How much physical activity is needed to minimize weight gain in previously obese women?1–3

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ABSTRACT Exercise is frequently identified as a predictor of weight maintenance after elective weight loss in retrospective studies of treatments for obesity. We conducted a prospective study to test whether physical activity measured soon after weight loss predicted weight maintenance and to determine how much physical activity was required to optimize maintenance. Thirty-two women [mean (± SD) age, 38 ± 7 y; body mass index (in kg/m²), 24 ± 3] were recruited through local advertising within 3 mo of reaching their target for weight loss (23 ± 9 kg). Total energy expenditure (TEE) was measured by the doubly labeled water method. Postabsorptive resting metabolic rate (RMR) and post-prandial RMR [expressed as thermic effect of a meal (TEM)] were measured by respiratory gas exchange. Women in the physically active group (ratio of TEE to RMR = 1.89 ± 0.08) gained 2.5 ± 3.1 kg during the 12 mo after reaching their target for weight loss, moderately active women (TEE:RMR = 1.64 ± 0.05) gained 9.9 ± 10.5 kg, and sedentary women (TEE:RMR = 1.44 ± 0.08) gained 7.0 ± 5.9 kg (P < 0.01). Retrospective analyses of weight regain as a function of energy expended in physical activity indicated a threshold for weight maintenance of 47 kJ·kg body wt−1·d−1. This corresponds to an average of 80 min/d of moderate activity or 35 min/d of vigorous activity added to a sedentary lifestyle. Am J Clin Nutr 1997;66:551–6.

KEY WORDS Energy metabolism, body composition, stable isotopes, mass spectrometry, doubly labeled water, weight loss, physical activity, postobese women

INTRODUCTION

An estimated 40% of women in the United States attempt to lose weight annually (1, 2). A small minority do this by undergoing surgical procedures but the majority of attempts are based on reductions in dietary intake, increases in physical activity, or both (2, 3). The success rate for weight loss has increased considerably over the past few decades and losses of 8–20 kg are not uncommon (3). A continuing problem, however, is that many individuals regain the weight lost within 1–3 y after completing a weight-loss program (3).

Participation in regular exercise is frequently cited as an important factor in individuals able to maintain weight (4–9). Most studies with findings supporting the use of exercise in weight control were qualitative retrospective studies that found a higher percentage of weight maintainers than nonmaintainers reported that they engaged in regular exercise (4–6). More recently, however, prospective studies found improved weight maintenance when exercise was included in a postweight-loss program (7–9).

On the basis of these studies, exercise is commonly prescribed for weight maintenance; however, the amount of exercise required for weight maintenance is not well known. The aims of this prospective study were to assess the effects of physical activity on weight maintenance and to determine the amount of physical activity required to minimize weight gain for 1 y after weight loss.

SUBJECTS AND METHODS

Subjects

Thirty-four women aged 20–50 y were recruited from the metropolitan Chicago area through newspaper advertisements and public service announcements. Entry criteria were a weight loss ≥ 12 kg, maintenance of weight stability within 1 kg for > 1 mo but not > 3 mo, and a current body mass index (in kg/m²) of 20–30. In all subjects, weight loss was documented in writing by a physician or director of a weight-loss program. Exclusion criteria included cigarette smoking, history of a metabolic disease such as diabetes mellitus or a thyroid disorder, hypertension, history of a psychiatric disorder, and a physical handicap that would interfere with exercise. The study was reviewed and approved by the Internal Review Board of the University of Chicago and informed written consent was obtained from each volunteer.

Of the 34 women, 33 completed the 1-y study. The woman who did not complete the study failed to keep scheduled appointments and did not respond to our telephone calls or letters. Data from this subject were excluded from this report. Data from two other women were also excluded; one did not have documentation of previous weight loss and the other indicated that her physical activity during the energy expenditure measurement period was not representative of her typical lifestyle because she spent ~30 h during one of the baseline

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weeks packing, carrying, and unpacking her possessions as part of a move to new living quarters.

Protocol
Subjects were enrolled for 12 mo during which they made five visits to the clinical research center—two at study entry and one each at 3, 6, 9, and 12 mo. Subjects were neither encouraged to nor discouraged from partaking in regular exercise and were told to follow whatever maintenance strategy they preferred. To minimize alterations in behavior during the periods of data collection, subjects were informed that the doubly labeled water method measured body composition. Furthermore, measurements of heart rate and self-reported dietary intake and physical activity were done after collection of the final urine sample for the doubly labeled water assessment.

