ORIGINAL RESEARCH

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Influence of Diet and/or Exercise on Body Composition and Cardiorespiratory Fitness in Obese Women

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The purpose of this study was to measure the influence of diet, exercise, or both on body composition and cardiorespiratory fitness in obese women. Ninety-one obese subjects were randomized into one of four groups: diet (D) (4.19–5.44 MJ or 1,200–1,300 kcal/day), exercise (E) (five 45-min sessions at 78.5 ± 0.5% maximum heart rate), exercise and diet (ED), and controls (C). Maximal aerobic power and body composition were measured in all subjects before and after a 12-week diet intervention period. Subjects in D and ED lost 7.8 ± 0.7 and 8.1 ± 0.6 kg body mass, with no significant change for E relative to C. Losses of percent body fat and fat mass were significantly greater in D and ED but not in E relative to C. The change in $\dot{V}O_2max$ was greater in ED and E but not D when compared to C. Results indicate that moderate aerobic exercise training during a 12-week period has no discernible effects on body composition but does improve cardiorespiratory fitness in dieting obese women.

Key Words: aerobic conditioning, energy restriction, maximal aerobic power, overweight, prevention, treatment

Although physical activity appears to be linked to the prevention of obesity, its role in the treatment of obesity is still unclear (22, 30). Several recent meta-analyses and reviews have indicated that exercise alone without energy restriction causes little change in body mass among the obese, while the combination of exercise and energy restriction has a minor influence in accelerating body mass loss or countering fat-free mass loss when compared to energy restriction alone (3, 6, 8, 9, 13, 14, 18, 22, 24, 25, 30). However, these reviewers cautioned that most studies lacked appropriate control groups (9, 18), the number of subjects was often small (only 4% of studies used 100 subjects or more) (18), and the frequency, duration, and intensity of exercise regimens were less than optimal (3, 8, 18, 30). Several studies failed to measure significant improvements in cardiorespiratory fitness by obese subjects following exercise training, indicating that the exercise program was probably of insufficient volume and intensity or that exercise adherence was poor (2, 17, 27, 29).

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Although a combination of moderate energy restriction (4.2–6.2 MJ/day) and near-daily activity has been prescribed to treat obesity (4, 22), most currently available studies have used very low energy diets (<1.9 MJ/day) (7, 12, 23, 25, 27, 29). Few randomized, controlled studies have been published on the influence of moderate to vigorous exercise and/or moderate energy restriction on the body composition and cardiorespiratory fitness levels of obese women (4, 10, 11, 16, 20). The purpose of this 12-week, randomized, controlled study was to determine the influence of moderate to vigorous aerobic exercise (five 45-min brisk walking sessions per week at 70–80% maximum heart rate), energy restriction (4.2–5.4 MJ/day), or both on body composition and cardiorespiratory fitness in a large group of obese women.

Methods

Subjects

Obese female subjects were recruited from the surrounding community through advertisements according to these selection criteria: (a) between the ages of 25 and 75 years; (b) in good health, with no known diseases including diabetes, cancer, or heart disease; (c) a body mass index between 25 and 65 kg/m^2; (d) not currently on a reducing diet or exercise program (less than three moderate to vigorous aerobic sessions of greater than 20 min duration per week); (e) willing to be randomized to any group and meet all requirements of the study; (f) not using cigarettes or abusing alcohol. Blood chemistry panels (two separate tests) revealed that all subjects were normoglycemic. Informed consent was obtained from each subject, and the experimental procedures were approved by the institutional review board of Appalachian State University.

Research Design

Cardiorespiratory fitness and body composition were measured in all subjects before and after a 12-week exercise and/or energy restriction intervention period (4.19–5.44 MJ/day or 1,200–1,300 kcal/day), with data analyzed using a 4 [obese control (C), exercise (E), diet (D), and exercise and diet (ED) groups] × 2 (pre- and poststudy) repeated-measures design. Obese subjects were randomized to one of the four groups. To control for subjects' expectations, social stimulation, and attention from the exercise training staff, the nonexercise groups met in the same facility as the walking groups and engaged in mild calisthenic exercises. The study was conducted from late January to April.

