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Exercise in the Treatment of Obesity
Effects of Four Interventions on Body Composition, Resting Energy Expenditure, Appetite, and Mood

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ABSTRACT

This study investigated changes in body composition, resting energy expenditure (REE), appetite, and mood in 128 obese women who were randomly assigned to 1 of 4 treatment conditions: diet alone, diet plus aerobic training, diet plus strength training, or diet combined with aerobic and strength training (i.e., combined training). All women received the same 48-week group behavioral program and were prescribed the same diet. Exercising participants were provided 3 supervised exercise sessions per week for the first 28 weeks and 2 sessions weekly thereafter. Participants across the 4 conditions achieved a mean weight loss of 16.5 ± 6.8 kg at Week 24, which decreased to 15.1 ± 8.4 kg at Week 48. There were no significant differences among conditions at any time in changes in weight or body composition. Women who received aerobic training displayed significantly smaller reductions in REE at Week 24 than did those who received strength training. There were no other significant differences among conditions at any time on this variable or in changes in appetite and mood.

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Exercise appears to be the single most important behavior for long-term weight control in obese individuals (Foreyt & Goodrick, 1994 ; Pronk & Wing, 1994). Several, although not all, controlled trials have shown that exercisers lose significantly more weight during treatment than do nonexercisers. More important, persons who maintain their weight loss almost universally report that they exercise regularly, whereas weight regainers do not (Jeffery et al., 1984 ; Kayman, Bruvold, & Stern, 1990).

The mechanisms by which exercise improves weight loss have been attributed to both physiological and psychological factors (Brownell, 1995 ; King & Tribble, 1991). In addition to expending calories, aerobic exercise may minimize the reductions in resting energy expenditure (REE) that accompany dieting, possibly by increasing sympathetic nervous system activity (Bouchard, Despres, & Tremblay, 1993 ; Poehlman, Melby, & Goran, 1991). This occurrence could help to prevent the slowing in weight loss that dieters frequently experience. Aerobic training has also been shown in many studies (but not all) to minimize losses of fat-free mass (FFM; Bouchard et al., 1993 ; King & Tribble, 1991), an occurrence that could also prevent reductions in REE, given the strong positive relation between REE and FFM (Ravussin & Bogardus, 1989). The most favorable findings for both REE and FFM generally have been obtained when exercise was combined with diets of 1,000—1,500 kcal/day rather than with very-low-calorie diets (VLCDs) providing 400—800 kcal/day (Poehlman et al., 1991 ; Sweeney, Hill, Heller, Baney, & DiGirolamo, 1993).

The psychological effects of exercise on weight control have received little attention, compared with its physiological effects, but according to Grilo, Brownell, and Stunkard (1993) "may be the most important mechanism" (p. 260). These and other investigators believe that exercise improves weight loss by enhancing self-esteem and mood which, in turn, may improve adherence to behavioral weight control strategies (King & Tribble, 1991). In addition, physical activity in the low-to-moderate range of intensity may maintain or even suppress appetite (Pi-Sunyer, 1992), thus facilitating long-term dietary adherence and weight loss.

The present investigation was designed to assess the effects of exercise training on several of the physiological and psychological variables described above. In conducting the study, we examined the effects not only of aerobic activity but also of strength training. The latter activity was selected because of its greater capacity than aerobic exercise to maintain or increase FFM, as shown in studies of athletes and older adults (Walberg, 1989). Thus, changes in weight, body composition, REE, appetite, and mood were examined over 48 weeks of treatment in 128 obese women who were randomly assigned to one of four conditions: diet alone, diet plus aerobic training, diet plus strength training, or diet combined with aerobic and strength training (i.e., combined training). We hypothesized that, as compared with nonexercisers, participants in all three exercise conditions would show significantly better preservation of both FFM and REE at Weeks 24 and 48, thus, resulting in superior maintenance of weight loss at Week 48. Women who received strength training, whether alone or in combination with aerobic activity, were expected to achieve the best maintenance of FFM, whereas those who received combined training were anticipated to show the smallest reductions in REE. We also hypothesized that participants in all three exercise groups, compared with nonexercisers, would show more favorable changes in appetite and mood.

Method

Participants

Participants were 128 women with a mean age of 41.1 ± 8.6 years, weight of 96.1 ± 13.5 kg, height of 164.1 ± 6.4 cm, and body mass index (BMI) of 36.5 ± 5.1 kg/m ^{2} . Ninety-nine women were Caucasian, 28 were African American, and 1 was Hispanic. Thirty-two were single, 70 were married, 21 were divorced, and the remainder were separated or widowed. Before treatment they completed an initial interview in which the requirements of the study were explained and participants' weight and dieting histories, eating and exercise habits, and psychological status were assessed (Wadden & Foster, 1992). Persons with bulimia nervosa, significant depression, or other major psychiatric disturbance were excluded, whereas those with binge eating disorder were not (and accounted for 13% of the sample). Participants also underwent a medical evaluation designed to identify contraindications including a recent myocardial infarction; a history of cerebrovascular, kidney, or liver disease; cancer; Type I diabetes; pregnancy; or the use of medications known to affect weight and energy expenditure. In the final screening, all participants completed a stress test to rule out cardiac abnormalities that might be exacerbated by exercise training. Women gave their written informed consent to participate.

Procedures

Participants were randomly assigned to the four conditions previously described. For the first 28 weeks, all participants attended weekly 90-min group treatment sessions of 7 to 10 members each. From Weeks 29 to 48, they attended 10 biweekly group sessions. Participants were treated in two cohorts, approximately 15 months apart. Those in the first cohort (n = 68) were treated at Syracuse University, and those in the second (n = 60) were treated at the University of Pennsylvania. The study was approved by each university's institutional review board.