For the baseline measurements at entry, women arrived at the research center at 1800 between the 5th and 12th day after the start of their previous menstrual period. Subjects were provided with dinner but no further intake of food or beverage other than water was allowed after 1930. Doubly labeled water for measurement of total body water (TBW) and total energy expenditure (TEE) was administered at 2000. The next morning, subjects were awakened between 0700 and 0800 and allowed to rise from bed and void; they then returned to bed for measurement of resting metabolic rate (RMR) while they remained fasting. Subjects were weighed while wearing only a hospital gown; results were recorded to the nearest 0.1 kg. The same electronic balance was used throughout the follow-up period. Subjects were provided with breakfast and the thermic effect of a meal (TEM) was measured for the next 4 h. Subjects were released from the research center in the afternoon and allowed to follow their normal routine.

Subjects returned to the research center 14 d later. Dinner was provided and the subjects fasted after 2000. RMR was measured in the morning while the subjects remained fasting. Physical activity over the preceding 7 d was estimated by the recall method. Subjects were given a diary in which to record their dietary intake over the next 7 d. They were also given a heart rate monitor that was used to record heart rate during waking hours for 3 of the next 7 d.

Subjects returned as outpatients to the research center 3, 6, 9, and 12 mo after the inpatient visit for measurement of weight. Physical activity over the previous 7 d was estimated by recall and a 7-d diary in which to record dietary intake was given to each subject.

Total energy expenditure
Doubly labeled water was administered at 2000. The doses were 0.12 g D$_2$O (99.9 atom percent)/kg estimated TBW and 2.0–2.5 g H$_2^{18}$O (10 atom percent)/kg estimated TBW. The lower dose was used when there was a shortage of H$_2^{18}$O. All urine was collected between 2000 and the first voiding of the next morning. The measured loss of deuterium in urine was subtracted from the dose given. Spot urine samples were collected before deuterium was administered, at 0800 the next morning, when the subjects awakened at home on day 8 after deuterium administration, and at 0800 on day 15, when the subjects were again inpatients in the research center.

Urine samples (5 mL) were treated with 200 mg dry carbon black, filtered, and frozen at −20 °C. After the samples were thawed, deuterium and $^{18}$O were measured as previously described (10). Briefly, deuterium was measured by using 2-µL aliquots that were distilled under vacuum, sealed in a quartz tube with zinc reagent (Friends of Geology, Bloomington, IN), reduced at 500 °C for 30 min, and analyzed on a 3–60 HD isotope-ratio–mass spectrometer (PARTCO, Belfonte, PA). Analyses were performed in triplicate and repeated if SD > 2.5%. The $^{18}$O abundance was measured after 1.5 mL urine was equilibrated with carbon dioxide for $\geq$ 24 h. The carbon dioxide was isolated under vacuum and analyzed on a 3–60 RMR isotope-ratio–mass spectrometer (PARTCO). Analyses were performed in duplicate and repeated if the difference $> 0.5\%$. The mean (± SD) ratio of $^2$H to $^{18}$O dilution space was 1.034 ± 0.015; the $^2$H and $^{18}$O elimination rates were 0.10 ± 0.028/d and 0.126 ± 0.027/d, respectively.

Body composition
Bioelectrical impedance analysis (BIA) was used to minimize the potential for artifacts in correlating energy expenditure from the doubly labeled water assessment with body composition. TBW was calculated from a 50-kHz tetrapolar resistance method by using an RJL 101 analyzer (RJL, Clinton, MI) (11). In these subjects, mean TBW loss in the urine measured by BIA (34.4 ± 4.3 kg) was not different from that obtained by the isotope dilution method (33.9 ± 4.6 kg; r = 0.93). Fat-free mass was calculated by assuming a hydration factor of 0.73 (12) and fat mass was calculated as the difference between fat-free mass and body mass.

Resting metabolic rate
RMR was measured after the subjects fasted overnight by using a DeltaTrac respiratory gas analyzer (Sensor Medics, Anaheim, CA). This is a fixed-flow open-canopy system with an infrared carbon dioxide detector and a paramagnetic oxygen detector. The system was calibrated by using methanol burns, which indicated a 2% analytic CV. Subjects were awakened and allowed to get out of bed and void; they then lay down again for 15 min. A clear plastic canopy was placed over their heads and respiratory gas exchange was measured for 45 min. Resting energy expenditure was calculated by using the modified Weir equation (13). Results of two determinations done 2 wk apart were averaged to better approximate average RMR over the course of the menstrual cycle. RMR was found to have a peak-to-peak change of 5–10% between the luteal and follicular phases of the cycle (14, 15). In 30 women we observed a significant difference of 3.4 ± 4.7% between the follicular and luteal RMR, with the luteal RMR being greater. The other four women had undergone hysterectomy before entering the study and were therefore excluded from this particular analysis.