During the week prior to and at the end of the 12-week study, weight, height, body mass index, and percent body fat were determined for each subject. Weight and height were determined using a physician's balance beam scale and stadiometer, respectively. Weekly weigh-ins were conducted on the same day (Wednesday) and time (12 noon) for all obese subjects during the 12-week intervention. Subjects wore light clothing and no shoes for body mass measurements. Body mass index was determined from height and weight. All subjects were tested for body composition using underwater weighing (19). Residual volume was measured by the nitrogen washout procedure using the Vmax 229LV metabolic cart from the SensorMedics Corporation (Yorba Linda, CA). Maximal aerobic power ($\dot{V}O_2max$) was determined utilizing the Bruce graded maximal treadmill protocol (5). Oxygen uptake and metabolic responses were measured using the MedGraphics CPX Express metabolic system (Medical Graphics Corporation, St. Paul, MN). The MedGraphics CPX metabolic system measures respiratory gases on a breath-by-breath basis and is a valid method of analyzing metabolic and respiratory function at rest and during exercise (28). Analyzers were calibrated using gases provided by MedGraphics Corporation: The calibration gas contained 5% CO_2, 12% O_2, and balance N_2. The standard specification of error for the reference and calibration gas is ±0.10% (Medical Graphics Corporation, St. Paul, MN). Gases were calibrated prior to each $\dot{V}O_2$max test.

Subjects in the two exercise groups (E and ED) were required to walk five times a week, 45 min per session, at 60–80% of maximum heart rate (MHR) for 12 weeks (60 total exercise sessions). Supervised sessions were held 4 days per week at an indoor track, where duration, heart rate, and distance walked were measured and recorded. Subjects walked one session per week without supervision. Duration and intensity of exercise were gradually increased over 3 weeks from 25–30 min/session at 60–65% MHR during the first week to 45 min at 70–80% MHR Weeks 4 through 12. Exercise heart rates were measured with chest heart rate monitors (Polar CIC Inc., Port Washington, NY). Subjects in the two nonwalking groups (C and D) reported to the exercise facility 4 days per week for 45 min of stretching and mild range-of-motion calisthenic exercises. The intent was to keep heart rates below 100 beats per minute while exposing C and D to the same staff attention received by E and ED.

Prior to the study, all subjects kept a 3-day food record after receiving instructions from the project dietitians. Obese subjects were placed on a 4.19–5.44 MJ/day (1,200–1,300 kcal) diet for 12 weeks. The menu was based on dietary exchanges (two fruit, three vegetable, two milk, six bread, two fat, five lean protein, and 0.42 MJ or 100 kcal optional foods) (15). Subjects were instructed by the project dietitians on portion sizes, food exchanges, and how to record dietary intake using a daily exchange checklist. Compliance to the diet was measured by random, weekly, 24-hr dietary recalls (11 per subject during the study) and weekly review of the daily exchange checklist (15, 19). Nutrient intake from the 3-day food records and 24-hr dietary recalls was assessed using the computerized dietary analysis system Food Processor Plus, Version 6.0 (ESHA Research, Salem, OR) (15). Subjects in the two diet groups also attended a weekly 45-min class during which they received additional instruction on study procedures, weight loss principles, nutrition guidelines, and the importance of compliance to the dietary regimen.

Statistical Analysis

Data were analyzed using a 4 (C, E, D, and ED groups) × 2 (pre- and poststudy time points) repeated-measures ANOVA. When the Group × Time interaction p value was ≤.05, we used the Duncan multiple comparison test to compare E, D, and ED changes relative to changes in C. Statistical significance was set at $p < .05$, and values are expressed as mean ± *SE*.