Diet

All participants were prescribed the same diet during the 48-week program. They were asked to maintain their usual food intake during the first week. During Weeks 2—17, they were prescribed a diet of approximately 900—925 kcal/day that consisted of four servings daily of a liquid meal replacement combined with a shelf-stable dinner entree and 2 cups of salad. Each serving of the liquid diet provided 150 kcal, 15 g of protein, 11.2 g of carbohydrate, and 5 g of fat (Nutritional Formula; Sandoz Nutrition Co., Minneapolis, MN). Each of the dinner entrees provided approximately 280—300 kcal, 20 g of protein, 35—40 g of carbohydrate, and 7 g of fat (Healthy Recipes; Sandoz Nutrition Co.).

Beginning at Week 18, participants decreased their consumption of the liquid diet while increasing their consumption of conventional foods so that by Week 20 they consumed approximately 1,250 kcal/day. The refeeding protocol was supervised by a registered dietitian who co-led group sessions from Weeks 17 to 26. From Weeks 22—48, participants were instructed to consume a self-selected diet of approximately 1,500 kcal/day, with 12%—15% of calories from protein, 55%—60% from carbohydrate, and 15%—30% from fat.

Behavioral Treatment

All participants received the same cognitive—behavioral weight loss program. Group sessions, the first 28 weeks, as well as biweekly meetings from Weeks 29—48, were led by clinical psychologists. The first 28 sessions were conducted following a modified version of the OPTIFAST Program, and participants were provided a 200-page manual that summarized the materials (Sandoz Nutrition Co., 1987). They were instructed in traditional behavioral methods of weight control that included recording food intake (amounts, calories, times and places of eating, etc.) and practicing other behaviors that have been described previously (Wadden & Foster, 1992). The only difference in treatment among the conditions was that exercisers took approximately 5—10 min each week to discuss adherence to their exercise program.

The biweekly weight maintenance program (Weeks 29—48) also followed a structured protocol, and participants were again provided an accompanying manual (Sandoz Nutrition Co., 1988). Meetings addressed the skills needed to maintain a weight loss, as described previously (Wadden, Foster, & Letizia, 1994).

Exercise Conditions

All participants in the exercise conditions were provided three on-site, supervised training sessions per week (on nonconsecutive days) for the first 28 weeks and two workouts per week during Weeks 29—48. Participants exercised with members of their behavioral treatment groups. All exercise sessions were led by graduate students in exercise physiology who followed structured protocols (described below).

Diet plus aerobic training.

Participants in this condition participated in step aerobics. Each training session was preceded by a 5- to 10-min warm-up and followed by a 5-min cool-down period. Participants began exercising for 12 min at Week 1 and added 2 min to the routine each week so that by Week 14 they performed 40 min of actual "stepping". All participants began using a 10-cm step; those who could exercise comfortably on either a 15- or 20-cm step did so beginning at Week 5. Participants were instructed to exercise at a moderate intensity level, as judged by a score of 11—15 on Borg's (1962) Rating of Perceived Exertion Scale. Participants in this condition agreed not to engage in strength training at any time during the 48-week study. During Weeks 29—48, they were assisted in developing a program of at-home exercise to replace the third exercise session that was deleted from their supervised training. For most, this consisted of purchasing a step and a videotape.

Diet plus strength training.

These participants engaged in strength training using either Universal Gym (Syracuse cohort) or Cybex (Pennsylvania cohort) equipment. The circuit of exercises targeted the large muscle groups. At Week 1, participants were familiarized with the equipment; at Week 2, they performed one set each on the bench press, latissimus pull-down, chest fly, shoulder press, leg extension and curl, leg press, arm curls and extensions, sit-ups and back extensions. They performed the exercises with a resistance that allowed them to do >=10 repetitions but not >14. Initial workouts lasted approximately 20 min exclusive of the 5- to 10-min warm-up and cool-down periods. During Weeks 3—14, an extra set of each of the exercises was added to the routine so that each participant eventually did two sets of each exercise at each session. By the end of Week 14, they engaged in weight training for approximately 40 min per session. This time was held constant from Weeks 14—48, but resistance was increased whenever participants were able to perform >14 repetitions for two consecutive sets. Participants agreed not to initiate aerobic training at any time during the 48-week study. During Weeks 29—48, they were assisted in developing a personal program of strength training to replace the third session deleted from the supervised practice. For most of these participants (and those in the combined condition), this consisted of joining a health club.

Diet plus combined training.

Participants in the combined-training condition spent approximately the same amount of time exercising each session as those in the two other conditions and progressed through the sequence of training on approximately the same schedule. At each session, they devoted approximately 60% of their time to strength training and 40% to aerobic activity. Women in the Syracuse cohort were prescribed step aerobics, whereas those in the Pennsylvania cohort, because of space limitations at the facility, were prescribed treadmill walking and stationary bicycling. The duration and intensity of aerobic activity were matched between the two cohorts.

Diet alone.

Participants in this condition agreed not to engage, during the 48-week study, in any program of regular activity that resembled the aerobic or strength training conditions. A review of their weekly activity logs indicated that none of the participants initiated such training. They were allowed to maintain lifestyle activities, such as occasionally playing tennis, bowling, or going for a lunchtime walk.

Dependent Measures Weight and body composition.