Thermic effect of a meal
TEM was measured after the RMR measurement during the luteal phase. Subjects ate a breakfast of cold cereal, milk, toast, butter, and jelly that had an energy content equal to 50% of the measured RMR. Subjects consumed the meal in $\leq$ 20 min and returned to bed, where respiratory gas exchange was measured for 4 h. The data from the first 10 min were not used and there was a gap of 5–10 min after 2 h, when the subjects were allowed to get out of bed to void. The sum of energy expenditure in excess of fasting RMR was calculated over 4 h and
expressed as a percentage of the metabolizable energy in the breakfast. TEM over 24 h was estimated by assuming that the subjects' average dietary energy intake was similar to their TEE and that the same percentage of consumed energy was expended as TEM as that measured for 4 h after the test breakfast (ie, 24-h TEM = TEE × TEM/100).

Reproducibility

During the initial phase of this study, we determined stability of the TEE measurement using doubly labeled water and of the RMR and TEM measurements using respiratory gas exchange across a 1-y period in six nonobese women with stable weight. These assessments were done with two different metabolic carts but methanol burns indicated that the carts had equivalent analytic accuracy and precision (2%). As reported elsewhere (16), the intrasubject CVs expressed as percentages of total daily energy expenditure were 7.8% for TEE, 2.4% for RMR, 2.0% for TEM, and 7.3% for energy expended in physical activity calculated by the difference [physical activity = TEE (1 – TEM/100) – RMR].

Physical activity recall

Subjects used a standard questionnaire (17, 18) to recall the number of hours in the past week during which they slept and the number of hours during which they engaged in moderate, hard, and very hard physical activities. Light activity was assumed to account for the remainder of the time. The volume of physical activity was calculated from the sum of the products of the number of hours spent per day at each level of activity and metabolic equivalent hours (METs) > 1 MET (rest), under the assumption that the number of METs > 1 were 0.5, 3, 5, and 9, respectively, for light, moderate, hard, and very hard physical activities (17).

Heart rate

Subjects wore heart rate monitors (Polar Vantage, Stamford, CT) during most waking hours for 3 d (2 weekdays and 1 weekend day). There was an average 1.2-h/d difference between the time the monitors were worn and the reported waking hours; this time was assumed to have been spent in light activity. Individual threshold values for activity levels were determined the week before the heart rate recording by having the subjects walk at various controlled speeds. The threshold between light and moderate activity was the subjects' heart rate while walking at a rate of 3.7 km/h (2.2 mph). The threshold between moderate and hard activity was the subjects' heart rate while walking at a rate of 6.3 km/h (3.7 mph). The threshold between hard and very hard activity was calculated as 70% of maximum heart rate adjusted for age (220 - age) (19).

The amount of physical activity measured by heart rate was calculated as the number of METs > 1 MET (rest) multiplied by the number of hours spent at each level of activity averaged over 3 d. Compared with the physical activity recall, the heart rate calibration used the slightly lower threshold value of 2.5 METs to separate low and moderate activity levels and 4 METs to separate moderate and vigorous activity levels (20). Because of these lower thresholds, the values used for METs in excess of the resting value for the heart rate data were 0.5, 2, 4, and 9, respectively, for light, moderate, hard, and very hard physical activities.

Dietary intake

Subjects recorded their dietary intake by using a pocket diary for 7 d. The diary had separate lined pages for each day of the week. Subjects were instructed on how to estimate portion sizes in common household units. They were asked to record a description and amount for all foods and energy-containing beverages consumed over the subsequent 7 d and to return the diary by mail. A dietitian reviewed the records and calculated the energy and macronutrient content of the subjects' diets by using the NUTRIPRACTOR III program (San Diego, CA). Food quotient was calculated for use in calculating TEE from data from the doubly labeled water studies (21).

