 (2)	0	0	0	1 (0)
Marital status, No. (%)					
Married	34 (68)	36 (72)	28 (56)	32 (63)	130 (65)
Separated	3 (6)	0	1 (2)	1 (2)	5 (2)
Divorced	3 (6)	4 (8)	7 (14)	3 (6)	17 (8)
Widowed	0	1 (2)	0	2 (4)	3 (1)
Never married	10 (20)	9 (18)	14 (28)	13 (25)	46 (23)
Cigarette smoking, No. (%)					
Yes	5 (10)	3 (6)	3 (6)	6 (12)	17 (8)
No	45 (90)	47 (94)	47 (94)	45 (88)	184 (92)

*Calculated as weight in kilograms divided by the square of height in meters.

the moderate intensity/moderate duration and moderate intensity/high duration groups. Similar results were shown for heart rate per exercise session for intensity effect ($P=.002$ for 0-6 months and $P<.001$ for 7-12 months) and exercise intensity × time ($P=.49$ for 0-6 months and $P=.06$ for 7-12 months) (Table 3). Walking was reported for 87.5% of the exercise sessions (brisk walking = 30.8%; treadmill walking = 56.7%) across the 12 months of treatment.

Data for leisure-time physical activity and energy intake are presented in Table 3. There was no significant difference in the pattern of change between groups for minutes of leisure-time physical activity of at least moderate intensity, total energy intake, and percentage of energy intake consumed as dietary fat.

Change in Body Weight

Percentage weight loss data are shown in FIGURE 2. Additional body weight and BMI data are presented in TABLE 4. The mean (SD) weight loss at 12 months was 8.9 (7.3) kg for the vigorous intensity/high duration group; 8.2 (7.6) kg, moderate intensity/high duration; 6.3 (5.6) kg, moderate intensity/moderate duration; and 7.0 (6.4) kg, vigorous intensity/moderate duration ($P<.001$). Weight loss was significant within all groups, but there was no significant effect of either exercise duration or exercise intensity on changes in body weight between groups. A similar pattern of change in BMI was observed (Table 4).

Change in Cardiorespiratory Fitness

Compared with baseline, cardiorespiratory fitness significantly increased following both 6 months and 12 months of treatment. All groups showed significant within-group mean (SD) percentage increases in oxygen consumption fol-

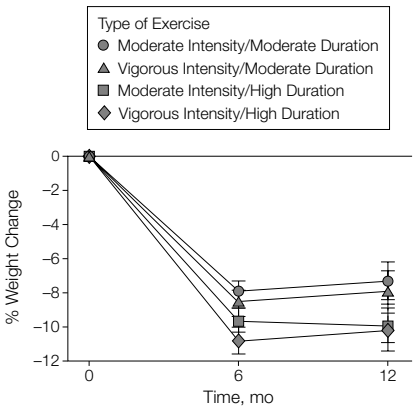
Table 3. Differences Between Intervention Groups at 6 and 12 Months*

