Effects of diet and exercise on energy expenditure in postmenopausal women[1–3]

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ABSTRACT The purpose of this study was to determine the effect of a 24-wk diet + exercise (DE) or diet-only program on basal metabolic rate (BMR), bone mineral density (BMD), energy expended during daily activities, muscle strength, and maximal oxygen consumption ($\dot{V}O_2$max) in 40 postmenopausal women. Daily energy need was determined by measuring BMR and assessing physical activity with 8-d self-reported activity records. The DE group consumed 2092 kJ/d less than the daily energy need and walked and performed strength-training exercises during which they expended an additional 837 kJ/d. The two diet-only groups consumed either 2092 kJ/d (D-2092) or 2929 kJ/d (D-2929) less than the daily energy need. BMD, BMR, muscle strength, $\dot{V}O_2$max, and energy expended during lying, sitting, standing, and walking were measured at baseline and after 12 and 24 wk of treatment. A significant decrease in BMR and energy expended during sitting and walking occurred in all groups, with no significant differences observed among groups. Although the declines in BMR were significant, they were small and may not have been physiologically relevant. No changes in BMD or $\dot{V}O_2$max occurred, whereas strength increased significantly in the DE group. The results showed that postmenopausal women significantly improved their body composition over a period of 6 mo without experiencing a large decline in BMR, BMD, or select components of energy expenditure. *Am J Clin Nutr* 1997;66:867–73.

KEY WORDS Basal metabolic rate, postmenopausal women, weight loss, muscle strength, daily energy need, bone mineral density, oxygen consumption, exercise, energy expenditure

INTRODUCTION

It is well known that dietary restriction can cause a significant decline in resting metabolic rate (RMR) (1). Because RMR accounts for 60–75% of total daily energy expenditure (EE) (2), this decrease in RMR can hinder additional weight loss in dieters or lead to difficulty in maintenance of weight loss.

Exercise training has been proposed as a means to prevent this decline in RMR seen with dieting by increasing metabolically active fat-free mass (FFM), and by having a chronic carryover effect on RMR (3, 4). The results of a recent meta-analysis (5) show that RMR declines significantly with diet alone and diet + exercise (DE) programs but the decline with diet alone is greater.

However, these results are based primarily on studies of premenopausal women who had relatively severe dietary restrictions (3347–5021 kJ/d, or 800-1200 kcal/d) for < 10 wk. In addition, few studies incorporated strength training into the exercise regimen. Adding strength training to an energy-restriction program could result in improved maintenance of FFM and RMR compared with aerobic exercise alone.

The issue of increased energy efficiency with dieting is extremely important to an aging population, including postmenopausal women. Metabolic rate declines with age whereas the percentage of body fat increases (6–8). Increased body fat and obesity are closely linked to many disease states, such as heart disease, cancer, hypertension, and diabetes (9). In addition, obesity is associated with an increased incidence of orthopedic problems, which limit mobility and the potential to remain physically active. Although it is often recommended that older individuals attempt to maintain a healthy body weight and improve fitness, traditional means of weight loss may cause a further decrease in RMR, preventing significant weight loss in this group. Lack of results with DE programs may lead to poor compliance and an increased dropout rate, which in turn contribute to poor health status.

The purpose of this study was to determine the effects of 24 wk of a moderate energy deficit alone and in combination with aerobic and strength-training exercises on both resting EE and EE during activity in postmenopausal women. Study endpoints included basal metabolic rate (BMR) and EE during lying, sitting, standing, and walking at two speeds. In addition, changes in body composition and bone density were determined. Changes in cardiovascular risk factors in this same group of subjects are reported elsewhere (10).

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SUBJECTS AND METHODS

Subjects

Forty postmenopausal women ($\bar{x} \pm$ SD age: 65 ± 3 y) who were 120–140% of ideal body weight according to the 1959 Metropolitan Life Insurance Company weight chart (11) volunteered for this study. None of the women had performed ≥ 2 h of aerobic exercise weekly for 1 y before the start of the study, and none were experienced with strength training. All subjects were healthy and free from any metabolic disorders; none were taking medications known to affect EE. Women who had been receiving estrogen replacement therapy (ERT) for ≥ 6 mo were included. All subjects gave written, informed consent as approved by the Human Subjects Committees of Stanford University and the Palo Alto Veterans' Affairs Health Care System.

Study design

The study was 26 wk in duration, including 2 wk of baseline measures followed by 24 wk of a diet-only or DE program. Subjects were studied as outpatients, except for 3-d stays in the metabolic unit at each study point. During the initial 2 wk of baseline, subjects completed 8 d of the diet and activity records. BMR, body composition, maximal oxygen consumption ($\dot{V}O_2$), and EE during lying, sitting, standing, and walking were determined while subjects were in the metabolic unit. These indexes were determined again at 12 and 24 wk of the program.