Statistical analysis

The subjects were divided into three groups on the basis of their physical activity levels at baseline. Physical activity at baseline was assessed by using the ratio of TEE to RMR (22). Cutoff values for the three groups were designated a priori as the midpoints of the TEE-RMR ratios between the light (< 1.55), moderate (1.55–1.75), and heavy (1.75) physical activity levels given in the recommended dietary allowances (23). The cutoff values for the three groups corresponded to the percentage of TEE expended at rest (100 RMR/TEE); those values were > 65%, 57–65%, and < 57%, respectively, for sedentary, moderately active, and active subjects. Analysis of variance (MINITAB; Minitab Inc, State College, PA) was used to make comparisons between groups. RMRs were also compared by using analysis of covariance; fat-free mass was the covariate. A repeated-measures design was used to compare physical activities assessed by physical activity recall at 3-mo intervals. Correlations between variables were univariant Pearson product. Results are expressed as means ± SDs except where noted otherwise. A P value of 0.05 was required for significance.

RESULTS

Weight regain

Weight change over the 12 mo after the weight-loss period was varied. Three of the 32 women lost weight, 14 gained

<table>
<thead>
<tr>
<th>TABLE 1</th>
<th>Subject characteristics at baseline&lt;sup&gt;1&lt;/sup&gt;</th>
<th>Group</th>
<th>Characteristic</th>
<th>Active (n = 9)</th>
<th>Moderately active (n = 15)</th>
<th>Sedentary (n = 8)</th>
</tr>
</thead>
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<tr>
<td></td>
<td>Age (y)</td>
<td>40 ± 7</td>
<td>38 ± 8</td>
<td>38 ± 5</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Weight (kg)</td>
<td>64 ± 8</td>
<td>68 ± 10</td>
<td>68 ± 10</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Fat-free mass (kg)</td>
<td>44 ± 5</td>
<td>47 ± 7</td>
<td>46 ± 3</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>BMI (kg/m&lt;sup&gt;2&lt;/sup&gt;)</td>
<td>23 ± 2</td>
<td>24 ± 3</td>
<td>25 ± 3</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Previous weight loss (kg)</td>
<td>18 ± 4</td>
<td>25 ± 11</td>
<td>27 ± 8</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Resting metabolic rate (MJ/d)</td>
<td>5.43 ± 0.54</td>
<td>5.55 ± 0.63</td>
<td>5.67 ± 0.49</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Thermic effect of meal (%)</td>
<td>5.6 ± 1.0</td>
<td>5.3 ± 2.0</td>
<td>5.0 ± 1.8</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Total energy expenditure (MJ/d)</td>
<td>10.3 ± 0.7</td>
<td>9.2 ± 0.9</td>
<td>8.2 ± 0.8&lt;sup&gt;2&lt;/sup&gt;</td>
<td></td>
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</tbody>
</table>

<sup>1</sup> x ± SD.

<sup>2</sup> Significant difference among groups, P < 0.01.
TABLE 2
Correlations between measures of physical activity at baseline

<table>
<thead>
<tr>
<th>Variable</th>
<th>TEE:RMR</th>
<th>PA</th>
<th>PAI</th>
<th>PAR</th>
</tr>
</thead>
<tbody>
<tr>
<td>TEE:RMR</td>
<td>—</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PA (MJ/d)</td>
<td>0.948</td>
<td>—</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PAI (MJ·kg⁻¹·d⁻¹)</td>
<td>0.955</td>
<td>0.899</td>
<td>—</td>
<td></td>
</tr>
<tr>
<td>PAR (MET·h)</td>
<td>0.413</td>
<td>0.355</td>
<td>0.472</td>
<td>—</td>
</tr>
<tr>
<td>HR (MET·h)</td>
<td>0.451</td>
<td>0.496</td>
<td>0.558</td>
<td>0.517</td>
</tr>
</tbody>
</table>

1 TEE, total energy expenditure; RMR, resting metabolic rate (postabsorptive); PA, energy expended in physical activity by doubly labeled water assessment; PAI, physical activity index by doubly labeled water assessment; PAR, 7-d physical activity recall; HR, 3-d heart rate recording; MET, metabolic equivalents. All correlations are significant, *P < 0.05.

< 4.5 kg, and 1 gained 40 kg. Average weight change was 7.1 ± 8.4 kg. The subjects were grouped on the basis of TEE:RMR during the baseline period, ie, 1–3 mo after weight loss (Table 1). There were no differences between the groups in physical characteristics although previous weight loss was somewhat smaller in the more active groups (*P = 0.09). RMR did not differ between groups, with or without adjustment for fat-free mass (Table 2). TEM did not differ between groups but TEE differed by design.

