Physiologic Changes After Diet Combined With Structured Aerobic Exercise or Lifestyle Activity

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Moderate intensity physical activity achieved through changes in lifestyle may promote weight management. However, little is known about changes in physiologic and metabolic variables when patients lose weight using moderate intensity lifestyle activity instead of traditional structured vigorous aerobic exercise. To compare changes in resting metabolic energy expenditure (REE), fat mass (FM), and fat-free mass (FFM) associated with a 12-week weight loss program combined with either: (1) aerobic exercise (AER); or (2) lifestyle activity (LIFE), we randomized 39 overweight adults (mean body mass index [BMI] = 30.9 ± 2.8 kg/m^2) to either diet plus AER (N = 18) or diet plus LIFE (N = 21). Both groups consumed a self-selected diet of 1,200 to 1,800 kcal/d (5,021 to 7,531 kJ/d). The AER group performed vigorous aerobic exercise for up to 45 minutes 3 to 4 d/wk. The LIFE group accumulated 30 minutes of moderate intensity physical activity on most days of the week. Compliance with the respective protocols was monitored on a weekly basis. REE was measured before and after treatment via open-circuit spirometry. The AER group decreased body weight by 8.4% ($P < .001$)while the LIFE had a reduction of 6.7% ($P < .001$) after treatment. Over the course of the interventions, the AER and LIFE groups experienced 10.9% ($P < .001$) and 10.2% ($P < .001$) reductions in REE, respectively. Aerobic exercise did not prevent reductions in REE to a greater extent than did lifestyle activity in patients consuming a reduced calorie diet. Change in REE was not related to changes in FFM or FM for either group, and there were no differences between groups in reductions of REE, weight, FM, or FFM. A program of diet plus lifestyle physical activity may be a suitable alternative for dieting adults who have difficulty adhering to a program of vigorous activity.

OBESITY HAS recently been added to the American Heart Association's list of risk factors that contribute to the development of coronary artery disease.[1] The prevalence of obesity is on the rise in the United States and in many other industrialized countries of the world.[2] When investigating causes of obesity, overeating alone does not explain the dramatic increase in its prevalence.[3]

The Surgeon General notes that significant health benefits can be obtained by including a moderate amount of physical activity (eg, 30 minutes of brisk walking or raking leaves or 15 minutes of running) on most, if not all, days of the week.[4] We recently reported that women, randomly assigned to a 16-week program of either a diet plus lifestyle activity or diet plus structure exercise group demonstrated similar improvements in cardiovascular risk profiles and comparable weight loss.[5] However, women in the lifestyle activity group lost significantly more fat-free mass (FFM) (1.4 ± 1.3 kg) than those who participated in structured aerobic exercise (0.5 ± 1.3 kg, $P = .03$). Moreover, at 1-year follow-up, the lifestyle activity group tended to regain less weight (0.08 kg) than the aerobic group (1.6 kg) ($P = .06$).

Although the literature is mixed on whether exercise affects the reduction in metabolic rate normally seen in those on a reduced calorie diet,[6] some studies have found that vigorous aerobic exercise may modestly reduce the drop in resting energy expenditure (REE) that accompanies a program of dieting without physical activity.[7-10] We are aware of no studies that have compared changes in REE and body composition in patients who are restricting their caloric intake and combining this with lifestyle physical activity. Therefore, the purpose of this study was to compare changes in body composition (ie, weight, FFM, fat mass [FM]), and REE in overweight adults who were randomly assigned to a program of: (1) diet plus aerobic exercise (AER); or (2) diet plus lifestyle activity (LIFE).

SUBJECTS AND METHODS

Mild-to-moderately overweight men and women[11] were recruited via a local newspaper ad to take part in a weight loss study. All participants were screened by phone conversation to determine that they were 15 to 50 pounds overweight,[11] that they were currently not involved in regular strength training, endurance exercise or doing physical activity (≤ 2 bouts per week), and that they did not take any medications that influence weight loss or metabolism. Participants were asked about current and past medical history; individuals having cardiovascular, metabolic, or orthopedic complications that would conflict with moderate intensity activity or vigorous exercise were excluded. At baseline, participants had a mean age (± SD) of 37.6 ± 5.7 years and body mass index (BMI) of 30.9 ± 2.8 kg/m^2. To assess eligibility, each subject underwent a physical examination, medical history, maximal treadmill test, and biochemical blood analysis. Persons who were clinically depressed or reported an eating disorder were excluded from the study. Participants gave their written informed consent to participate in the investigation, which was approved by the Institutional Review Board (IRB) at Johns Hopkins Bayview Medical Center. Baseline characteristics are presented in Table 1.