	Intervention Groups				*P* Value						
	Vigorous Intensity/ High Duration	Moderate Intensity/ High Duration	Moderate Intensity/ Moderate Duration	Vigorous Intensity/ Moderate Duration	Exercise Intensity Effect†	Exercise Duration Effect‡	Intensity × Duration	Time Effect	Intensity × Time	Duration × Time	Intensity × Duration × Time
Duration, min/wk											
Month 0-6	189.6 (53.1)	189.3 (65.0)	167.1 (53.1)	152.5 (51.5)	.07§	.04§	.39§	.84§	.25§	.64§	.95§
Month 7-12	186.5 (71.2)	210.8 (94.4)	177.5 (57.9)	144.3 (48.5)	.002‖	<.001‖	.44‖	<.001‖	.08‖	.03‖	.09‖
Duration, min/d											
Month 0-6	38.9 (8.5)	38.7 (8.9)	36.1 (9.7)	32.4 (8.1)	.002	.048	.16	<.001	.02	.26	.92
Month 7-12	42.4 (11.9)	48.9 (13.4)	43.6 (12.2)	33.7 (7.7)							
Frequency, d/wk											
Month 0-6	4.9 (0.8)	4.8 (0.8)	4.6 (0.8)	4.7 (0.7)	.62§	.57§	.75§	<.001§	.63§	.33§	.63§
Month 7-12	4.4 (1.0)	4.2 (1.1)	4.1 (0.7)	4.3 (1.1)	.06‖	.001‖	.52‖	.003‖	.89‖	.80‖	.58‖
Perceived exertion per session											
Month 0-6	12.7 (1.1)	12.0 (1.4)	11.6 (2.0)	12.8 (1.2)	<.001§	.64§	.61§	.71§	.04§	.37§	.63§
Month 7-12	13.3 (1.5)	12.0 (0.9)	12.1 (1.6)	13.3 (1.8)	<.001‖	.98‖	.21‖	.20‖	.02‖	.36‖	.04‖
Heart rate per exercise session, beats/min											
Month 0-6	127.4 (10.8)	117.0 (11.8)	120.2 (13.0)	128.7 (10.3)	.002§	.02§	.09§	.01§	.49§	.03§	.03§
Month 7-12	137.5 (12.3)	115.8 (8.7)	126.5 (14.2)	136.3 (11.5)	<.001‖	.004‖	.04‖	.005‖	.06‖	.68‖	.15‖
Leisure-time physical activity, min/wk											
Baseline	134.3 (288.8)	160.6 (248.8)	108.3 (221.7)	115.2 (245.3)	.14	.49	.32	.002	.34	.44	.28
6 mo	328.0 (240.1)	286.9 (200.7)	266.4 (211.3)	198.8 (161.9)							
12 mo	175.7 (170.3)	189.9 (119.0)	206.6 (242.0)	140.1 (115.4)							
Energy intake, kcal/d											
Baseline	2099 (796)	2116 (981)	2027 (743)	2200 ± 875	.27	.30	.21	<.001	.85	.65	.88
6 mo	1446 (666)	1498 (464)	1438 (500)	1533 ± 558							
12 mo	1471 (532)	1557 (531)	1350 (422)	1449 ± 502							
Energy intake, % of fat											
Baseline	38.6 (6.7)	38.7 (8.8)	38.7 (6.5)	36.8 (5.2)	.81	.90	.42	<.001	.18	.32	.49
6 mo	29.6 (4.5)	27.1 (5.0)	28.5 (6.3)	28.8 (6.1)							
12 mo	31.1 (6.1)	30.3 (6.4)	29.2 (6.0)	30.2 (5.5)							

*Values expressed as mean (SD) unless otherwise indicated. Based on mixed effect statistical procedure using intention-to-treat analysis (N = 196).
†Exercise intensity effect compares vigorous intensity groups (vigorous intensity/high duration and vigorous intensity/moderate duration) with moderate-intensity groups (moderate intensity/high duration and moderate intensity/moderate duration).
‡Exercise duration effect compares high-duration groups (vigorous intensity/high duration and moderate intensity/high duration) with moderate-duration groups (vigorous intensity/moderate duration and moderate intensity/moderate duration).
§Computed using unstructured dependence structure.
‖Computed assuming autoregressive-dependent structure using weekly data.

lowing 12 months of treatment (vigorous intensity/high duration = 22.0% [19.9%]; moderate intensity/high duration = 14.9% [18.6%]; moderate intensity/moderate duration = 13.5% [16.9%]; vigorous intensity/moderate duration = 18.9% [16.9%]) (P = .04). However, there were no significant effects of either exercise intensity (P = .11) or exercise duration (P = .35) on changes in cardiorespiratory fitness between groups across 12 months of treatment (Table 4).