Group assignment

Subjects were assigned to one of three groups. One group participated in the DE program whereas the other two groups completed a diet-only program. One diet-only group was instructed to consume 2092 kJ/d (500 kcal/d) less than needed for weight maintenance determined during the baseline period (D-2092); the second group consumed 2929 kJ/d (700 kcal/d) less than needed for weight maintenance (D-2929). The subjects in the DE group were instructed to consume 2092 kJ/d less than needed for weight maintenance, and performed exercises that expended an additional 837 kJ/d (200 kcal/d), for a total energy deficit of 2929 kJ/d.

It became apparent during the telephone screening process that many potential volunteers were not able to commit to the DE portion of the program because of time constraints. Thus, only those subjects who were capable of participating regularly in the DE program for the entire 24-wk period were self-selected into that group. Remaining qualified volunteers were randomly assigned to the two diet-only groups. An attempt was made to match the groups for initial age, height, and weight (**Table 1**).

Assessment of daily energy need

The energy needs of each subject were estimated from self-reported activity records completed during the baseline period and from BMR measured during this same period. The records were completed over 4 weekdays and 4 weekend days. Subjects recorded all activities and time spent at each activity throughout each 24-h period. Investigators tallied the total time spent performing each activity, and daily EE was computed by using individual BMR values and multiplying each subjects' BMR by energy values reported by Mulligan and Butterfield (12). The average estimated daily energy need was 1.5 × BMR for all subjects. Previous studies completed in our laboratory using a similar technique for postmenopausal women (13, 14) found the estimated daily energy need to be within 837 kJ/d (200 kcal/d) of the actual energy need as determined by feeding to nitrogen balance.

TABLE 1

Descriptive characteristics of 40 postmenopausal women participating in the diet only or diet + exercise (DE) program[1]

Variable	
Age (y)	66 ± 3[2]
Height (cm)	161.9 ± 6.3
Weight (kg)	79.3 ± 7.6
Fat-free mass (kg)	42.9 ± 5.2
Body fat (%)	42.4 ± 5.4
$\dot{V}O_2$max (mL · kg^{-1} · min^{-1})	20.2 ± 3.6
Basal metabolic rate (kJ/d)	5852 ± 695
Number of women receiving ERT	15

[1] Mean values for each treatment group are reported in reference 10. ERT, estrogen replacement therapy.

[2] $\bar{x} \pm$ SD.

Diet program

All subjects were instructed by a registered dietitian on how to use the American Diabetic Association's exchange list program. Each woman's program was individually designed to provide an energy intake that was either 2092 or 2929 kJ/d less than that estimated as needed to maintain body weight at the initiation of the program. The macronutrient content of the diet was prescribed to meet the American Heart Association's guidelines of 30% of energy as fat, 50–55% as carbohydrates, and 10–15% as protein. Subjects were instructed by the dietitian to self-select foods meeting these criteria. Adherence was monitored by having subjects complete 3-d diet records once per week during the first month of the program and bimonthly for the remaining 5 mo. Subjects met individually with a dietitian or trained diet counselor during these times to discuss dietary issues and to have their body weight measured while in a light hospital gown with an electronic scale (measured to the nearest 0.1 kg). All subjects were encouraged throughout the program to decrease their total and saturated fat intakes and to increase their intake of complex carbohydrates. All subjects attended classes regarding low-fat cooking and eating-out and shopping guidelines.

Exercise program

Subjects participating in the DE program were required to exercise 5 d/wk according to the guidelines recommended by the American College of Sports Medicine (15). All exercise sessions were supervised by a trained exercise counselor. Three of the 5 d of exercise consisted of subjects walking 3 d/wk for 1 h at a heart rate consistent with 60–75% of measured $\dot{V}O_2$max. Heart rate was monitored by each subject at 20-min intervals during the walk. Subjects unable to complete the full hour at the start of the program were allowed to gradually increase exercise time. All subjects were able to complete 1 h of walking by week 5 of the program.

The remaining 2 d of exercise consisted of participation in a strength-training program 2 d/wk. The strength-training program consisted of 12 exercises working the major muscle groups of the upper and lower body. Subjects performed three sets of 10 repetitions of all exercises at 80% of one repetition maximum (1 RM). Workload was assessed once every 2 wk, and any necessary adjustments were made to maintain lifting intensity at 80% of 1 RM.

BMR and activity energy expenditure

BMR was measured by indirect calorimetry over three consecutive mornings. Subjects were gently awakened at 0600 and breathed into a Hans-Rudolph three-way valve attached to a Douglas bag (Warren E Collins, Braintree, MA). Expired gases were collected for 10 min and subsequently analyzed for oxygen and carbon dioxide contents with oxygen and carbon dioxide analyzers (Ametek, Pittsburgh) calibrated previously by using gases of known concentration. Volume was measured with a Parkinson-Cowen gasometer (Instrumentation Associates, Inc, New York). BMR (kcal/min) was calculated by using the Weir equation (16). The means of the BMR values that most closely matched were taken to represent BMR for each subject. Reliability of the BMR measures in this group of subjects, as determined by intraclass correlation, was $r = 0.95$.