Participants were randomly assigned to 1 of the 2 treatment conditions (described below) after all of their baseline assessments were completed. Treatment lasted for 12 weeks. They met weekly for a 60-minute behavioral group session (5 to 10 persons). Using The

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Table 1. Baseline Characteristics of Participants

Characteristic	Aerobic (n = 18)	Lifestyle (n = 21)	*P*
Age (yr)	37.6 ± 4.7	37.6 ± 6.6	.97
Height (cm)	168.6 ± 10.6	166.2 ± 10.0	.44
Weight (kg)	83.2 ± 15.5	80.6 ± 11.9	.68
% Female	66.7	69.6	.84
Body mass index (kg/m^2)	30.8 ± 4.2	31.0 ± 3.1	.85
Fat-free mass (kg)	51.0 ± 13.8	47.9 ± 10.0	.50
Fat mass (kg)	32.2 ± 4.8	32.7 ± 5.9	.77
Resting energy expenditure (kcal/d)	1,657 ± 341	1,568 ± 311	.57
Resting energy expenditure (kJ/d)	6,933 ± 1427	6,561 ± 1,301	.57

NOTE: (Mean ± SD). *P* represents between group differences.

LEARN Program for Weight Control,[12] group sessions were conducted by experienced weight management clinicians (ie, psychologists, dietitians, and exercise scientists) who adhered to standardized weekly lesson plans. Physiologic evaluations were conducted before starting treatment and after participants stabilized, defined as being within ± 0.5 pounds of their weight at week 12 for 2 weeks. Evaluations of participants whose weight was not stabilized were delayed until they achieved this stability.

Participants were prescribed a self-selected diet of 1,200 to 1,800 kcal/d (5,021 to 7,531 kJ/d). This dietary prescription was followed for the entire 12 weeks and was consistent with American Heart Association guidelines for healthy weight reduction.[13] Participants were educated on proper nutrition habits by a registered dietitian, and weekly food diaries were collected to ensure compliance to the dietary protocol.

The AER group (N = 21) performed their choice of structured moderate-vigorous aerobic activity, such as stationary cycling, videotape workouts, or brisk walking (outdoors or on a treadmill) 3 to 4 days each week for up to 45 minutes per session. Participants were taught to monitor exercise intensity using the Borg 6-20 Relative Perceived Exertion (RPE) Scale. Patients were instructed to exercise at an intensity that produced feelings of exertion of 13 to 15 on the 6 to 20 scale, which is moderate to hard in intensity.[14] Mean durations of exercise bouts for AER were 65, 62, 53, 44, and 45 minutes during weeks 2, 4, 8, and 12, respectively. This translates into 82%, 72%, 72%, and 47% of the participants in the AER group meeting or exceeding the prescribed duration of exercise activity during weeks 2, 4, 8, and 12, respectively. If a participant failed to comply with the aerobic prescription for a given week, ways to increase compliance were discussed with their group leader.

Those randomized to the LIFE treatment (N = 22) were directed to accumulate a minimum of 30 minutes of moderate intensity physical activity on a minimum of 5 days a week. Participants were taught how to fit short bouts of moderate-intensity physical activity into their day and/or perform long-term physical activity for at least 30 minutes a day. Group leaders educated participants on the perceptual feelings that should be associated with engaging in moderate intensity physical activity. Intensity was taught by using the Rating of Perceived Exertion (RPE) scale[14] with a focus on achieving an RPE of approximately 12 to13 (somewhat hard). Examples of moderate-intensity physical activity are raking leaves, mowing the lawn, washing the car, and performing household cleaning. Physical activity diaries were collected weekly to ensure compliance. If a participant failed to comply for a given week, ways to increase compliance were discussed with their group leader. For weeks 2, 4, 8, and 12, LIFE participants achieved a mean duration of lifestyle physical activity of 38, 45, 60, and 58 minutes per day, respectively. This translated into 60%, 60%, 70%, and 84% of the participants in the LIFE group meeting or exceeding the prescribed duration of exercise activity during weeks 2, 4, 8, and 12, respectively.