Weight was measured at each visit on a balance-beam scale. Body composition was assessed by densitometry at baseline and Weeks 8, 24, and 48 using methods previously described (Wadden, Foster, & Letizia, 1994). On each occasion, underwater weight was taken six or more times after complete voluntary exhalation; the heaviest duplicated reading was used in calculating body composition. Residual lung volume was measured by the oxygen dilution technique with subjects seated in the same position as they had been underwater (Wilmore, 1969). Body density was derived from the formula of Brozek, Grande, Anderson, and Keys (1963) , and fat was determined using Siri's (1956) formula.

REE.

REE was measured at baseline and at Weeks 8, 24, and 48 by indirect calorimetry (DeltaTrac, SensorMedics, Yorba Linda, CA), following methods previously described (Wadden, Foster, Letizia, & Mullen, 1990). Participants were instructed to consume only water and to refrain from smoking or taking any over-the-counter medications for the 12 hr preceding each measurement (all of which were obtained between 7:00 am and 10:00 am); they were prohibited from exercising for a minimum of 24 hr. Participants were required to be weight stable (i.e., change <0.5 kg) for the 2 weeks preceding the measurements at Weeks 24 and 48, to control for the effects on REE of caloric restriction and weight loss (Wadden et al., 1990). Measurements were repeated in the event of protocol violations, with a maximum of one retest at each assessment period.

Appetite and mood.

Hunger, satiety, preoccupation with eating, and intensity of food cravings were assessed at baseline and at Weeks 5, 9, 13, 17, 25, and 48 using 100-mm bipolar visual analogue scales, as described previously (Foster et al., 1992). Participants' adherence to the prescribed diet was assessed at Weeks 5, 9, 13, and 17 by calculating the number of excess calories that they consumed, as determined from their weekly diet diaries. Mood was measured at the same times as appetite using the Beck Depression Inventory (BDI; Beck & Steer, 1987). It was also assessed at baseline and at Weeks 9, 25, and 48 by the Profile of Mood States (POMS; McNair, Lorr, & Droppleman, 1981).

Statistical Analyses

A preliminary analysis of variance showed that participants in the two cohorts did not differ significantly in baseline measures of age, weight, fat, BMI, FFM, REE, appetite, or mood; nor did the four treatment conditions differ on these measures at baseline, and there were no Treatment × Cohort interactions. Thus, the two cohorts were collapsed. Baseline characteristics of participants in the four conditions are shown in Table 1 . Changes in the principal measures were assessed using analysis of covariance, with initial values as the covariates. A series of one-way univariate tests were used at each time period to maximize the available sample size.

Attrition.

Ninety-nine of 128 (77.3%) participants completed the entire 48-week study. Of the 29 participants who discontinued treatment, 7 did so because of medical conditions that required treatment, and 1 became pregnant. Data for these 8 participants were not included in any analyses. Twenty-one dropped out because of scheduling conflicts, disruptive life events, or dissatisfaction with treatment–1 during the first 8 weeks, 6 between Weeks 9—24, and 14 between Weeks 25—48. Collectively, these participants remained in treatment an average of 25.2 ± 9.1 weeks and had a mean weight loss of 9.1 ± 5.8 kg when they discontinued. There were no differences in attrition between cohorts or among conditions. Dropouts were retained in the analyses of the data until the time of their attrition.

Additional exclusions.

Three additional participants were excluded from the analysis of the body composition data (but not other measures) because of protocol violations (i.e., they were fearful of water or did not exhale sufficiently underwater). REE data (but not other data) for 6 participants were excluded because of repeated protocol violations (i.e., respiratory quotient >1, reports of smoking before testing, failure to remain weight stable). Exclusions were distributed evenly across conditions.

Results

Attendance Treatment sessions.

Attendance of group treatment sessions was excellent during the first 8 weeks, averaging 97.2% ±

7.5% of possible visits (with no significant differences among conditions). During Weeks 9—24, it averaged 86.2% ± 14.4% of possible visits. Again, there were no differences among conditions but the decline in attendance, compared with Weeks 1—8, was significant, t (118) = 9.09, $p < .001$. During Weeks 25—48, attendance fell to an average of 65.6% ± 22.2% of possible visits (with no significant differences among conditions). The decline from the preceding period was again highly significant, t (111) = 13.37, $p < .001$.

Exercise sessions.

Attendance of exercise sessions generally paralleled that for group sessions. During the first 8 weeks, participants in the aerobic-, strength-, and combined-training conditions attended an average of 84.3% ± 15.1%, 91.5% ± 7.4%, and 92.0% ± 7.9% of possible exercise sessions, respectively. Differences among conditions were significant, F (2, 88) = 4.87, p < .01, with participants in the aerobic condition attending significantly fewer sessions than those in the two other groups. There were no significant differences among conditions from Weeks 9—24 or 25—40. (Attendance data were recorded only through Week 40 in the Syracuse cohort as the result of an error.) Collapsing across conditions, attendance averaged 68.7% ± 22.2% of possible visits during Weeks 9—24, which represented a significant decline from the first 8 weeks, t (88) = 11.04, $p < .001$. During Weeks 25—40, it fell to an average of 56.9% ± 24.4% of possible visits, which was again a significant decline from the previous period, t (84) = 6.72, $p < .001$.

Weight Losses

Participants in the four conditions lost an average of 10.0 ± 3.7 kg during the first 8 weeks and 14.3 ± 5.8 kg by Week 17 (the last week of the 925-kcal/day diet). Average losses increased to 16.5 ± 6.8 kg at Week 24 but decreased to 15.1 ± 8.4 kg at Week 48. Analysis of covariance revealed that there were no significant differences in weight loss among conditions at any time (see Table 2). Changes from Week 8 to Week 17 were significant, t (111) = 13.34, $p < .001$, as were those from Week 17 to Week 24, t (105) = 7.61, $p < .001$, and from Week 24 to Week 48, t (98) = 4.86, $p < .001$. Thus, participants gained a small but significant amount of weight during the maintenance program.