After the BMR measurement, subjects were allowed to rise and void and then returned to bed. Subjects rested in the supine position for ≥ 30 min after returning to bed, after which expired gases were collected for 10 min and subsequently analyzed. Subjects then dressed, and expired gases were collected while they were sitting in a chair, standing on a treadmill, and walking at 37.5 m/min (1.4 mph) and 64.3 m/min (2.4 mph) on the same treadmill. All gases were analyzed by using equipment and procedures identical to those used to measure BMR.

Body composition and $\dot{V}O_2$max

Body composition and total bone mineral density were determined with dual-energy X-ray absorptiometry (Hologic 2000, version 5.54; Hologic Inc, Waltham, MA). The CV for replicate measures in our laboratory was < 1%. Bone mineral density was reported as g/cm^2. $\dot{V}O_2$max was measured by using indirect calorimetry and a treadmill-walking protocol in which subjects warmed up for 2 min at 37.5 m/min, after which speed was increased to 59.0 m/min (2.2 mph), and the slope was increased 1%/min. Heart rate was monitored continuously and blood pressure was recorded every 3 min. Subjects were strongly encouraged to walk until $\dot{V}O_2$ plateaued and a respiratory exchange ratio > 1.1 was reached. Achievement of $\dot{V}O_2$max was assumed given these parameters at volitional cessation of walking.

Follow-up measurements of body weight

After completion of the program, 29 of the original 40 subjects agreed to return to our laboratory for a measurement of body weight. This weight measurement was done on a day that corresponded to a 3–5-mo period between program completion and follow-up. All women were weighed under conditions similar to those during study participation. This follow-up measurement was done to determine whether subjects maintained, lost, or gained weight after completion of the program.

Statistical analyses

Data were analyzed by using Statistical Analysis Software for Personal Computers (SAS-PC, version 6.2; SAS Institute Inc, Cary, NC). Data were compared by using a 3 × 3 × 2 (group × time × ERT) analysis of variance (ANOVA) with repeated measures. Tukey's post hoc tests were used to determine significant differences. Multiple-regression analyses were performed to examine the relation between changes in the select EE components relative to changes in FFM among the treatments. In addition, analysis of covariance (ANCOVA) was used to test for any treatment effects on the components of EE whereas differences in FFM were adjusted for. Significance was set at an α level of $P \leq 0.05$.

RESULTS

Descriptive characteristics of the three treatment groups were reported previously (10). All groups were well matched for all characteristics; thus, the average values for all treatment groups are reported in Table 1.

There was no effect of ERT on any of the dependent variables; thus, the data for those women receiving ERT were combined with the data for the other women in the same treatment group. As reported previously (10), body weight, body fat mass, and percentage body fat decreased significantly in all groups ($P < 0.05$). FFM also showed a small but significant decrease ($P < 0.05$) (10). There was no change in bone mineral density for any of the groups over the treatment period (**Figure 1**).

There was a significant time effect for BMR ($P = 0.0001$), with values at 12 and 24 wk being significantly lower than values at baseline for all groups (**Figure 2**, panel A for DE, panel B for D-2092, and panel C for D-2929). The consistent change in BMR for each subject in each treatment group is illustrated in **Figure 3**. ANOVA revealed no significant

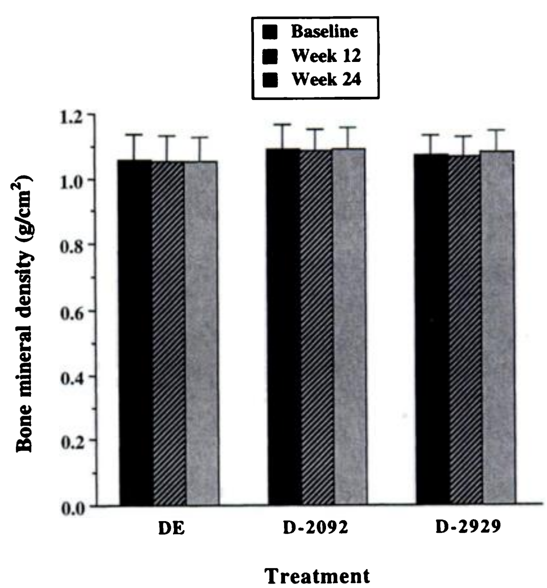

FIGURE 1. Changes in bone mineral density of 40 postmenopausal women participating in a 24-wk program of diet + exercise (DE; $n = 16$), a diet providing 2092 kJ/d less than the energy need (D-2092; $n = 13$), or a diet providing 2929 kJ/d less than the energy need (D-2929; $n = 11$).