From the lifestyle patients physical activity diaries, we found this group chose to perform primarily moderate intensity activities. During weeks -2 and -4, 91.3% and 85.5% of self-reported activities were performed at a moderate intensity, while 88.1% and 95.4% of reported activities were moderate at weeks -8 and -12, respectively. The average daily time spent doing moderate and vigorous activities is plotted in Fig 1. We also calculated the number of bouts of activity that lifestyle patients reported each day at weeks 2, 4, 8, and 12. A repeated measure analysis of variance (ANOVA) found that the number of bouts of physical activity did not change over the course of the intervention (F = 1.45, *P* = .277). At weeks 2 and 4, patients averaged 2.9 ± 2.4 and 1.9 ± 1.6 bouts of activity per day, whereas activity was performed in 3.1 ± 2.5 and 2.5 ± 2.1 bouts per day at weeks 8 and 12, respectively. Walking was the most commonly cited mode of activity with at least 87% of lifestyle activity participants reporting walking from weeks 2 to 12. Stair climbing, housework, and yardwork were

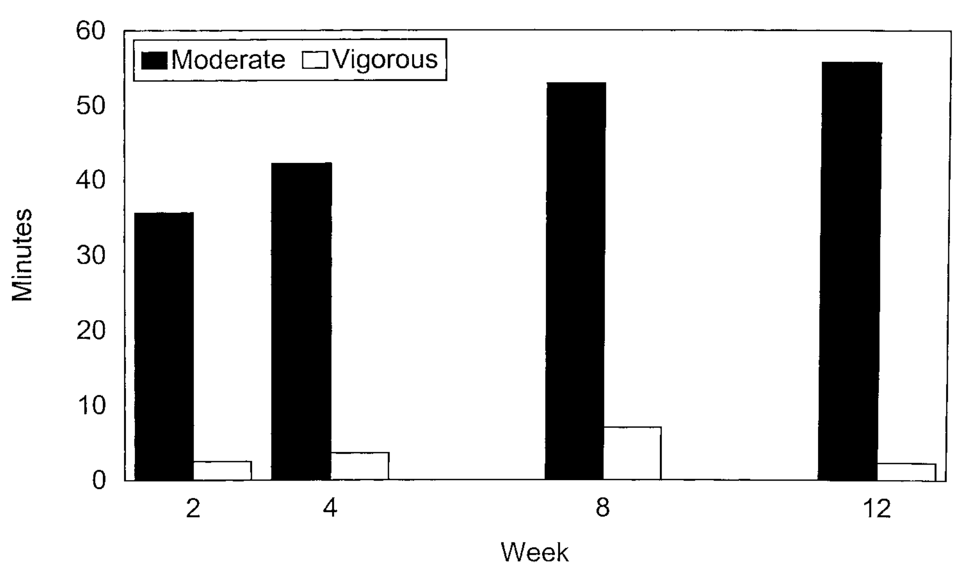

Fig 1. Mean self-reported daily minutes of moderate and vigorous activity in patients treated with diet-plus lifestyle physical activity.

also commonly reported as ways of performing lifestyle activity. The percent of the total physical activity time that was spent doing walking, housework, yard work, and stair climbing at weeks 2, 4, 8, and 12 are plotted below in Fig 2.

Weight was measured on a Detecto medical electronic scale (Webb City, MO) without shoes in normal clothing, and height was measured without shoes to the nearest quarter of an inch on a wall stadiometer. Dual energy x-ray absorptiometry (DXA) was used to determine fat mass (FM), FFM, and body fat percentage, using a Hologic QDR-4500A (Waltham, MA) whole body scanner with Hologic 9.02 whole body scan systems software. Participants were scanned for 3 minutes with 1 mrem of radiation that differentiated between dissimilar body tissues. Women of child-bearing age were required to have a negative urine pregnancy test before undergoing the DXA scan.

REE was measured using indirect calorimetry during the hours of 6:30 AM to 10:30 AM after a 12-hour fast. Participants were asked to avoid exercise and physical activity for 36 hours before testing, to ingest less than 1,000 kcal for their dinner meal on the evening before testing, and to abstain from smoking on the morning of the test. Calibrations of the metabolic cart were made before testing each morning. Participants arrived at the testing facility shortly after awakening and were seated for 30 minutes in a quiet climate-controlled room before testing began. REE measurements were performed via open circuit spirometry with a SensorMedics MBM-100, Deltatrac Metabolic Monitor (Anaheim, CA) for a minimum of 30 minutes until equilibrium was achieved. A ventilated hood was used for collection of gases to attain continuous measurements of 0_2 and $C0_2$ at 1-minute intervals until equilibrium was obtained. Equilibrium has been described previously[15] as 5 consecutive data points for 0_2 and $C0_2$ with a coefficient of variation of 5% or less. These equilibrated measurements were averaged to acquire steady-state estimates of REE and respiratory quotient.