Weight change during the 1-y prospective observation was significantly different between groups (Figure 1). The lowest average regain occurred in the active group but there was no evidence of a dose effect because weight-retain values in the sedentary and moderately active groups were similar. The proportions of weight regained as fat did not differ significantly between groups (90%, 100%, and 65%, respectively, in the sedentary, moderately active, and active groups). In all subjects, the changes in fat mass were linearly related to weight change (Δ fat mass (kg) = 0.85 (± 0.03) Δ weight (kg) + 0.3 (± 0.3); *r = 0.98*).

FIGURE 1. Mean (± SEM) body weights in three groups of previously obese women in the year after completion of weight loss. Time-group interaction, ANOVA, and post hoc *t* testing indicated that increases in weight were less in active women (TEE:RMR > 1.75).

Comparisons of measures of physical activity

Physical activity was measured by 7-d recalls and 3-d heart rate monitoring and the results were expressed as MET·h. It was also measured as the difference between TEE and RMR plus TEM, with the results expressed both as energy expended in physical activity (MJ/d) and as a physical activity index (PAI; in kJ·kg body wt⁻¹·d⁻¹, where body weight was that measured on the day doubly labeled water was administered).

The five measures of physical activity were significantly correlated in the 33 subjects (Table 2). However, the high correlations among the three expressions based on energy expenditure measured by the doubly labeled water method (TEE:RMR, physical activity, and PAI) were likely inflated because they were derived from common variables. In all three groups the activity patterns assessed from self reports in diaries kept for 7 consecutive days were stable throughout the year (Table 3).

Individual predictors of weight and fat gain

None of the methods for assessing physical activity at baseline were predictive of weight or fat gain by univariate analysis. One subject, however, was an outlier because of a dramatic weight gain (Figure 2). When this subject was omitted from the regression analysis, PAI was a predictor of both weight gain (*r = 0.392*, *P < 0.05) and fat gain (*r = 0.399*, *P < 0.05). The relation was not linear but instead showed a threshold of physical activity for minimizing weight gain. This threshold corresponds to 47 kJ·kg body wt⁻¹·d⁻¹.

DISCUSSION

This study confirmed findings of retrospective and semi-quantitative studies of the effects of physical activity on weight maintenance after voluntary weight loss (4–8). During the year after weight loss, only two of eight subjects who were categorized as active at baseline gained > 4.5 kg. In contrast, 13 of 24 subjects categorized as moderately active or sedentary at baseline gained > 4.5 kg during the year. More importantly, this study provided a measure of the amount of physical activity required to minimize weight gain in the year after voluntary

TABLE 3
Physical activity assessed by self report and heart rate in three groups over time

<table>
<thead>
<tr>
<th>Variable</th>
<th>Group</th>
<th></th>
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<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Physical activity (MET·h)</td>
<td>Active</td>
<td>Moderately active</td>
<td>Sedentary</td>
<td></td>
</tr>
<tr>
<td>Baseline</td>
<td>18 ± 7</td>
<td>16 ± 5</td>
<td>14 ± 3</td>
<td></td>
</tr>
<tr>
<td>3 mo</td>
<td>16 ± 3</td>
<td>16 ± 4</td>
<td>15 ± 32</td>
<td></td>
</tr>
<tr>
<td>6 mo</td>
<td>17 ± 4</td>
<td>15 ± 4</td>
<td>14 ± 3</td>
<td></td>
</tr>
<tr>
<td>9 mo</td>
<td>20 ± 10²</td>
<td>14 ± 4²</td>
<td>12 ± 2²</td>
<td></td>
</tr>
<tr>
<td>12 mo</td>
<td>17 ± 7</td>
<td>16 ± 4²</td>
<td>13 ± 2</td>
<td></td>
</tr>
<tr>
<td>Heart rate (MET·h)</td>
<td>24 ± 8</td>
<td>20 ± 6</td>
<td>15 ± 3</td>
<td></td>
</tr>
<tr>
<td>Baseline</td>
<td>23 ± 8²</td>
<td>18 ± 7²</td>
<td>15 ± 4</td>
<td></td>
</tr>
</tbody>
</table>

1 *x ± SD*. Differences between groups were significant *P < 0.01, but there were no significant differences between assessment times within groups.

2 Data were missing for 1 or 2 subjects.
weight loss. When the data were reanalyzed on a retrospective basis to determine the PAI that provided maximum differentiation between gainers and maintainers, a value of 47 kJ · kg body wt−1 · d−1 (11 kcal · kg body wt−1 · d−1) was determined. Three of 16 subjects with a PAI > 47 kJ · kg body wt−1 · d−1 gained > 4.5 kg whereas 12 of 17 subjects who were less active gained > 4.5 kg.