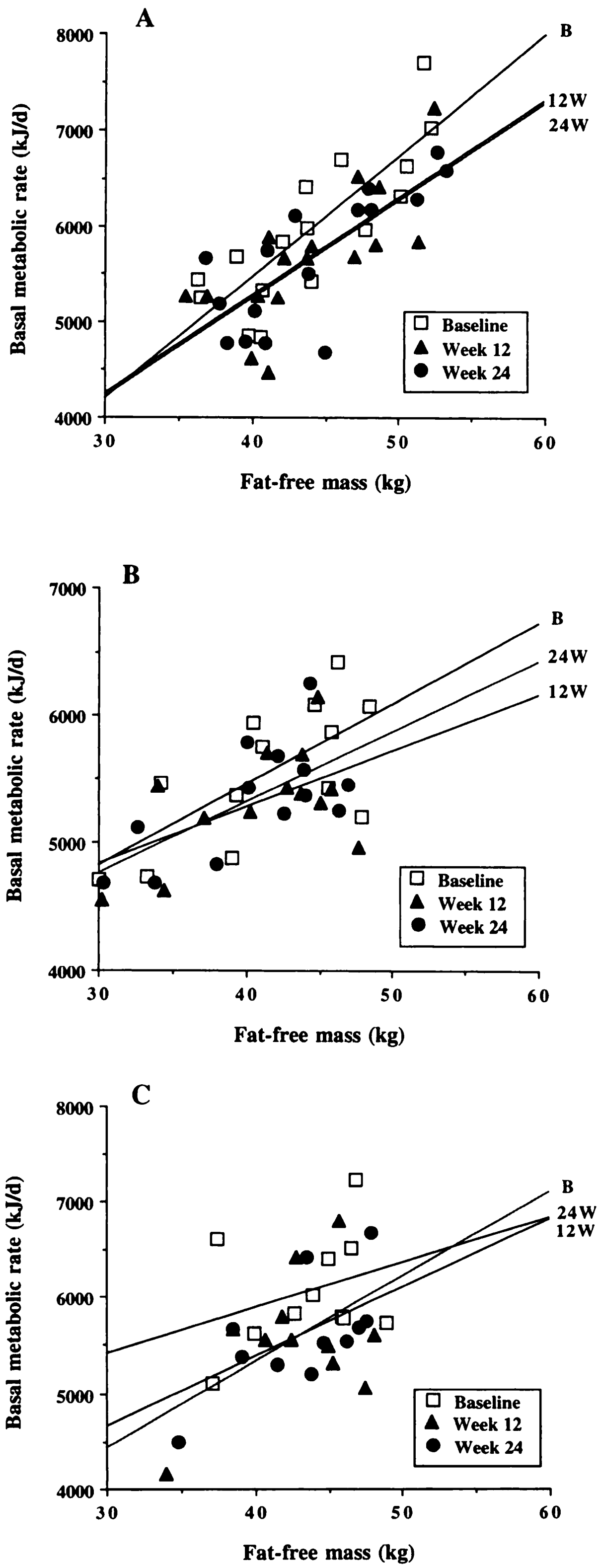

FIGURE 2. Changes in basal metabolic rate relative to changes in fat-free mass of 40 postmenopausal women participating in a 24-wk program of diet plus exercise (A; n = 16), a diet providing 2092 kJ/d less than the energy need (B; n = 13), or a diet providing 2929 kJ/d less than the energy need (C; n = 11). Values at baseline were significantly higher than those at weeks 12 and 24 of treatment ($P \leq 0.05$).

changes in EE across time while subjects were resting (P = 0.204) or standing (P = 0.224). EE values while subjects were sitting (P = 0.003) and walking at 37.5 (P = 0.0001) and 64.3 m/min (P = 0.0001) decreased significantly over time for all treatments, with no significant differences among the groups. Multiple-regression analysis also revealed no significant differences among treatment groups for changes in any component of EE relative to changes in FFM. In addition, ANCOVA showed no significant differences among treatment groups for changes in any component of EE when differences in FFM were adjusted for. Mean changes in BMR and EE from baseline to 24 wk while subjects were resting, sitting, standing, and walking are reported in **Table 2**.

Although the subjects in the DE group participated in > 80% of all walking sessions, there was no significant change in $\dot{V}O_2max$ for any of the groups ($P > 0.05$). Compliance with strength training was high, with subjects attending > 90% of all sessions. There was a significant increase in strength with each exercise performed from baseline to 24 wk for those in the DE group who performed all of the exercises (**Table 3**). This increase in strength ranged from 19% for the military press to 164% for the leg curl. There was also a significant increase in strength from all exercises from 12 to 24 wk of treatment except for the leg press and back extension.