Statistical Analyses

Changes in physiologic and metabolic variables both over time and between groups were assessed with repeated measures ANOVA. We also used analysis of covariance models to examine the effects of confounding variables. Alpha was set at 0.05 minimum. We examined relationships between physiologic and metabolic variables using Pearson product moment correlations. Analyses were conducted using SPSS version 10.0 (SPSS, Chicago, IL).[16]

Attrition. Thirty-nine of the 43 participants completed the study. Two participants were lost in each of the treatment groups. Three patients discontinued treatment for disruptive life events or disinterest and 1 patient did not stabilize her weight at the end of treatment and continued to lose weight. Data for these 4 participants were not included in any analyses.

Table 2. Twelve-Week Changes in Weight, Body Composition, and Resting Metabolic Rate

Variable	Aerobic	Lifestyle	*P*
Weight (kg)	−6.27 ± 3.2	−5.21 ± 3.2	.28
Fat-free mass (kg)	−0.89 ± 1.29	−1.13 ± 2.56	.70
Fat mass (kg)	−5.41 ± 2.84	−4.48 ± 3.35	.33
Resting energy expenditure (kcal/d)	−152.2 ± 155.9 (−648 ± 653 kJ/d)	−158.9 ± 129.2 (−666 ± 540 kJ/d)	.87

NOTE: Mean ± SD. *P* represents between-group differences.

RESULTS

Changes in body composition for each group are presented in Table 2. No between group differences were found after 12 weeks of diet for any of the body composition variables. Body fat, expressed as percentages of body weight decreased from 39.7% ± 6.0% to 35.8% ± 7.2% for the AER group and from 40.8% ± 6.3% to 37.5% ± 7.0% for the life. No between group differences were found in the percent of weight lost as FFM for AER (15.1% ± 28.9%) or LIFE (16.0% ± 52.4%) groups (P = .84). No effects for treatment condition or condition by time interactions were observed.

The REE for the AER group decreased by 9.9% from 1,610.5 ± 336.2 to 1,451.6 ± 283.8 kcal/d, ($P < .001$). Likewise, the REE for the LIFE group decreased by 9.8% from 1,555.4 ± 299.3 to 1,403.2 ± 228.8 kcal/d ($P < .001$). However, comparison of the changes in REE expressed either as

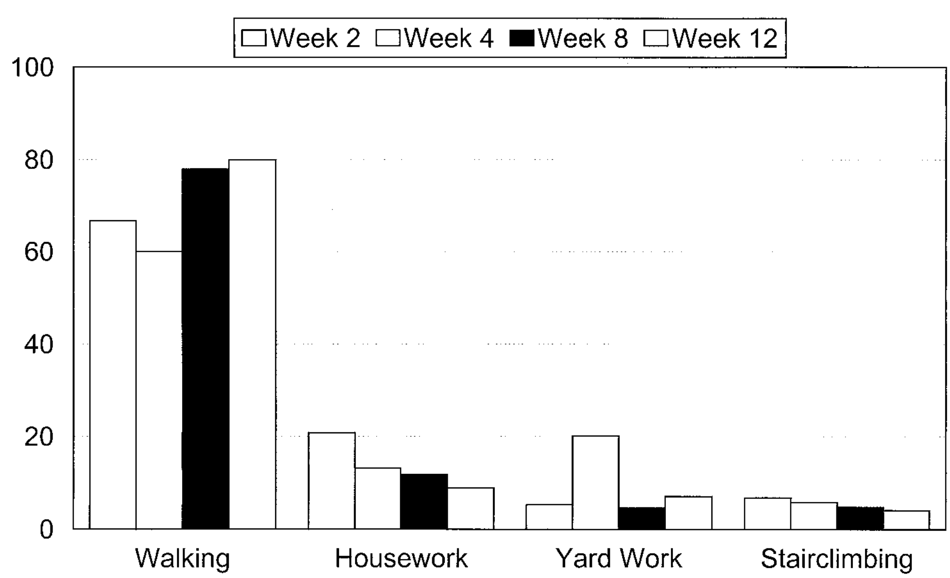

Fig 2. The percent of self-reported total physical activity time among lifestyle activity patients that was spent doing walking, housework, yard work, and stair climbing at weeks 2, 4, 8, and 12.