The data were reanalyzed to include only those participants in the exercise conditions who had attended at least 67% of possible exercise visits at Weeks 8 and 24. These analyses, which were conducted to maximize the likelihood of detecting differences between exercisers and nonexercisers (i.e., the diet-alone condition), resulted in the deletion of only 2 participants at Week 8 but a total of 19 of 86 (22.1%) participants at Week 24. Deletions were distributed evenly across conditions. These analyses, however, did not change the weight loss findings. There were no differences among the conditions at any time, and mean weight losses for these "exercise completers" were only 0.1 to 1.5 kg greater than those for the full sample of exercisers.

Changes in Fat and FFM

Participants in all four conditions showed very favorable changes in FFM and fat (see Table 2). However, contrary to expectations, there were no significant differences among conditions at any time on either variable. At Week 8, 82.1% ± 22.9% of participants' weight loss (across conditions) was derived from fat; values at Weeks 24 and 48 were 91.9% ± 22.0% and 83.8% ± 27.2%, respectively. As with the weight loss data, analysis of only the "exercise completers" did not change the findings or the conclusion that exercise did not significantly affect short- or long-term changes in body composition. Participants with more body fat at baseline had greater reductions on this measure at Week 8 (r = .31), Week 24 (*r* = .47), and Week 48 (r = .32, all *p* s < .003), whereas those with more initial FFM lost more lean mass at each of the three periods (r s = .31, .39, and .42, respectively; all p s < .001).

Changes in REE

During the first 8 weeks, REE fell an average of 153.1 ± 125.7 kcal/day in participants in the four conditions, with no significant differences among conditions (see Table 2). At Week 24, however, significant differences were observed among groups, as determined by analysis of covariance, F (3, 102) = 3.06, p < .03. Participants in the aerobic condition had significantly smaller reductions in REE than did those in the strength condition (as determined by Tukey's honestly significant difference [HSD]). There were no other significant differences among conditions at this time, although participants in both conditions that included aerobic training had smaller reductions in REE than did those in the diet-alone and strength-training alone conditions. There were no significant differences among conditions at Week 48, although participants in all the three exercise conditions had smaller reductions in REE than did those in the diet-alone condition. None of these findings changed when the data were reanalyzed including only the "exercise completers." Partial correlation analyses, controlling for the effects of treatment condition, revealed a positive relation between baseline REE and changes on this measure at Week 8 (r = .47), Week 24 (*r* = .48), and Week 48 (r = .42, all *p* s < .001). Thus, higher baseline REE values were associated with greater reductions on this measure at all periods.

Appetite Hunger.

Analysis of covariance showed that there were no significant differences among conditions at any time in changes in hunger, satiety, preoccupation with food, or intensity of food cravings. Table 3 presents the mean values on the four measures, collapsed across conditions. Additional analyses showed that participants reported significantly less hunger, compared with baseline, beginning the fifth week of treatment, t (113) = 5.38, *p* < .001, and continued to do so through Week 48, t (65) = 3.00, *p* < .004. Reports of preoccupation with food were significantly lower than baseline at Week 5, t (113) = 3.04, *p* < .003, and Week 9, t (109) = 3.63, *p* < .001, but did not differ significantly from baseline thereafter. Changes in satiety and cravings did not differ significantly from baseline at any time. The same findings were obtained on all measures when data were reanalyzed using only the exercise completers.

Caloric deviation.

Table 4 presents data concerning participants' self-reported deviation from their prescribed dietary intake. At no time were there significant differences among conditions (including when only data for exercise completers were examined). Participants on average, reported consuming an extra 352 ± 724 kcal/week at Week 5, which increased significantly to 521 ± 737 kcal/week at Week 9, t (112) = 2.87, *p* < .005, and to 1,020 ± 1,176 kcal/week at Week 13, t (84) = 5.07, *p* < .001. Excess intake at Week 17 averaged 1,032 ± 1,203 kcal/week, which did not differ significantly from the previous period.

Mood

There were no significant differences among conditions at any time in changes in BDI scores. As shown in Table 5 , scores declined significantly at Week 5, t (109) = 10.88, *p* < .001, and remained significantly below baseline for the remainder of treatment.

There were also no significant differences among conditions in changes on any of the POMS scales. Participants across conditions reported significant increases in vigor at Week 9, t (110) = 3.54, $p < .001$, that persisted over the 48 weeks of treatment. These increases were paralleled by reports of significant reductions in fatigue at Week 8, t (110) = 3.94, $p < .001$, that were also sustained at the end of treatment. Changes in depression, as measured by the POMS, approached significance at Week 9 ($p < .10$) and were significant at Week 25, t (103) = 2.13, $p < .04$, but not at Week 48. None of these findings changed when the data were reanalyzed, examining only exercise completers.

Correlates of Weight Loss

Changes in weight at Weeks 24 and 48 were examined in relation to two physiological and three behavioral variables that have been shown previously to correlate with weight loss (Wadden & Letizia, 1992). They included baseline measures of BMI, REE, and depression, as well as process measures of group treatment attendance and dietary adherence (as assessed from Weeks 2—17 by deviation from the prescribed diet). As shown in Table 6 , BMI, REE, attendance and adherence accounted for 33% of the variance in weight loss at Week 24. Thus, a higher initial BMI and REE, as well as better treatment attendance and dietary adherence, were all positively related to weight loss at Week 24. Treatment attendance and initial BMI (in that order) accounted for 22% of the variance in weight loss at Week 48 (with no other variables contributing significantly). Treatment attendance was the only variable that was significantly correlated with the maintenance of weight loss between Weeks 25—48. Participants who attended more group sessions during this time had more favorable changes in weight from Weeks 25—48 ($r = .26$, $p < .05$).