Changes in body weight at the follow-up measurement done 3–5 mo after the program ended are shown in **Table 4**. Of the 29 subjects who participated in the follow-up weight check, 12 were from the DE group and 17 were from the two diet-only groups. The average weight for the DE group did not change significantly from the end of the program to the time of the follow-up measurement. Interestingly, 7 of the 12 women in the DE group reported continuing exercise on their own and experienced a weight loss of 2.1 ± 0.9 kg at follow-up. Of the five who reported discontinuing exercise, an average increase of 1.3 ± 1.4 kg was experienced.

A similar pattern in weight change at follow-up was observed for those women in the diet-only groups (Table 4). The 17 subjects in the diet-only group had an average weight of 71.7 ± 6.1 kg at the end of the program and 72.0 ± 6.6 kg at follow-up. Four of the 17 women in this group reported starting an exercise program at the end of the experimental program, and these women experienced an average weight loss of 0.3 ± 1.1 kg at follow-up. The remaining 13 women did not start an exercise program, and experienced an increase of 0.5 ± 1.5 kg in body weight at follow-up.

DISCUSSION

This study is one of only a few studies to measure the effects of a moderate-dietary-restriction program combined with aerobic and strength-training exercises on EE in postmenopausal women. The experimental treatment was longer than treatments in other published studies, and a follow-up measurement of body weight was also made to determine potential weight changes 3–5 mo after the end of a diet-only or DE program. One limitation of this study was that only select components of total daily EE were measured. Without the use of the doubly labeled water method, it is difficult to assess the effects of the present treatments on 24-h, free-living EE. It is possible that unmeasured components of total daily EE were affected, influencing the present findings.

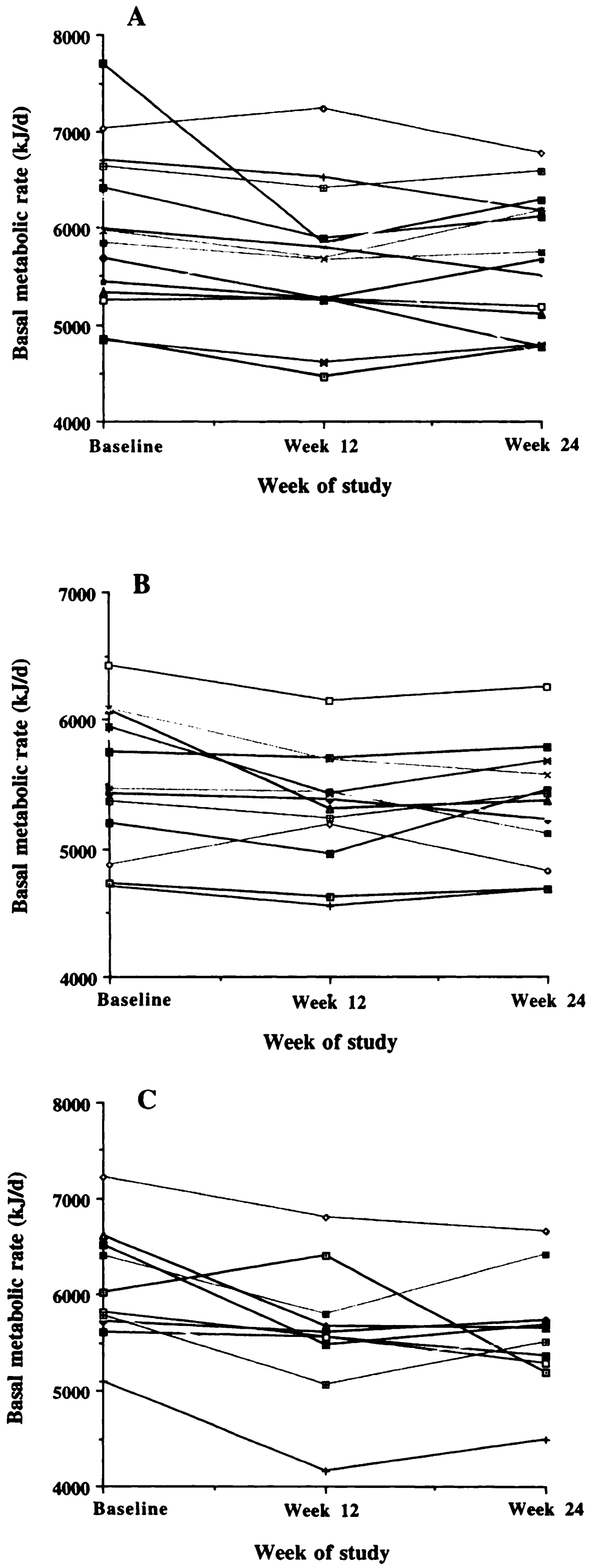

FIGURE 3. Individual changes in basal metabolic rate of 40 postmenopausal women participating in a 24-wk program of diet plus exercise (A; n = 16), a diet providing 2092 kJ/d less than the energy need (B; n = 13), or a diet providing 2929 kJ/d less than the energy need (C; n = 11).