This value can be placed in perspective by using the commonly accepted values of 1.5 METs for light activities, 4 METs for moderate activities, and 6 METs for vigorous activities. On the basis of these values, the PAI equivalent of the sedentary lifestyle would be 33 kJ · kg body wt−1 · d−1 (16 h × 0.5 METs in excess of rest), which is in agreement with the observed PAI in the sedentary group (31 ± 5 kJ · kg body wt−1 · d−1). To increase this to 47 kJ · kg body wt−1 · d−1, sedentary individuals would have to add 1.3 h/d of moderate activity, such as brisk walking, or 0.6 h/d of vigorous activity, such as fast bicycling or aerobics, to their physical activities.

This level of moderate physical activity is higher than the 1995 Centers for Disease Control and Prevention and American College of Sports Medicine joint recommendation of 0.5 h/d of moderate-intensity physical activity to promote health and reduce disease (24). It also exceeds the 0.5 h/d of moderate-intensity physical activity or 0.25 h/d of vigorous activity recommended by the Surgeon General for preservation of health (25). These differences in recommended levels of activity are not unexpected because the goals of the recommendations were to improve cardiovascular fitness and overall health. Some of the difference, however, may be related to the definition of sedentary. Our definition of a sedentary lifestyle was one with no activity beyond that defined as light; thus, any amount of moderate activity done at home or work would count toward meeting the goal for weight control.

Although this definition of sedentary may seem extreme, activity levels this low have been observed. In this study we observed a PAI ≤ 33 kJ · kg body wt−1 · d−1 in 7 of 33 previously obese subjects. In a previously published review (26), we reported that 15 of 173 females were at or below this level. Black et al (22), in a review that included some of the same primary data, reported that 25% of women have TEE:RMR ratios ≤ 1.4, which corresponds to 16 h of light activity plus a TEM of 6%. Thus, sedentary activity levels consistent with no activity in the moderate range were confirmed by using doubly labeled water, although the value of TEE:RMR < 1.4 was likely inflated because of random measurement errors that increased the spread in the frequency distribution at both the low and high end.

The calculation of threshold of physical activity also depends on the tool used to assess physical activity. We used PAI, which is TEE minus the sum of that energy expended in resting metabolism and TEM, all divided by body weight. This index was used because we thought it would resemble traditional measures of physical activity, such as the 7-d physical activity recall, more closely. In this regard, we found that PAI had a higher correlation with both physical activity recall and heart rate than did either TEE:RMR or physical activity not divided by body weight. This index was criticized by Black et al (22) and Prentice et al (27) because they found that it was not directly proportional to physical activity and that it thus overcorrected for differences in body weight. We, however, were unable to confirm this observation and found a proportional relation between energy expended in physical activity in excess of RMR and body weight for most light activities (JD Jefford and DA Schoeller, unpublished observations, 1997); therefore, we do not agree with this criticism.

The issue of body size in the analysis of energy expenditure is important. Indeed, despite our efforts to minimize this issue by recruiting only currently nonobese women for our study, there was a trend for the active group to have the lowest weights (P = 0.2). There was also a trend for the active group to have had the least weight loss before enrollment (P = 0.1). Given our recruitment design, we could not determine whether either of these trends confounded our findings; additional studies are needed.

The finding of better weight control in the active group is consistent with results of previous studies indicating that body weight is better regulated at a higher energy flux. Two studies done in a metabolic unit found that obese women did not increase energy intake when exercise was added to a sedentary inpatient regimen (28, 29). Our findings are also consistent with the existence of a threshold of physical activity for weight control previously hypothesized by Meyer et al (30). They found that rodents with different levels of exercise increased and decreased intake in a compensatory manner to maintain body weight over a wide variety of activity levels. However,
when exercise was reduced to a very low level, both intake and body weight began to increase. A cross-sectional study of men living in India found a similar relation. Weight was relatively constant between groups of men whose occupations were classified as active or very active whereas subjects with sedentary jobs had a higher body weight, indicating a poorer regulation of body weight at the lower levels of physical activity (31).

In conclusion, using relatively precise objective measures of energy expenditure based on the doubly labeled water method in a prospective study, we found that active postobese women maintained their reduced weight better than those who were inactive. The relation between physical activity and weight gain was not linear but showed a threshold-like relation for weight control. This threshold corresponded to 80 min/d of moderate-intensity physical activity or 35 min/d of vigorous physical activity.

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REFERENCES