Results

Of the 102 obese, Caucasian subjects (43.2 ± 0.6% body fat, 44.9 ± 1.1 years of age) recruited for the study, all but 11 complied with the research design, giving a final subject count of 91. During the 12-week study, subjects in the calisthenics exercise groups (C and D) were required to attend 48 sessions; actual attendance was 84%, with makeup sessions increasing this to 95%. Heart rates during the calisthenics exercise sessions averaged 96 ± 2 beats/min. Subjects in the walking groups were required to attend 48 sessions and exercise once per week on their own time (60 total sessions). Actual attendance at the supervised walking sessions was 83%; unsupervised and makeup sessions resulted in an overall 95% exercise record (just under the goal of five walking sessions per week). Following the initial 3-week period of adaptation to the walking program, subjects in the walking groups averaged 45 min per session at a heart rate of 137 ± 2 beats/min (78.5 ± 0.5% of maximum heart rate) and walked an average of 4.33 ± 0.08 km/session. The average estimated gross energy expenditure during the training sessions was 255 kcal/session (1). Attendance by the subjects in the energy restriction groups at the weekly weight management classes was 83% for the 12-week study period.

Energy intake during the study as assessed by 11 random 24-hr dietary recalls per subject averaged 5.31 ± 0.16 MJ/day (1,270 ± 39 kcal/day) for D and ED, with percent energy as carbohydrate, fat, and protein measured at 60.3 ± 0.9%, 22.3 ± 0.7%, and 19.1 ± 0.3%, respectively. Prior to the study, 3-day food records indicated an intake of 8.63 ± 0.32 MJ/day (2,065 ± 76 kcal/day) and 7.88 ± 0.35 MJ/day (1,884 ± 84 kcal/day) for the groups randomized to D and ED, and C and E, respectively.

Subject characteristics are summarized in Table 1 for each group. The groups did not differ in age, height, body mass, body mass index, or blood pressure. Subjects ranged in age from 20 to 70 years, body mass 61.4 to 149.1 kg, and body mass index 25.6 to 64.7 kg/m^2. Subjects included both premenopausal and postmenopausal women. Body composition and cardiorespiratory responses did not differ between the premenopausal and postmenopausal women in response to the 12-week intervention. In addition, all subjects were normotensive, and neither systolic or diastolic blood pressure differed between the groups.

Body composition data for pre- and poststudy measurements are given in Table 2. Significant Group × Time interaction statistics were found for body mass, body mass index, percent body fat, fat mass, fat-free mass, and waist/hip ratio. Subjects in D and ED lost 7.8 ± 0.7 and 8.1 ± 0.6 kg body mass, with no significant

Table 1 Subject Characteristics

	Controls (n = 22)		Exercise (n = 21)		Diet (n = 26)		Exercise & diet (n = 22)	
	M	*SE*	*M*	*SE*	*M*	*SE*	*M*	*SE*
Age (years)	43.7	2.4	44.6	2.5	45.4	1.9	48.7	2.2
Height (m)	1.66	0.01	1.65	0.01	1.63	0.01	1.66	0.01
Body mass (kg)	90.5	2.4	88.4	2.9	90.6	3.8	89.9	2.5
Body mass index (kg/m^2)	32.8	1.0	32.3	1.1	34.2	1.6	32.6	1.0
Systolic blood pressure (mmHg)	122	3.0	125	3.0	124	4.0	127	3.0
Diastolic blood pressure (mmHg)	80	3.0	84	2.0	83	3.0	83	2.0

change for E relative to C, $F(3, 87) = 51.05$, $p < .001$ (Figure 1). Loss of percent body fat was significantly greater in D (4.5 ± 0.6%) and DE (4.5 ± 0.5%) but not E (1.0 ± 0.5%) relative to C (1.0 ± 0.6%), $F(3, 87) = 17.17$, $p < .001$. In addition, a significant decrease in body mass index was found to be greater in D (2.9 ± 0.38) and DE (2.9 ± 0.27) but not E (0.3 ± 0.30) relative to C (0.3 ± 0.30), $F(3, 87) = 50.78$, $p < .001$. Significant reductions were found for fat mass in both D (6.8 ± 0.6 kg) and DE (7.2 ± 0.6 kg) but not E (1.3 ± 0.5) when compared to C. However, no significant changes were found for fat-free mass in either D, DE, or E when compared to C.