Discussion

This study examined the effects of exercise on weight, body composition, REE, appetite, and mood in obese women who consumed 925—1,500-kcal/day. Highly positive changes were observed on all five measures but exercise significantly affected only REE. At Week 24, participants in the aerobic-training (alone) condition had significantly smaller reductions in REE than those in the strength-training (alone) condition; differences between the aerobic-training and diet-alone conditions were in the expected direction. Thus, our findings are consistent with those of other investigators who found favorable effects of aerobic activity on REE in participants who consumed diets providing 1,200—1,500 kcal/day, as our participants were prescribed at the 24-week assessment (Nieman, Haig, De Guia, Dizon, & Register, 1988 ; Tremblay et al., 1986).

Our findings, however, at the 8-week assessment also confirm those of investigators who failed to find an effect on REE of aerobic training in participants who consumed VLCDs. Phinney, LaGrange, O'Connell, and Danforth (1988) , in fact, found that participants who exercised strenuously while consuming 720 kcal/day had significantly greater reductions in REE than did nonexercising dieters. Similar results were reported by two other research teams (Heymsfield, Casper, Heran, & Guy, 1989 ; Krotkiewski, Toss, Björntorp, & Holm, 1981). This occurrence appears to be the consequence of compounding the marked caloric deficit introduced by the VLCD with that introduced by exercise. Strenuous exercise could increase the degree of participants' negative energy balance, particularly if they were prohibited, as they are on VLCDs, from compensating for the energy cost of their physical activity by increasing food intake. Previous studies have shown that the greater the participants' caloric deficit (i.e., negative energy balance), the greater the reduction in REE (Sweeney et al., 1993 ; Wadden et al., 1990). Thus, we did not find an effect of aerobic training on REE at Week 8 when participants were prescribed a 925 kcal/day diet and reported generally good adherence. By contrast, a positive effect was observed at Week 24 when participants had terminated their marked caloric restriction. We suspect that no effects were observed for aerobic training at Week 48 because of participants' reduced frequency of training from Weeks 24 to 48. Similarly, no effects were probably observed, at any time, for the combined-training condition because participants in this group engaged in only 20 min of aerobic activity at each exercise session.

Participants in all treatment conditions showed favorable changes in body composition. At no time in any condition did the percentage of weight lost from FFM exceed 22%, an amount within Yang and VanItallie's (1992) recommended upper limit of 25% from FFM. Despite these favorable results, we did not find that aerobic training spared the loss of FFM, compared with diet alone. Moreover, strength training, which we had specifically selected because of its capacity to increase muscle mass, did not result in significantly better preservation of FFM than did diet alone, despite a tendency in this direction at Weeks 8 and 48 in participants in the combined condition (aerobic plus strength training).

Our negative finding for both aerobic and strength training replicate those reported by Donnelly, Pronk, Jacobsen, Pronk, and Jakicic (1991) , who found no significant differences in changes in weight, FFM, or fat in obese women randomly assigned to the same four conditions included in the present study. We believed that their failure to find effects of strength training on FFM were attributable to the prescription of a diet inadequate in energy and protein (505 kcal/day and 50 g/day, respectively), as well as an exercise training period that was possibly too brief (i.e., 12 weeks). Thus, we substantially increased all of these values but still failed to achieve the expected results. Our exercisers, however, did display substantially smaller reductions in REE at the end of treatment than did Donnelly et al.'s (1991) participants.

We are aware of only two studies of dieting obese women that have demonstrated increases in FFM with strength training (Ballor, Katch, Becque, & Marks, 1988 ; Marks, Ward, Morris, Castellani, & Rippe, 1995). In each case, participants consumed a balanced diet of at least 1,200 kcal/day, lost an average of only 4 to 5.5 kg, and increased their FFM (above baseline) by an average of only 0.4 to 0.7 kg (which did not differ significantly from changes produced by diet alone in the study by Marks et al., 1995). We suspect that larger weight losses (of 10 kg or more) are associated with an obligatory loss of FFM, because excess body weight comprises approximately 25% to 30% of FFM (Yang & VanItallie, 1992).

REE was not measured in either the Ballor et al. (1988) or Marks et al. (1995) studies. Other investigations, however, have shown that the relationship between changes in FFM and those in REE is not a simple, linear one. Thus, weight-stable, strength-trained men studied by Broeder, Burrhus, Svanevik, and Wilmore (1992) significantly increased their FFM by 2.1 kg but failed to show a significant increase in REE. Campbell, Crim, Young, and Evans (1994) demonstrated a significant increase in REE in older men and women subjected to strength training but concluded that the increase was "due to an increase in the metabolic activity of lean tissue and not an increase in the amount of lean tissue" (1994, p. 174). Thus, further research is needed to illuminate the metabolic pathways associated with changes in REE in exercising participants. The effects of aerobic versus strength training are likely to be mediated by different mechanisms (Poehlman et al., 1991).

Participants across our four treatment conditions reported significant reductions in dysphoria and fatigue, as well as increased vigor, findings comparable with those reported previously in obese dieters (Foster & Wadden, 1995). This, however, is the first controlled study of obese women of which we are aware to assess the effects on mood of exercise plus diet, compared with diet alone.