Figure 2. Percentage Change in Weight Based on Intensity and Duration (N = 196)



Exercise Dose-Response Results

In post hoc analysis, participants were grouped based on the amount of physical activity that was classified as at least moderate intensity based on the 7-day physical activity recall completed at both 6 and 12 months. Participants were placed into the following groups: (1) averaging less than 150 min/wk for both 6 and 12 months (n = 31); (2) averaging 150 min/wk or more at month 6 and less than 150 min/wk at month 12, or averaging less than 150 min/wk at month 6 and 150 min/wk or more at month 12 (n = 81); (3) averaging 150 min/wk or more for both 6 and 12 months (n = 33); (4) averaging 200 min/wk or more for both 6 and 12 months (n = 51). There was a significant difference in minutes per week of at least moderate intensity exercise between groups at month 6 and month 12 (P < .05).

Change in body weight and BMI are presented in FIGURE 3 and TABLE 5. After Bonferroni adjustment for multiple comparisons, weight loss at 12 months was significantly greater in the group with 200 min/wk or more of exercise compared with both the group with less than 150 min/wk of exercise and the other (inconsistent) exercise group. Weight loss in the group with 150 min/wk or more of exercise did not differ from other groups.

Percentage change in cardiorespiratory fitness was significantly greater at 12 months in the group with 200 min/wk or more of exercise compared with the group with less than 150 min/wk of exercise (P = .007) and the other group (P = .003). Percentage change in fitness in the group with 150 min/wk or more of exercise was not sig-

Table 4. Differences in Weight Loss and Cardiorespiratory Fitness Between Intervention Groups at 6 and 12 Months*

	Intervention Groups				*P* Value†						
	Vigorous Intensity/ High Duration	Moderate Intensity/ High Duration	Moderate Intensity/ Moderate Duration	Vigorous Intensity/ Moderate Duration	Exercise Intensity Effect	Exercise Duration Effect	Intensity × Duration	Time Effect	Intensity × Time	Duration × Time	Intensity × Duration × Time
Body weight, kg											
Baseline	87.7 (10.9)	87.2 (14.7)	87.1 (13.2)	87.9 (14.7)							
6 mo	78.3 (11.7)	79.2 (15.9)	80.0 (12.2)	80.4 (14.4)	.85	.78	.86	<.001	.89	.37	.45
12 mo	78.9 (13.4)	79.0 (17.0)	80.7 (13.3)	81.0 (14.3)							
Body mass index‡											
Baseline	32.9 (3.9)	32.3 (3.9)	32.7 (4.3)	32.7 (4.6)							
6 mo	29.3 (4.2)	29.3 (4.5)	30.0 (4.2)	29.9 (4.6)	.96	.41	.77	<.001	.90	.32	.43
12 mo	29.5 (4.8)	29.2 (4.8)	30.3 (4.5)	30.2 (4.6)							
Cardiorespiratory fitness, mL/kg per min											
Baseline	20.2 (2.9)	19.4 (3.2)	19.7 (3.7)	19.7 (3.1)							
6 mo	23.7 (4.2)	21.9 (3.9)	21.2 (4.0)	22.2 (3.8)	.35	.90	.31	<.001	.20	.24	.84
12 mo	24.5 (4.8)	22.1 (4.0)	22.2 (4.6)	23.3 (4.5)							
Percent change in cardiorespiratory fitness											
Baseline to 6 mo	17.8 (16.0)	13.4 (14.9)	9.0 (16.7)	13.3 (15.0)	.11	.35	.83	.04	.73	.35	.72
Baseline to 12 mo	22.0 (19.9)	14.9 (18.6)	13.5 (16.9)	18.9 (16.9)							
Time to achieve 85% of maximal heart rate, min											
Baseline	11.5 (3.1)	11.0 (4.0)	10.8 (3.8)	11.4 (3.3)							
6 mo	15.9 (4.4)	14.3 (3.6)	13.9 (3.8)	15.0 (4.6)	.26	.55	.90	<.001	.66	.81	.57
12 mo	14.8 (4.1)	14.2 (4.3)	13.6 (3.8)	14.3 (3.5)							

*Values expressed as mean (SD) unless otherwise indicated. Based on mixed effect statistical procedure using intention-to-treat analysis (N = 196).
†Based on repeated measures analysis of variance, which included all data collection periods (baseline, 6 months, and 12 months).
‡Calculated as weight in kilograms divided by the square of height in meters.

nificantly different compared with the other groups (Table 5).