Maximal cardiorespiratory data for pre- and poststudy measurements are given in Table 3. Significant Group × Time interaction statistics were found for $\dot{V}O_2max$. There were no significant Group × Time interactions for the submaximal treadmill data. The change in $\dot{V}O_2max$ was significantly greater for DE (4.2 ± 0.4 ml $\cdot$ kg^{-1} $\cdot$ min^{-1} or 18.8%), E (3.5 ± 0.5 ml $\cdot$ kg^{-1} $\cdot$ min^{-1} or 15.2%), and D (2.6 ± 0.4 ml $\cdot$ kg^{-1} $\cdot$ min^{-1} or 11.5%) relative to C (1.0 ± 0.4 ml $\cdot$ kg^{-1} $\cdot$ min^{-1}), $F(3, 87) = 9.97$, $p < .001$. The change in $\dot{V}O_2max$ when expressed as ml $\cdot$ min^{-1} was significantly greater in DE (193 ± 29 ml $\cdot$ min^{-1} or 9.7%) and E (293 ± 48 ml $\cdot$ min^{-1} or 14.6%) but not D (52 ± 32 ml $\cdot$ min^{-1}) when compared to C (70 ± 19 ml $\cdot$ min^{-1}), $F(3, 87) = 11.53$, $p < .001$ (Figure 2).

Table 2 Effects of Exercise Training and Energy Restriction on Body Composition Over 12 Weeks in Obese Females

	Controls (n = 22)		Exercise (n = 21)		Diet (n = 26)		Exercise & diet (n = 22)		Group × Time effect
	M	*SE*	*M*	*SE*	*M*	*SE*	*M*	*SE*	*p* value
Body mass (kg)									
Pre	90.5	2.4	88.4	2.9	90.6	3.8	89.9	2.5	<.001
Post	89.7	2.5	87.4	2.8	82.8*	3.7	81.8*	2.3	
Body mass index (kg/m²)									
Pre	32.8	1.0	32.3	1.1	34.2	1.6	32.6	1.0	<.001
Post	32.5	1.0	32.0	1.1	31.3*	1.5	29.7*	0.9	
Body fat (%)									
Pre	43.2	1.0	43.1	1.3	44.3	1.1	43.4	1.2	<.001
Post	42.2	1.2	42.1	1.5	39.8*	1.4	38.9*	1.3	
Fat mass (kg)									
Pre	39.3	1.7	38.6	2.3	39.7	2.3	39.5	1.9	<.001
Post	38.2	1.8	37.3	2.3	32.9*	2.4	32.3*	1.7	
Fat-free mass (kg)									
Pre	51.1	1.2	49.7	1.1	48.6	1.1	50.8	1.4	<.05
Post	51.5	1.2	50.1	1.2	47.8	1.1	50.0	1.2	
Waist/hip ratio									
Pre	0.78	0.01	0.81	0.02	0.80	0.02	0.80	0.01	<.001
Post	0.80	0.01	0.80	0.01	0.77*	0.01	0.72*	0.01	

*$p < .05$, Duncan multiple comparison test, group changes pre- to poststudy, compared to controls.