Neither aerobic nor strength training was associated with significantly greater improvements in psychological status than diet alone. We believe that this is because the favorable effects on mood of weight loss (and possibly of group cognitive behavioral treatment) were so robust as to obscure the possible effects of exercise training (i.e., the effects were not additive). In addition, our psychological measures may not have been sensitive to the effects of increased physical activity.

The findings for appetite and dietary adherence paralleled those for mood. Thus, participants in all four conditions reported significant reductions in hunger and preoccupation with food at several periods, findings that replicate those found with the consumption of VLCDs (Foster et al., 1992 ; Wing, Marcus, Blair, & Burton, 1991). Exercisers did not report significantly greater improvements than nonexercisers on any of the appetite measures, nor did they report better adherence to the portion-controlled diet during the first 17 weeks of treatment. If anything, exercisers tended to report greater consumption of excess calories (off the diet) than did nonexercisers. They may have been compensating for the calories expended in their supervised exercise bouts. Lean individuals reliably demonstrate such compensation, although obese individuals do not (Pi-Sunyer, 1992).

Results of this study raise several issues concerning the traditional dietary and behavioral treatment of obesity. The 925-kcal/day portion-controlled diet that we used produced excellent weight losses, only slightly smaller than those produced by VLCDs (Wadden & Stunkard, 1986 ; Wadden et al., 1994 ; Wing, Marcus, Salata, et al., 1991). The higher calorie intake allowed us to significantly reduce the schedule of medical monitoring, thus, reducing the cost of treatment. In addition, our clinical impression was that patients experienced minimal anxiety during the refeeding period when conventional foods were reintroduced, since they had consumed a dinner meal throughout treatment. This easy transition contrasts with the distress reported by a significant minority of persons when they terminate a liquid-only VLCD (Wadden & Foster, 1992).

The study also demonstrates the difficulty of maintaining obese individuals in long-term treatment, despite the need for long-term management of this disorder (Perri & Fuller, 1995). Almost 18% of the participants discontinued treatment prematurely, and attendance of group treatment sessions declined significantly during the 24-week maintenance program. This occurred despite the reduction in the frequency of meetings (from weekly to biweekly) during this time and staff members stressing throughout treatment the importance of participating in the maintenance program. Further study is clearly needed to determine the best method of maintaining a long-term therapeutic relationship with patients that does not prove to be burdensome to them or treatment staff.

The concern about long-term treatment applies equally to exercise training. Although exercise has a strong association with long-term weight control, the decline in our participants' exercise attendance, particularly during the maintenance period, clearly shows that a large percentage of participants who are prescribed an exercise regimen will not adhere adequately to it. This problem has been well documented in the short term (Dishman, 1990 ; King & Tribble, 1991). Differences in long-term exercise adherence probably contribute to conflicting findings from controlled trials concerning whether persons treated by diet plus exercise, compared with diet alone, maintain better long-term weight losses once treatment ends (Perri et al., 1988 ; Pronk & Wing, 1994 ; Wing et al., 1988). In addition, the type of exercise regimen prescribed may influence adherence. King, Haskell, Taylor, Kramer, and DeBusk (1991) , for example, have shown that home-based activity programs are superior to clinic-based interventions (the latter of which were used in this study).

The present study had several strengths including its large sample size that, even after attrition and exercise nonadherence, provided ample power (>=.90) to detect the hypothesized differences among conditions in RMR, FFM, appetite, and psychological status. The study, however, could have been improved in two important ways. The first would have been to train participants to a predetermined exercise criterion, as assessed in the aerobic condition by changes in heart rate or maximal oxygen consumption and in the strength condition by changes in regional muscle mass or strength. Our participants exercised at a frequency, duration, and intensity that we thought was appropriate for significantly obese, deconditioned individuals, but it is possible that more aggressive training would have produced the hypothesized changes in FFM and RMR. The second improvement would have been to assess participants' daily total energy expenditure by doubly labeled water or another method. This would have allowed us to document that participants in the diet-alone condition did not (as instructed) increase their physical activity, whereas those in the exercise conditions maintained (if not increased) their usual at-home activity level. Such measurement would have also helped to verify whether participants in the exercise conditions completed three exercise bouts a week during Weeks 29—48 of treatment, as instructed.

This study did not address the question of whether exercise was associated with superior long-term weight control, beyond our 20-week maintenance period. Our failure, however, to find a persistent effect of exercise on RMR, as well as any effect on body composition, appetite, or mood suggests that exercise may be a correlate rather than a cause of long-term weight control (Pronk & Wing, 1994). The minority of obese individuals in clinical trials who achieve long-term weight control may do so not only because they are among the minority who continue to exercise but also because they achieve a sense of personal awareness and control that facilitates their consuming a low-fat diet, monitoring their weight regularly, coping successfully with stress and, more generally, taking better care of their personal needs (Jeffery et al., 1984 ; Kayman et al., 1990). This potentially complex relationship between exercise and long-term weight control requires further study.

References

Ballor, D. L., Katch, V. L., Becque, M. D. & Marks, C. R. (1988). Resistance weight training during caloric restriction enhances lean body weight maintenance.(*American Journal of Clinical Nutrition, 47,* 19—25.)

Beck, A. T. & Steer, R. A. (1987). *Manual for the Beck Depression Inventory.* (New York: Psychological Corporation)

Borg, G. V. (1962). *Physical performance and perceived exertion.* (Lund, Sweden: Gleerup)

Bouchard, C., Despres, J. P. & Tremblay, A. (1993). Exercise and obesity.(*Obesity Research, 1,* 133—147.)

Broeder, C. E., Burrhus, K. A., Svanevik, L. S. & Wilmore, J. H. (1992). The effects of either high-intensity resistance or endurance training on resting metabolic rate.(*American Journal of Clinical Nutrition, 55,* 802—810.)