Analysis of energy intake showed no significant difference between groups. When collapsed across all groups, mean (SD) baseline energy intake was 2118 (849) kcal/d and was reduced to 1480 (552) kcal/d at 6 months and 1456 (500) kcal/d at 12 months.

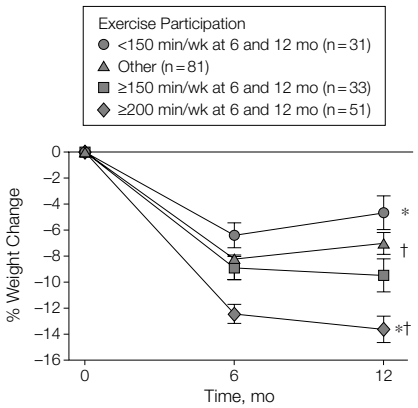
COMMENT

While exercise is established as an important component of a behavioral weight loss program, the optimal amount of exercise necessary to improve long-term weight loss has yet to be determined. In this study examining the impact of prescribing durations of exercise (moderate vs high) and 2 intensities of exercise (moderate vs vigorous) on 12-month weight loss in previously sedentary and overweight women, higher amounts of exercise resulted in a 10% weight loss compared with an 8% weight loss for a lesser amount of exercise, but this difference was not statistically significant.

Previous studies examining varying intensities of exercise on changes in body weight and body composition typically did not exceed 6 months in duration, and showed no effect for exercise intensity on body weight or body composition.[7,12] Unlike these previous studies, the current study included a strong dietary component in the intervention and was significantly longer (12 months), yet higher intensity exercise did not significantly increase weight loss. This finding may be a result of the difference in exercise intensity not resulting in a difference in energy expenditure.

While exercise has been shown to be a significant predictor of long-term weight loss, maintaining reductions in energy intake may be equally important. The lack of a significant difference in 12-month weight loss between the 4 intervention groups may be a result of all groups maintaining reductions in energy intake. Recently,

Figure 3. Percentage Change in Weight Based on Exercise Duration (N=196)



Participant data were based on the average amount of exercise per week at month 6 and month 12 for exercise participation groups: (1) less than 150 min/wk at 6 and 12 months, (2) 150 min/wk or more at 6 and 12 months, and (3) 200 min/wk or more at 6 and 12 months. The other exercise participation category indicates that participant data averaged 150 min/wk or more at month 6 and less than 150 min/wk at month 12, or averaging less than 150 min/wk at month 6 and 150 min/wk at month 12. Groups that have the same symbol (asterisk or dagger) are significantly different.

Table 5. Differences in Weight Loss and Cardiorespiratory Fitness Based on Exercise Participation at 6 and 12 Months*

	Exercise Participation Group, min/wk at 6 and 12 mo†				*P* Value§		
	<150 (n = 31)	Other (n = 81)‡	≥150 (n = 33)	≥200 (n = 51)	Group	Time	Group × Time
Body weight, kg							
Baseline	83.6 (13.2)	90.0 (13.8)	88.7 (12.9)	85.1 (12.2)			
6 mo	78.4 (14.0)	82.5 (14.3)	80.7 (12.1)	74.6 (11.8)	.01	<.001	<.001
12 mo	79.8 (14.2)	83.9 (15.2)	80.2 (12.9)	73.5 (12.4)			
Body mass index‖							
Baseline	31.7 (3.9)	33.1 (4.0)	33.2 (4.8)	32.2 (4.0)			
6 mo	29.7 (4.3)	30.3 (4.3)	30.2 (4.6)	28.2 (4.1)	.07	<.001	<.001
12 mo	30.2 (4.4)	30.8 (4.7)	30.0 (4.8)	27.8 (4.3)			
Cardiorespiratory fitness, mL/kg per min							
Baseline	20.0 (2.8)	19.5 (3.4)	20.3 (3.6)	19.6 (3.1)			
6 mo	21.4 (4.0)	22.0 (4.0)	22.0 (4.2)	23.3 (4.0)	.20	<.001	<.001
12 mo	22.3 (4.6)	22.1 (4.3)	23.9 (4.6)	24.5 (4.6)			
Percent change in cardiorespiratory fitness							
Baseline to 6 mo	6.8 (13.2)	13.5 (14.6)	9.1 (15.6)	20.2 (17.2)	<.001	<.001	.01
Baseline to 12 mo	11.3 (14.3)	13.6 (17.2)	18.9 (16.7)	26.2 (20.2)			
Time to achieve 85% of maximal heart rate, min							
Baseline	11.8 (3.7)	10.8 (3.5)	11.1 (3.8)	11.5 (3.5)			
6 mo	14.7 (4.3)	14.2 (4.2)	14.7 (4.7)	15.7 (3.6)	.07	<.001	.02
12 mo	14.5 (3.9)	13.1 (3.7)	14.5 (3.7)	15.8 (3.9)			