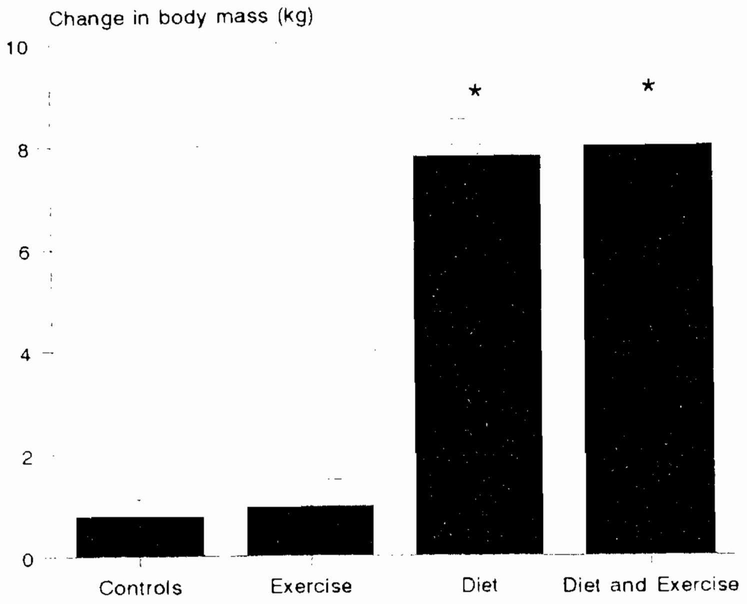

Figure 1 — Means ± *SEM* for the decrease in body mass (kg) by group during the 12-week period. *Means significantly different ($p < .05$) from the controls.

Table 3 Effects of Exercise Training and Energy Restriction on Maximal Treadmill Data Over 12 Weeks in Obese Females

	Controls (n = 22)		Exercise (n = 21)		Diet (n = 26)		Exercise & diet (n = 22)		Group × Time effect
	M	*SE*	*M*	*SE*	*M*	*SE*	*M*	*SE*	*p* value
$\dot{V}O_2max$ (ml · kg^{-1} · min^{-1})									
Pre	22.2	0.9	23.1	0.7	22.6	0.8	22.4	0.8	<.001
Post	23.2	0.9	26.6*	0.9	25.2*	1.0	26.6*	0.9	
$\dot{V}O_2max$ (ml · min^{-1})									
Pre	1,964	76	2,011	59	1,982	46	1,985	74	<.001
Post	2,034	70	2,304*	79	2,034	59	2,178*	70	
Maximum heart rate (bpm)									
Pre	175	3	178	3	176	3	174	2	.897
Post	175	3	178	2	176	3	173	2	
Maximum ventilation (L · min^{-1})									
Pre	76.2	3.8	79.1	3.7	76.5	2.8	76.3	3.0	.390
Post	80.1	3.7	88.7	3.1	80.9	3.1	84.0	3.2	
Respiratory rate (breaths · min^{-1})									
Pre	41.4	1.9	39.1	1.7	42.9	1.8	39.1	1.0	.142
Post	41.5	2.1	42.6	1.8	45.1	1.8	43.6	1.7	
Respiratory exchange ratio (RER)									
Pre	1.22	0.02	1.25	0.02	1.21	0.02	1.24	0.03	.850
Post	1.22	0.02	1.24	0.02	1.19	0.02	1.22	0.02	

*$p < .05$, Duncan multiple comparison test, group changes pre- to poststudy, compared to