Brownell, K. D. (1995). Exercise in the treatment of obesity.(In K. D. Brownell & C. G. Fairburn (Eds.), Eating disorders and obesity: A comprehensive handbook (pp. 437—438). New York: Guilford Press.)

Brozek, J., Grande, F., Anderson, J. T. & Keys, A. (1963). Densitometric analysis of body composition: Revision of some quantitative assumptions.(*Annals of the New York Academy of Science, 110,* 113—140.)

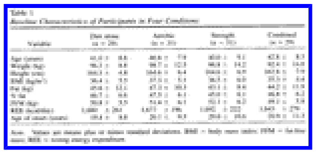
Campbell, W. W., Crim, M. C., Young, V. R. & Evans, W. J. (1994). Increased energy requirements and changes in body composition with resistance training in older adults.(*American Journal of Clinical Nutrition, 60,* 167—175.)

Dishman, R. K. (1990). Determinants of participation in physical activity.(In C. Bouchard, R. J.

Shephard, T. Stephens, J. R. Sutton, & B. D. McPherson (Eds.), Exercise, fitness, and health (pp. 75—102). Champaign, IL: Human Kinetics.)
Donnelly, J. E., Pronk, N., Jacobsen, D. J., Pronk, S. J. & Jakicic, J. A. (1991). Effects of a very-low-calorie diet and physical-training regimens on body composition and resting metabolic rate in obese females.(*American Journal of Clinical Nutrition, 54,* 56—61.)
Foreyt, J. P. & Goodrick, K. (1994). Do's and dont's for weight management.(Exercise is always good, but are some foods bad? Obesity Research, 2, 378—379.)
Foster, G. D. & Wadden, T. A. (1995). The social and psychological effects of weight loss.(In K. D. Brownell & C. G. Fairburn (Eds.), Eating disorders and obesity: A comprehensive handbook (pp. 426—430). New York: Guilford Press.)
Foster, G. D., Wadden, T. A., Peterson, F. J., Letizia, K. A., Bartlett, S. J. & Conill, A. M. (1992). A controlled comparison of three very-low-calorie diets: Effects on weight, body composition, and symptoms.(*American Journal of Clinical Nutrition, 55,* 811—817.)
Grilo, C. M., Brownell, K. D. & Stunkard, A. J. (1993). The metabolic and psychological importance of exercise in weight control.(In A. J. Stunkard & T. A. Wadden (Eds.), Obesity: Theory and therapy (pp. 253—273). New York: Raven Press.)
Heymsfield, S. B., Casper, K., Heran, J. & Guy, D. (1989). Rate of weight loss during underfeeding: Relation to physical activity.(*Metabolism, 38,* 215—223.)
Jeffery, R. W., Bjornson-Benson, W. M., Rosenthal, B. S., Lindquist, R. A., Kurth, C. L. & Johnson, S. L. (1984). Correlates of weight loss and its maintenance over two years of follow-up among middle-aged men.(*Preventive Medicine, 13,* 155—168.)
Kayman, S., Bruvold, W. & Stern, J. S. (1990). Maintenance and relapse after weight loss in women: Behavioral aspects.(*American Journal of Clinical Nutrition, 52,* 800—807.)
King, A. C., Haskell, W. L., Taylor, C. B., Kramer, H. C. & DeBusk, R. F. (1991). Group- vs.(home-based exercise training and healthy older men and women. Journal of the American Medical Association, 266, 1535—1542.)
King, A. C. & Tribble, A. C. (1991). The role of exercise in weight regulation in nonathletes.(*Sports Medicine, 11,* 331—349.)
Krotkiewski, M., Toss, L., Björntorp, P. & Holm, F. (1981). The effect of a very-low-calorie diet with or without chronic exercise on thyroid and sex hormones, plasma proteins, oxygen uptake, insulin and peptide concentrations in obese women.(*International Journal of Obesity, 5,* 287—293.)
Marks, B. L., Ward, A., Morris, D. H., Castellani, J. & Rippe, J. M. (1995). Fat-free mass is maintained in women following a moderate diet and exercise program.(*Medicine and Science in Sports and Exercise, 27,* 1243—1251.)
McNair, D. M., Lorr, M. & Droppleman, D. (1981). *Manual for the Profile of Mood States.* (San Diego, CA: Educational and Industrial Testing Services)
Nieman, D. C., Haig, J. L., De Guia, E. D., Dizon, G. P. & Register, U. D. (1988). Reducing diet and exercise training effects on resting metabolic rates in mildly obese women.(*Journal of Sports Medicine and Physical Fitness, 28,* 79—88.)
Perri, M. G. & Fuller, P. R. (1995). Success and failure in the treatment of obesity: Where do we go from here?(*Medicine, Exercise, Nutrition, and Health, 4,* 255—272.)
Perri, M. G., McAllister, D. A., Gange, J. J., Jordan, R. C., McAdoo, W. G. & Nezu, A. M. (1988). Effects of four maintenance programs on the long-term management of obesity.(*Journal of Consulting and Clinical Psychology, 56,* 529—534.)
Phinney, S. D., LaGrange, B. M., O'Connell, M. O. & Danforth, E. (1988). Effects of aerobic exercise on energy expenditure and nitrogen balance during very low calorie dieting.(*Metabolism, 37,* 758—765.)
Pi-Sunyer, F. X. (1992). The effects of increased physical activity on food intake, metabolic rate, and health risks in obese individuals.(In T. A. Wadden & T. B. VanItallie (Eds.), Treatment of the seriously obese patient (pp. 190—210). New York: Guilford Press.)