*Values expressed as mean (SD) unless otherwise indicated. Based on mixed effect statistical procedure (N = 196).
†Participant data were categorized based on average amount of exercise per week at month 6 and month 12.
‡Averaged 150 min/wk or more at month 6 and less than 150 min/wk at month 12, or averaging less than 150 min/wk at month 6 and 150 min/wk or more at month 12.
§Based on repeated measures analysis of variance, which included all data collection periods (baseline, 6 months, and 12 months).
‖Calculated as weight in kilograms divided by the square of height in meters.

Jakicic et al[13] demonstrated that both exercise and eating behavior significantly contribute to 18-month weight loss. Moreover, McGuire et al[14] reported that reductions in energy expenditure and increases in intake of dietary fat were associated with weight regain in participants in the National Weight Control Registry. However, energy intake data should be interpreted with caution because overweight adults underestimate their energy intake by approximately 300 to 500 kcal/d.[15]

There is limited evidence from long-term clinical trials to support the recommendation of 30 min/d of moderate intensity physical activity[4,16] or 60 min/d to enhance weight loss[5] when incorporated into a standard behavioral weight loss program that includes a dietary component. Our findings suggesting that long-term weight loss is improved as exercise participation increases appear to be consistent with the recommendation by the Institute of Medicine and confirms previously published results.[9,17]

The results of this study also have important implications independent of the effects of the exercise interventions on changes in body weight. Literature suggests that exercise and improvements in cardiorespiratory fitness may enhance health independent of body weight.[18-21] The current study showed that all levels of exercise that were prescribed resulted in significant improvements in cardiorespiratory fitness.

This study also has several limitations. The lack of a diet-only comparison group prevents this study from determining the effect of different durations and intensities of exercise on body weight vs a nonexercise intervention. This study also used an intensive behavioral intervention to maximize exercise participation, and this approach may not be practical in most clinical settings. Therefore, it may be important to examine the cost-effectiveness of these intensive interventions in future weight loss studies. In addition, because the majority of exercise performed in this study was brisk walking, the effect of other forms of exercise (eg, resistance exercise) on long-term changes in body weight could not be determined. Moreover, body composition data are not available across this 12-month study, and therefore the effect of exercise intensity and duration on these parameters cannot be examined.

The results of this study have implications for prescription of exercise for sedentary, overweight adults engaging in weight loss efforts. Our results suggest that moderate to high doses of exercise in combination with a decrease in energy intake resulted in 8% to 10% reductions in body weight following a 12-month intervention. Moreover, participants randomized to vigorous exercise intensity did not have greater weight loss than those randomized to a similar dose of exercise performed at a moderate intensity. However, when data were analyzed based on the amount of exercise performed, greater levels of exercise were associated with a greater magnitude of weight loss following 12 months of treatment. Thus, interventions should initially target the adoption and maintenance of at least 150 min/wk of moderate intensity exercise, and when appropriate, eventually progress to exercise levels consistent with the Institute of Medicine's recommendation of 60 min/d.

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Drafting of the manuscript: Jakicic, Marcus, Gallagher, Lang.
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