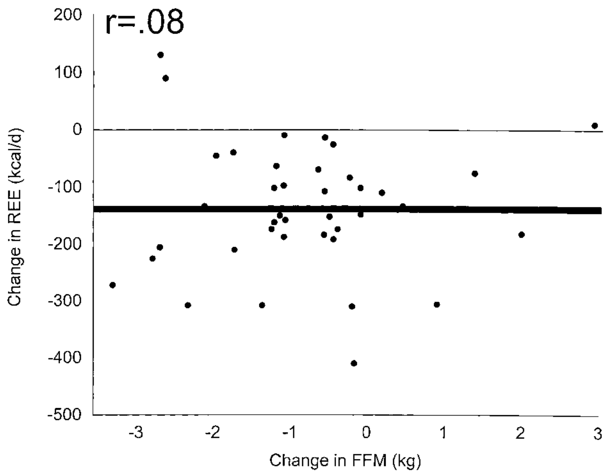

Fig 3. Relationship between 12-week changes in FFM and REE.

absolute change or percent change was not significant ($P <$ 0.39). The resting Respiratory Exchange Ratio (RER) did not differ between groups at baseline or after treatment. The RER averaged 0.81 ± 0.05 at baseline and was not significantly different after treatment (P = .10).

The amount of body weight lost by men (N = 14) (7.3 ± 3.3 kg) was significantly more (P = .027) than the amount lost by women (N = 29) (5.0 ± 2.9 kg). There was no difference in the amount of FM lost by the men (6.1 ± 3.2 kg) or women (4.4 ± 3.0 kg) (P = .08). Likewise, there was no difference in the amount of FFM lost by the men (1.1 ± 1.1 kg) and women (1.0 ± 2.4 kg) (P = .80). The reduction in REE of 227.6 ± 145.2 kcal/d (952 ± 608 kJ/d) accompanying weight loss in the men was different (P = .020) from the 121.7 ± 129.8 kcal/d (509 ± 543 kJ/d) reduction seen in the women. A 3-factor repeated measures ANOVA (with factors time, gender, and treatment) showed no significant 3-way interactions among time, condition, and REE or body composition variables.

Because there were no significant differences in the reductions of weight, FM, FFM, and REE between treatment groups, we collapsed participants across treatment groups to examine the relationship between change in REE and changes in body weight, FM, and FFM after 12 weeks of treatment. The change in REE correlated with change in FM (r = .54, $P < .001$) and the change in body weight (r = .59, $P < .001$), but not FFM (r = .08, P = .07) . (see Figs 3, 4, and 5).

Figure 6 shows the effect of weight loss on REE. We collapsed participants into tertiles of weight loss (2.2 ± 1.4, 5.5 ± 0.6 and 9.2 ± 1.9 kg, respectively). A 1-way analysis of variance demonstrated corresponding reduction in REE occurred as weight loss increased (F = 6.6, P = .003). A Tukey's post hoc analysis showed that the mean reduction of REE in group 3 was 243 ± 154 kcal/d (1,017 ± 666 kJ/d) , which was significantly ($P < .05$) more than groups 1 and 2, which averaged 73 ± 94 (306 ± 393 kJ/d) and 145 ± 123 kcal/d (607 ± 515 kJ/d), respectively. We also found no significant treatment by weight change interactions using a 2-factor ANOVA to examine the influence on REE.

DISCUSSION

Compared with baseline, both groups lost a significant amount of weight. However, differences in weight loss between the AER and LIFE groups were not significant. These findings are consistent with our recent study, which reported no short-term differences in weight change in obese dieting women randomized to either structured aerobic exercise or lifestyle physical activity.[5] These findings provide further justification for the use of lifestyle physical activity as a component of safe, effective weight loss treatment. The present study demonstrates that not only were the weight losses comparable between the groups, but similar changes in metabolic variables and body composition were also produced.

