The first concern is that older subjects may already have, or are at increased risk of developing, the chronic diseases associated with old age (8). Accordingly, most practitioners assume that higher body weights with ample endogenous nutrient stores at the outset of a chronic illness afford some long-term protection during potential periods of undernutrition.

A second prevailing concern with weight loss treatment of the elderly is that it remains unresolved whether excessive adiposity poses health risks in older individuals as it does in younger adults (3). Nevertheless, many older individuals enroll in weight loss programs or purchase weight loss products in the hope of restoring body weight to levels maintained earlier in life.

A third concern, and the focus of the present investigation, is based on the observation that senescence in humans is associated with loss of lean tissues, particularly fat-free body mass (FFM) and its main component, skeletal muscle (SM) (10, 12, 39). Elderly obese subjects may therefore have a reduced lean tissue mass at the commencement of a weight loss program. A concern is that weight loss treatment, unless accompanied by vigorous physical activity, may produce excessive lean tissue losses in the elderly, including FFM, SM, body cell mass (BCM), and other functionally important components such as bone mineral (33). Whether or not lean tissue losses with dieting are actually disproportionate in the elderly relative to those observed in younger subjects remains untested, although anabolic potential and protein metabolic processes in the elderly differ from those of younger subjects.

The aim of this prospective study was to test the hypothesis that obese postmenopausal women would demonstrate a disproportionate loss in FFM with weight loss produced by a hypocaloric diet. To test this hypothesis, we compared the effects of dieting on FFM in obese postmenopausal women in the present study with FFM changes reported after weight loss in young obese women. A secondary aim was to gain further
Subjects of young obese women reported in earlier studies. The changes in body composition and protein metabolism observed after a 16-wk weight loss treatment program were first examined. Body weight and body composition evaluations were then repeated after a 1- to 2-y follow-up period.

The hypothesis was tested by comparing changes in FFM observed in the postmenopausal women after the 16-wk weight loss phase and subsequent follow-up phase with those of young obese women reported in earlier studies.

Subjects

Obese postmenopausal women. Subjects were obese postmenopausal women with a body mass index (BMI) of 30≤BMI≤40 kg/m², and without a history of cardiovascular disease, diabetes mellitus, or high blood pressure. Inclusion criteria required that subjects be ≥5 yr since menopause, ambulatory, nonexercising, and nonsmoking and have maintained current body weight ±3 kg in the preceding 6 mo. Subjects on estrogen replacement therapy or those who were taking other medications that could potentially influence body composition or protein metabolism were excluded from the study. Recruitment occurred through advertisements in newspapers and flyers posted in the local community.

Reference group. The hypothesis was tested by comparing the observed reduction in FFM relative to body weight (i.e., ΔFFM/ΔBW) with that published in a literature compilation for young dieting obese women (1) at two time points, 16 wk and 2-y follow-up.

There have been many studies that explore ΔFFM/ΔBW with weight loss under different diet and exercise conditions in women. The most comprehensive and appropriate synthetic summary to date is the meta-analysis by Ballor and Poehlman (1), which included 40 published studies on the composition of diet-alone induced weight loss in women. Data on baseline and post-weight-loss values for BW, fat mass, and FFM in women were used to determine the relationship between ΔFFM and ΔBW in obese women. Study selection was based on the following criteria: 4 wk or more of diet-only induced weight loss intervention, and baseline and post-weight-loss values for BW, fat mass, and/or FFM. The group mean ΔFFM/ΔBW from the Ballor and Poehlman study (1) was selected for comparative purposes, because the selected papers for inclusion were reported in peer-reviewed journals, studies employed appropriate design and body composition methodology, conventional weight loss diets were prescribed, and subjects were similar in BMI and weight loss to those evaluated in the present study.

Experimental Procedures

During a screening visit to the Center, each experimental subject completed a medical examination that included blood tests, blood pressure, electrocardiogram, and a gallbladder ultrasound after an overnight fast. Only subjects without diagnosed medical conditions were enrolled in the weight loss study. Specifically, subjects with diabetes (fasting blood glucose >140 mg/dl) or high blood pressure (>140 mmHg systolic or >90 mmHg diastolic) were excluded from the study. The investigation was approved by the Institutional Review Board of St. Luke’s-Roosevelt Hospital, and all subjects gave written consent to participate.

Weight Control Program

Protocol. Enrolled subjects participated in 2 days of testing, at baseline and after the 16-wk weight loss phase. Subjects reported on the morning of day 1 in a fasted state (≥8 h) to the Human Body Composition Laboratory, where body composition studies were carried out in the morning and afternoon. Blood samples were taken and sent to a commercial laboratory (Quest Diagnostics, Teterboro, NJ) for analysis of serum electrolytes, liver function tests, lipids, and glucose.