TABLE 2

Decreases in basal metabolic rate (BMR) and energy expenditure (EE) while 40 postmenopausal women were resting, sitting, standing, and walking at 37.5 and 64.3 m/min at baseline and after a 24-wk diet + exercise (DE) or diet-only (D-2092 and D-2929) program

	DE	D-2092	D-2929
BMR (kJ/d)			
Baseline	5968 ± 803[1]	5535 ± 551	6056 ± 587
Week 24	5669 ± 716[2]	5336 ± 450[2]	5602 ± 581[2]
Change	−299	−199	−454
Resting EE (kJ/d)			
Baseline	6073 ± 649	5699 ± 698	6125 ± 830
Week 24	5914 ± 822	5843 ± 755	5709 ± 613
Change	−159	+144	−416
Sitting EE (kJ/hr)			
Baseline	295 ± 59	261 ± 28	275 ± 28
Week 24	260 ± 37[2]	244 ± 28[2]	264 ± 40[2]
Change	−35	−17	−11
Standing EE (kJ/hr)			
Baseline	316 ± 55	296 ± 45	309 ± 51
Week 24	307 ± 50	277 ± 43	302 ± 50
Change	−9	−19	−7
Walking EE (kJ/hr)			
37.5 m/min			
Baseline	810 ± 198	734 ± 134	803 ± 155
Week 24	654 ± 112[2]	637 ± 80[2]	606 ± 96[2]
Change	−156	−97	−197
64.3 m/min			
Baseline	1071 ± 268	973 ± 114	1016 ± 113
Week 24	916 ± 222[2]	859 ± 130[2]	836 ± 108[2]
Change	−155	−114	−180

[1] $\bar{x}$ ± SD.
[2] Significantly different from baseline, $P \leq 0.05$.

The results of this study support the contention that a moderate-energy-deficit diet in combination with exercise training can assist in the maintenance of BMR in postmenopausal women. Although BMR decreased significantly in all groups, the decline was slight. The maintenance of BMR was most likely due to a very small decline in FFM in these subjects (10). One explanation for the small but significant decrease in BMR observed in the present study was the high precision of the method used to measure this variable. This small change may not be physiologically relevant even though it was significant.

The average decreases in BMR for the DE and diet-only groups were 297 kJ/d (71 kcal/d) and 326 kJ/d (78 kcal/d), respectively. These data are in marked contrast with data from other diet-only and DE studies, in which more severe energy restrictions were prescribed (< 5021 kJ/d, or < 1200 kcal/d) to premenopausal women over 8–12 wk. The average decreases in BMR in these studies were 573 kJ/d (137 kcal/d) and 753 kJ/d (180 kcal/d) for DE and diet-only groups, respectively (5). It is difficult to compare the results of the present study with those of premenopausal women because of differences in methodology between the studies. In one of the few studies in which premenopausal women participated in a program of relatively moderate energy deficit (280 kJ, or 1170 kcal/d) and walking exercise, FFM and BMR were reported to be maintained (17).

Only one study of diet-only and DE groups of postmenopausal women could be found in the literature (18). Both FFM and RMR were measured after 12 wk of a diet-only (4200 kJ)

TABLE 3
Maximal oxygen uptake ($\dot{V}O_2max$) and muscular strength in 16 postmenopausal women participating in a 24-wk diet + exercise program[1]

	Baseline	Week 12	Week 24
$\dot{V}O_2max$ (mL · kg^{-1} · min^{-1})	19.86 ± 3.67	22.17 ± 3.16	23.28 ± 3.30
Muscular strength (kg)			
Bench press	20.3 ± 4.5	24.1 ± 4.3[2]	25.1 ± 4.2[2,3]
Biceps curl	10.4 ± 3.2	12.7 ± 3.0[2]	13.8 ± 3.1[2,3]
Triceps extension	15.4 ± 3.4	18.0 ± 3.8[2]	20.5 ± 3.8[2,3]
Upright row	13.1 ± 4.9	20.0 ± 7.4[2]	23.3 ± 7.8[2,3]
Latissimus dorsi pull	21.7 ± 7.7	27.6 ± 5.6[2]	29.5 ± 6.1[2,3]
Military press	22.0 ± 5.5	25.0 ± 4.1[2]	26.2 ± 5.2[2,3]
Leg curl	7.5 ± 3.0	15.1 ± 4.1[2]	19.7 ± 4.9[2,3]
Leg extension	17.0 ± 6.4	31.5 ± 6.9[2]	33.8 ± 17.9[2,3]
Leg press	45.3 ± 13.5	67.3 ± 15.2[2]	69.8 ± 15.2[2]
Back extension	30.1 ± 14.2	42.7 ± 17.9[2]	50.1 ± 14.3[2]