It is well known that weight loss is associated with a corresponding decrease in REE.[15] Aerobic exercise and resistance training have been used in the hope of attenuating the reduction of REE during weight loss.[17] However, a meta-analysis of studies investigating the effects of aerobic exercise and/or dietary restriction on REE found no greater attenuation in REE reduction after weight loss with structured aerobic exercise compared with dieting without the addition of exercise,[7] suggesting that further research is needed to examine the complex relationship between variables such as rate of weight loss, age, fitness, and gender to changes in REE. Despite recent public health recommendations that encourage Americans to engage in regular physical activity to achieve health benefits,[4,18,19] this is the first study we are aware of to investigate the impact of lifestyle physical activity on REE in dieting individuals. We found that structured aerobic exercise did not affect the reduction in REE any more successfully than did an intervention of moderate intensity physical activity. Thus, because weight losses are comparable, either approach appears effective in promoting short-term weight loss.

FFM is metabolically active tissue that has been shown to correlate highly with REE.[9,20] As such, we hypothesized that changes in REE would be associated with changes in FFM. One reason for lack of association between REE and FFM may be the modest losses of FFM in both groups. Our participants engaged in only a modest caloric restriction, and FFM mea-

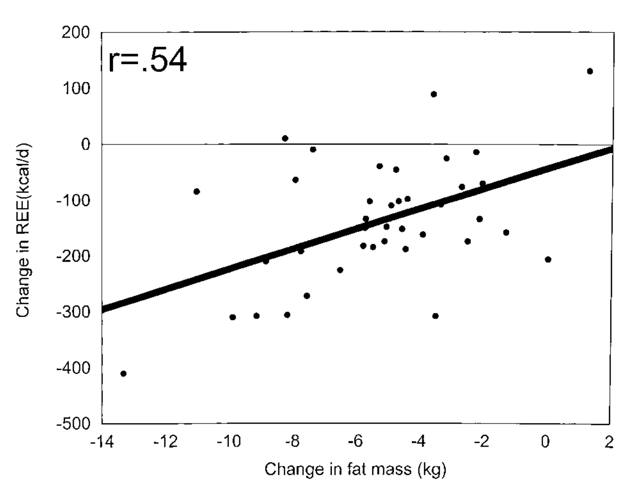

Fig 4. Relationship between 12-week changes in FM and REE.

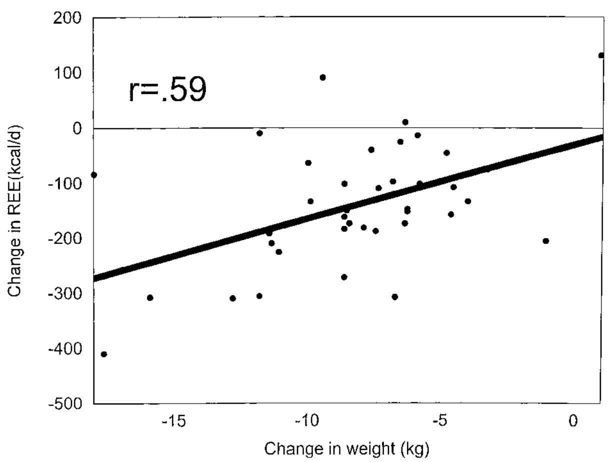

Fig 5. Relationship between 12-week changes in weight and REE.

surements indicated sparing of this tissue during weight loss. Geliebter et al[21] found that FFM accounted for 20% of weight loss (nearly twice the representation of FFM loss in our sample) in a mixed sample of men and women during an 8-week study using aerobic exercise and moderate caloric restriction (≃ 1,200 kcal/d, 5,021 kJ/d). Investigations using very low-calorie diets (ie, < 925 kcal/d, 3,870 kJ/d) have found moderate to high correlations between reductions in FFM and REE.[22] Therefore, more substantial reductions in FFM or severe caloric restriction may be necessary before related decreases in REE and FFM are observed. Our data also suggest that factors other than the loss of lean tissue may be associated with reductions in REE in patients who are losing weight through a combination of diet and exercise.