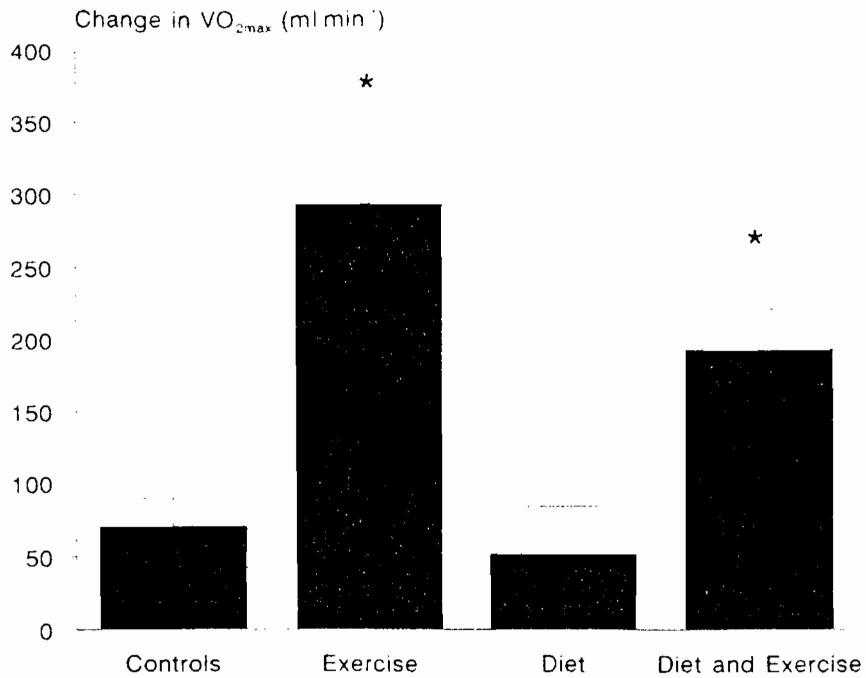

Figure 2 — Means ± *SEM* for the change in $\dot{V}O_2max$ (ml · min^{-1}) by group during the 12-week period.

Discussion

In this randomized, controlled 12-week study of a group of 91 obese women, exercise training alone or in combination with moderate energy restriction was associated with significant improvement in cardiorespiratory fitness but no change in body mass or the proportion lost as fat-free mass. The size of our sample and the use of appropriate randomized control groups lend strength to these findings.

Absolute maximal aerobic power increased 10–15% in our two exercise groups. Other researchers have reported similar improvements in $\dot{V}O_2max$, but only when the exercise intensity was moderately high (2, 4, 12, 20). Ballor et al. (2), for example, reported that high-intensity exercise (80–90% $\dot{V}O_2max$, three 25-min sessions per week for 8 weeks) increased $\dot{V}O_2max$ 17% in obese subjects during moderate energy restriction, compared to only 4% in subjects exercising at a lower intensity (40–50% $\dot{V}O_2max$, three 50-min sessions per week). These and other researchers have cautioned, however, that low-intensity exercise may be more appropriate during the early phases of obesity treatment due to safety and compliance considerations (2, 17, 22, 29, 30).

In the diet-only group, 87% of the mean 7.8-kg body mass loss was fat mass, nearly identical to the 89% of the 8.1-kg loss measured in the diet and exercise group. During moderate energy restriction, most of the body mass loss is fat mass, and the majority of researchers have reported that moderate exercise training has only a minor influence in accelerating the total amount of fat mass loss or in attenuating diet-induced losses in fat-free mass (8–11, 18, 23–25, 27). Results of the present study indicate that moderate exercise training independent of diet had a minor, nonsignificant effect on fat mass (a 1.3-kg reduction). The net energy expenditure for the exercise sessions was relatively small (approximately 187 kcal/session), equating to a 1.45-kg loss in fat mass in 12 weeks (19). Garrow and Summerbell

(9), in their meta-analysis of 28 studies, concluded that aerobic exercise training may reduce diet-induced fat-free mass loss by 0.5–1.2 kg in women and men, but that this may contain more water and potassium than average fat-free mass. Resistance exercise appears to be more useful than moderate aerobic exercise in protecting diet-induced losses in fat-free mass (9). In other words, moderate exercise such as brisk walking appears to be insufficient to significantly protect fat-free mass during energy restriction.

In our study, subjects in the two exercise groups were nearly 100% compliant in walking five times a week, 45 min per session, at a moderately high intensity (75–80% of maximum heart rate). While greater volumes of exercise over a longer period of time may have accelerated body fat-mass loss beyond that reported in this study, injuries and diminished exercise adherence would have posed significant problems, as reported by other researchers and reviewers (4, 8, 17, 22, 29).

In summary, moderate exercise training during a 12-week period improved cardiorespiratory fitness but had no significant effect in accelerating diet-induced losses in body fat mass in a large number of obese women. The net energy expenditure of moderate exercise training during obesity treatment has been described as rather diminutive when considered within the context of total energy intake and expenditure (6, 13). Nonetheless, the numerous health benefits (e.g., enhanced psychological mood state, improved blood lipid profile, and reduced risk of obesity-related diseases such as diabetes, heart disease, and hypertension) associated with regular exercise training have led most reviewers to conclude that it is an essential component of a comprehensive obesity treatment program (6, 10, 14, 19, 20, 27, 30).

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