[1] $\bar{x}$ ± SD.
[2] Significantly different from baseline, $P \leq 0.05$.
[3] Significantly different from week 12, $P \leq 0.05$.

or DE (4200 kJ plus aerobic and strength-training exercise) program. The exercise program was similar to that of the present study, with subjects initially performing 30 min of aerobic exercise and eight weight-training exercises 3 d/wk, with the duration of aerobic exercise increasing to 55 min over the course of the study. A decrease in RMR of 192 kJ/d (46 kcal/d) and 360 kJ/d (86 kcal/d) were reported for the DE and diet-only groups, respectively. In the present study, BMR decreased by 301 kJ/d (72 kcal/d) and 335 kJ/d (80 kcal/d) in the DE and diet-only groups, respectively. The similar reductions in BMR and RMR between the studies are somewhat surprising considering that the reported energy intake was ≈4498 kJ/d (1075 kcal/d) in the previous study. This is > 2092 kJ/d lower than the average energy intake of the women in the present study. In addition, subjects in the diet-only group of the previous study lost twice the amount of weight and FFM of the diet-only subjects in the present study but experienced a similar decline in RMR.

It is possible that the women in the previous study (18) had a higher energy intake than they self-reported, which is a commonly observed phenomenon (19). In addition, the method used for measuring BMR and RMR differed, there being the potential for better experimental control and reliability with the method used in the present study (ie, subjects staying overnight on a metabolic unit, with measures taken before their rising on three separate occasions). It is not clear whether RMR was measured on more than one occasion in the previous study and the reliability of the RMR measures for the subjects in the previous study were not reported. These limitations make comparisons of changes in metabolic rate between the studies difficult to interpret.

TABLE 4
Body weight of 29 postmenopausal women after 24 wk (program cessation) of either a diet + exercise (DE) or diet-only (D-2092 and D-2929) program and after 3–5 mo (follow-up)[1]

	DE (*n* = 12)	D-2092 (*n* = 9)	D-2929 (*n* = 8)
		kg	
Weight at program cessation	73.1 ± 8.9	71.0 ± 4.7	72.4 ± 7.6
Weight at follow-up	72.5 ± 9.9	71.6 ± 5.8	72.4 ± 7.7
Change in weight	−0.7 ± 2.1	0.6 ± 1.5	0.0 ± 1.2

[1] $\bar{x}$ ± SD.

The addition of exercise to the moderate-energy-deficit diet prescribed to subjects in the present study did not seem to have a significant protective benefit as evidenced by the small decrease observed in BMR. However, there was a trend for those in the DE group to experience a smaller decrease in BMR and EE while walking than those in the D-2929 diet-only group. Because the theoretical energy deficit for both of these groups was 2929 kJ/d, these findings may support some protective benefit of exercise training added to a diet regimen. A recently published meta-analysis (5) of diet-only and DE studies of predominantly premenopausal women showed that the addition of exercise to a diet program can help prevent some of the decrease observed in BMR and results in a smaller decrease in FFM, despite similar weight loss, compared with diet alone.

Many of the subjects in this study experienced a plateau in weight loss after 12 wk of participation (10). This plateau could be directly attributed to lack of compliance with the dietary program as well as to the decrease in EE observed at rest and during sitting and walking. Although reported activity levels remained consistent throughout the program, it is possible that these women compensated for the increase in EE during exercise training by increasing the amount of time spent in more sedentary activities such as lying, sitting, and sleeping. Such a change in activity pattern has been shown to occur in energy-restricted men (20) and obese premenopausal women (21). In addition, many of the subjects in the present study reported eating significantly more food, and in particular, selecting more fat exchanges than were prescribed after the first 12 wk of treatment.

The ability of postmenopausal women to increase their muscle strength with strength training has been reported by others (22, 23). Contrary to the findings of Pyka et al (22) and Charette et al (23), our subjects did not experience the plateau in strength observed previously in elderly women after 8 wk of strength training. The only exercises in the present study that resulted in such a plateau were the leg press and back extension. However, the strength gains for all exercises in the present study were more dramatic over the first 12 wk of training; a similar pattern was reported by Pyka et al (22) and Charette et al (23).

Exercise participation was associated with continued weight loss 3–5 mo after the program ended. Both the subjects in the DE group who continued to exercise and those in the diet-only groups who initiated an exercise program experienced additional weight loss after completion of the program. Weight gain occurred in those who discontinued exercise or who never initiated an exercise program. van Dale et al (24) reported a significant increase in body weight from 6 to 42 mo after a DE program in premenopausal women. The follow-up in the present study was relatively short, and it is unknown whether the body weight of the subjects in the present study would have increased with a longer follow-up period. However, these short-term findings emphasize an added benefit of exercise to weight loss and maintenance of weight loss in overweight postmenopausal women.