The absence of an association between REE and FFM may be due to our precise control over testing procedures. We used a strict protocol for measurement of REE that necessitated that participants were tested ≥ 36 hours after their last exercise bout, based, in part, on recommendations of Wilmore et al[6] that measurements should be performed at least 24 hours postexercise. Participants were also weight stable for at least 1 week, and measures of gas exchange were taken between 30 to 60 minutes of assessment after a 30-minute rest. Berke et al[23] note that caution is warranted when comparing measurements of REE between laboratories and with individuals who have completed a regimen of exercise training. Moreover, some investigators suggest that such inconsistency and poor technique during the actual procedure may produce discrepant results in measurements of REE.[24,25]

We tried to have both groups of patients expend approximately the same amount of energy each week. Since the decreases in weight, FFM, FM, and REE were comparable between those engaging in structured aerobic exercise and lifestyle physical activity, healthcare professionals may welcome the opportunity to advise overweight patients to engage in lifestyle physical activity, instead of traditional structured aerobic exercise, as a means of weight control. This is important because lifestyle activity may be well received by patients who do not enjoy the feelings associated with structured aerobic activities or exercise that involves using high-tech equipment in a fitness center. Although speculative, if an overweight patient is introduced to lifestyle physical activity, feelings of self-efficacy may prompt the adoption of more vigorous exercise over time, which, in turn, may produce greater increases in cardiovascular conditioning. Lifestyle activity is also flexible in that it can involve splitting up activity into several bouts throughout the day. This is particularly important because Americans commonly cite lack of time as the primary barrier to exercise.[26] It is interesting that participants chose to do activities that were on average over 15 minutes. Many people are under the impression that lifestyle activity is always done by accumulation a series of very short bouts of activity. These intermittent bouts of activity have been shown to provide health benefits that are comparable to one continuous bout.[27] Ideally, the object of an exercise/physical activity intervention is to ensure maintenance of weight loss by introducing the lifelong habit of increasing overall daily energy expenditure.[5,17] This may be especially important because previous research has found that among successful maintainers, 92% are regular exercisers.[28] Thus, those who remain active after weight loss will increase the likelihood of long-term weight maintenance.[5,28]

We acknowledge that this study does have limitations. First, our modest sample size may limit our ability to detect small between group differences. However, this study was powered to detect clinically meaningful changes in metabolic parameters. Furthermore, we acknowledge that the relatively few male participants in this study make it difficult to examine the data for gender differences. We chose to include men in this trial because there is a paucity of weight loss trials that have included men in their sample. Given the increasing prevalence of obesity in men, we felt that it was important to include those who sought treatment in the study. Clearly, future interventions need to more carefully examine the health and metabolic changes that accompany diet and exercise programs in both

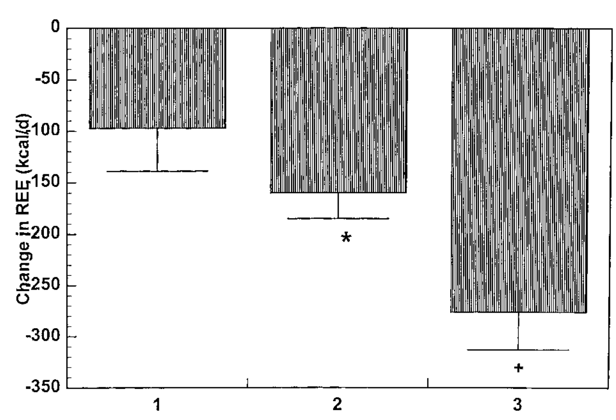

Fig 6. Effects of weight loss on reduction (×= ± SEM) in REE. Participants are broken into tertiles of weight change with group 1 experiencing the least amount of weight loss and group 3 experiencing the greatest weight loss. *,†Significantly different from the 1st tertile.

men and women. The lack of an objective measure of physical activity is also a limitation of this study. Finally, the absence of a control group that did not perform physical activity is also a limitation of this study. However, most clinical guidelines stress that comprehensive weight management programs should include strategies to promote a more physically active lifestyle as critical part of treatment.[2]

In summary, a weight reduction program combined with either lifestyle physical activity or structured aerobic exercise resulted in similar changes in weight, REE, and body composition. Our findings indicate that among moderately overweight adults who follow a self-selected, low-fat diet of 1,200 to 1,800 kcal/d (5,021 to 7,531 kJ/d),[13] vigorous aerobic exercise did not reduce the decrease in REE observed during weight reduction to a greater extent than did lifestyle activity. This suggests that neither approach is superior to the other in decreasing the reductions in REE associated with dieting. Future research in this area should seek to examine whether the maintenance of REE during weight loss affects either the magnitude of weight loss or the maintenance of weight lost.

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