Poehlman, E. T., Melby, C. L. & Goran, M. J. (1991). The impact of exercise and diet restriction on daily energy expenditure.(*Sports Medicine, 11,* 78—101.)
Pronk, N. P. & Wing, R. R. (1994). Physical activity and long-term maintenance of weight loss. (*Obesity Research, 2,* 587—599.)
Ravussin, E. & Bogardus, C. (1989). Relationship of genetics, age, and physical fitness to daily energy expenditure and fuel utilization.(*American Journal of Clinical Nutrition, 49,* 968—975.)
Sandoz Nutrition (1987). *Core program: Group leaders' guide.* (Minneapolis, MN: Author)
Sandoz Nutrition (1988). *Encore! program: Group leaders' guide.* (Minneapolis, MN: Author)
Siri, W. E. (1956). *Advances in biological and medical physics.* (Orlando, FL: Academic Press)
Sweeney, M. E., Hill, J. O., Heller, P. A., Baney, R. & DiGirolamo, M. (1993). Severe vs.(moderate energy restriction with and without exercise in the treatment of obesity: efficiency of weight loss. American Journal of Clinical Nutrition, 57, 127—134.)
Tremblay, A., Fontaine, E., Poehlman, E. T., Mitchel, D., Perron, L. & Bouchard, C. (1986). The effect of exercise training on resting metabolic rate in lean and moderately obese individuals. (*International Journal of Obesity, 10,* 511—517.)
Wadden, T. A. & Foster, G. D. (1992). Behavioral assessment and treatment of markedly obese patients.(In T. A. Wadden & T. B. VanItallie (Eds.), Treatment of the seriously obese patient (pp. 290—230). New York: Guilford Press.)
Wadden, T. A., Foster, G. D. & Letizia, K. A. (1994). One-year behavioral treatment of obesity: A comparison of moderate and severe caloric restriction and the effects of weight maintenance therapy. (*Journal of Consulting and Clinical Psychology, 62,* 165—171.)
Wadden, T. A., Foster, G. D., Letizia, K. A. & Mullen, J. L. (1990). Long-term effects of dieting on resting metabolic rate in obese outpatients.(*Journal of the American Medical Association, 264,* 707—711.)
Wadden, T. A. & Letizia, K. A. (1992). Predictors of attrition and weight loss in patients treated by moderate and severe caloric restriction.(In T. A. Wadden & T. B. VanItallie (Eds.), Treatment of the seriously obese patient (pp. 290—230). New York: Guilford Press.)
Wadden, T. A. & Stunkard, A. J. (1986). A controlled trial of very-low-calorie diet, behavior therapy, and their combination in the treatment of obesity.(*Journal of Consulting and Clinical Psychology, 4,* 482—488.)
Walberg, J. L. (1989). Aerobic exercise and resistance weight-training during weight reduction: Implications for obese persons and athletes.(*Sports Medicine, 47,* 343—356.)
Wilmore, J. (1969). A simplified method for the determination of residual lung volume.(*Journal of Applied Physiology, 27,* 96—100.)
Wing, R. R., Epstein, L. H., Paternostro-Bayles, M., Kriska, A., Norwalk, M. P. & Gooding, W. (1988). Exercise in a behavioural weight control programme for obese patients with Type 2 (non-insulin-dependent) diabetes.(*Diabetologia, 31,* 902—909.)
Wing, R. R., Marcus, M. D., Blair, E. H. & Burton, L. R. (1991). Psychological response of obese type II diabetic subjects to very-low-calorie diet.(*Diabetes Care, 14,* 596—599.)
Wing, R. R., Marcus, M. D., Salata, R., Epstein, L. H., Miaskiewicz, S. & Blair, E. H. (1991). Effects of a very-low-calorie diet on long-term glycemic control in obese type II diabetics.(*Archives of Internal Medicine, 151,* 1334—1340.)
Yang, M.-U. & VanItallie, T. B. (1992). Effect of energy restriction on body composition and nitrogen balance in obese individuals.(In T. A. Wadden & T. B. VanItallie (Eds.), Treatment of the seriously obese patient (pp. 83—106). New York: Guilford Press.)

Table 1.



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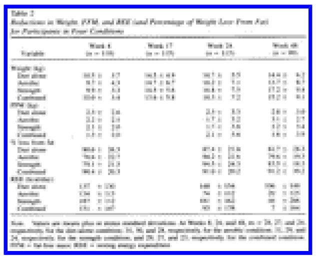

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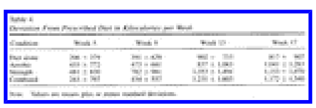

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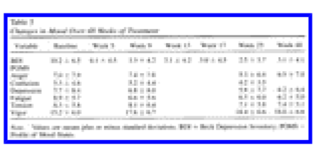

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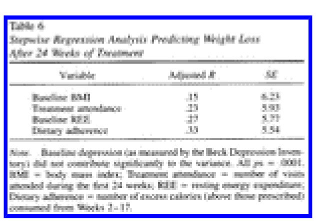

Table 6
Stepwise Regression Analysis Predicting Weight Loss After 24 Weeks of Treatment

Variable	Adjusted R^2	*SE*
Baseline BMI	.15	6.23
Treatment attendance	.23	5.93
Baseline REE	.27	5.77
Dietary adherence	.33	5.54

Note. Baseline depression (as measured by the Beck Depression Inventory) did not contribute significantly to the variance. All *p*s = .0001. BMI = body mass index; Treatment attendance = number of visits attended during the first 24 weeks; REE = resting energy expenditure; Dietary adherence = number of excess calories (above those prescribed) consumed from Weeks 2–17.