The results of this study show that postmenopausal women can lose significant body weight and body fat without experiencing a large decline in BMR. Because there was a trend for the women in the D-2929 group to experience a greater decrease in EE than the DE and D-2092 groups at rest and during walking, it may be that the addition of exercise to a moderate-energy-deficit diet is somewhat protective of the maintenance of EE. The addition of exercise was also beneficial in subjects achieving continued weight loss after the end of the program. These findings are important because it is critical for overweight postmenopausal women to maintain BMR and bone mass while reducing body fat.

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REFERENCES

1. Apfelbaum M, Bostsarron J, Lacatis D. Effect of caloric restriction and excessive caloric intake on energy expenditure. Am J Clin Nutr 1971;24:1405–9.
2. Ravussin E, Bogardus C. Relationship of genetics, age, and physical fitness to daily energy expenditure and fuel utilization. Am J Clin Nutr 1989;49:968–75.
3. Poehlman ET. A review: exercise and its influence on resting energy metabolism in man. Med Sci Sports Exerc 1989;21:515–25.
4. Molé PA. Impact of energy intake and exercise on resting metabolic rate. Sports Med 1990;10:72–87.
5. Thompson JL, Manore MM, Thomas JR. Effects of diet and diet-plus-exercise programs on resting metabolic rate: a meta-analysis. Int J Sport Nutr 1996;6:41–61.
6. Vaughan L, Zurlo F, Ravussin E. Aging and energy expenditure. Am J Clin Nutr 1991;53:821–5.
7. Poehlman ET, Goran MI, Gardner AW, et al. Determinants of decline in resting metabolic rate in aging females. Am J Physiol 1993;264:E450–5.
8. Fukagawa NK, Bandini LG, Young JB. Effect of age on body composition and resting metabolic rate. Am J Physiol 1990;259:E233–8.
9. National Institutes of Health Consensus Development Panel. Health implications of obesity: National Institutes of Health consensus development conference statement. Ann Intern Med 1985;103:1073–7.
10. Fox AA, Thompson JL, Butterfield GE, Gylfadottir U, Moynihan S, Spiller G. Effects of diet and exercise on common cardiovascular disease risk factors in moderately obese older women. Am J Clin Nutr 1996;63:225–33.
11. Metropolitan Life Insurance Company. New weight standards for men and women. Stat Bull Metropol Life Insur Co 1959:40:1–4.
12. Mulligan K, Butterfield GE. Discrepancies between energy intake and expenditure in physically active women. Br J Nutr 1990;64:23–36.
13. Thompson JL, Butterfield GE, Marcus R, et al. The effects of recombinant human insulin-like growth factor-I and growth hormone on body composition in elderly women. J Clin Endocrinol Metab 1995;80:1845–52.
14. Holloway L, Butterfield G, Hintz RL, Gesundheit N, Marcus R. Effects of recombinant human growth hormone on metabolic indices, body composition, and bone turnover in healthy elderly women. J Clin Endocrinol Metab 1994;79:470–9.
15. American College of Sports Medicine. Position stand: the recommended quantity and quality of exercise for developing and maintaining cardiorespiratory and muscular fitness in healthy adults. Med Sci Sports Exerc 1990;22:265–74.
16. Weir JB de V. New methods for calculating metabolic rate with special reference to protein metabolism. J Physiol 1949;109:1–9.
17. Belko AZ, Van Loan M, Barbieri TF, Mayclin P. Diet, exercise, weight loss, and energy expenditure in moderately overweight women. Int J Obes 1987;11:93–104.
18. Svendsen OL, Hassager C, Christiansen C. Effect of an energy-restrictive diet, with or without exercise, on lean tissue mass, resting metabolic rate, cardiovascular risk factors, and bone in overweight postmenopausal women. Am J Med 1993;95:131–40.
19. Sawaya AL, Tucker K, Tsay R, et al. Evaluation of four methods for determining energy intake in young and older women: comparison with doubly labeled water measurements of total energy expenditure. Am J Clin Nutr 1996;63:491–9.
20. Gorsky RD, Calloway DH. Activity pattern changes with decreases in food energy intake. Hum Biol 1983;55:577–86.
21. Kempen KPG, Saris WHM, Westerterp KR. Energy balance during an 8-wk energy-restricted diet with and without exercise in obese women. Am J Clin Nutr 1995;62:722–9.
22. Pyka G, Lindenberger E, Charette S, Marcus R. Muscle strength and fiber adaptations to a year-long resistance training program in elderly men and women. J Gerontol 1994;49:M22–7.
23. Charette SL, McEvoy L, Pyka G, et al. Muscle hypertrophy response to resistance training in older women. J Appl Physiol 1991;70:1912–6.
24. Van Dale D, Saris WHM, Hoor FT. Weight maintenance and resting metabolic rate 18–40 months after a diet/exercise treatment. Int J Obes 1990;14:347–59.