Subjects were then hospitalized overnight, and the protein turnover study was completed on the following morning. Upon completion of this protocol, subjects were given a 1-wk supply of food, were counseled by a dietician, and discharged. Subjects returned on a weekly basis to be weighed, meet with the dietician, and receive the subsequent week’s food supply. This testing protocol was repeated at the end of the 16-wk weight loss period while subjects maintained their hypocaloric diet intake.

Subjects were periodically contacted after completion of the active weight loss phase. Beginning 16 mo after the final weight loss phase evaluation, subjects were asked to return for a follow-up body composition evaluation. Subjects reported to the body composition laboratory in a fasted state and completed selected body composition tests.

Diet. During the 2 days of baseline tests, subjects consumed a liquid diet (Sustacal: 15% protein, 45% carbohydrate, 40% fat) equivalent in energy to 1.25× resting energy expenditure (~1,800 kcal and 0.8 g protein/kg per day). During the 16-wk weight loss phase, subjects were counseled to eat a 1,200 kcal and ~0.7 g protein/kg per day diet. Prepackaged breakfasts, lunches, dinners, snacks, and multivitamins were provided to the subjects, who supplemented their diet with fresh fruits and vegetables. The recommended diet had 15–20, 50–60, and 25–30% of total calories as protein, carbohydrates, and fat, respectively.

Body Composition Analysis

The evaluated body composition compartments spanned three body composition levels, molecular, cellular, and tissue system (38). FFM and four of its major components, appendicular lean soft tissue (LST, a measure of SM) mass, total body water (TBW), BCM, and bone mineral mass were evaluated in each subject before and after the 16-wk weight loss phase. Total body SM mass was also evaluated in a subgroup of subjects.

Observed LST (i.e., SM, BCM, and TBW) changes were qualitatively examined for appropriateness relative to changes in FFM. FFM and closely related adipose tissue-free mass are approximately one-half of SM, one-third of BCM, and three-fourths of water (35). These explorations were aimed at searching for extreme deviations, such as a disproportionately large weight change accounted for largely by either water (i.e., fluid) or SM.

TBW was quantified by tritium dilution (28), and FFM, appendicular LST mass, and bone mineral mass were quantified by dual-energy X-ray absorptiometry (DEXA) (16). BCM was estimated using total body potassium (TBK) as derived by counting the natural γ-ray decay of 40K in a whole body counter (29). Total body SM mass was evaluated by whole body multislice magnetic resonance imaging (MRI) (15, 32). Subjects on whom MRI studies were performed were...
selected on the basis of scanner availability at baseline, and repeat studies were performed at the 16-wk evaluation.

The labeled leucine study was designed to evaluate protein dynamics (22) in relation to changes in protein-containing FFM.

Lipid compartment measurements included total body fat by DEXA in all subjects and total body and visceral adipose tissue by MRI (15, 32) in the same subgroup of subjects that completed SM studies.

The weight-maintenance body composition reevaluation included evaluation of selected lean components, including FFM, appendicular LST, and BCM.

Body weight and height were measured to the nearest 0.1 kg and 0.5 cm with a digital scale (Weight Tronix; New York, NY) and stadiometer (Holtain; Crosswell, Wales), respectively. Waist and hip circumferences were measured while the subjects were wearing only their undergarments and standing with their heels together. Minimum waist circumference was measured between the lower rib margin and iliac crest. Maximum hip circumference was measured below the iliac crest, with the subject viewed from the front.

DEXA. A slow-mode DEXA scan (DPX, software version 3.6; Lunar Radiation, Madison, WI) was used in all studies before and after weight loss. The DEXA system provided an estimate of total body fat, with FFM calculated as the difference between total body mass and total body fat. Appendicular LST mass was considered equivalent to the sum of LST (i.e., nonfat, nonbone mineral mass) in arms and legs (14, 16). Appendicular LST mass is highly correlated with MRI-derived total body SM mass in healthy adults (13). Appendicular SM represents ~70–80% of total body SM mass (13). The between-measurement technical errors for DEXA fat, FFM, and appendicular LST in the same subject are 3.4, 1.2, and 3.0%, respectively.

Tritium dilution volume. A blood sample was taken before and 3 h after subjects received 0.19 Bq of $^3$H$_2$O (32). Calculation of $^3$H$_2$O dilution volume was made after correction for urinary isotope losses. The within-subject technical error for $^3$H$_2$O dilution volume is 1.5% (28). TBW volume was estimated as the $^3$H$_2$O dilution space × 0.96, based on correction for nonaqueous hydrogen exchange (30). TBW, in kilograms, was calculated as the product of TBV volume and density at 37°C (0.994 g/cm$^3$).

Whole body $^{40}$K counting. The St. Luke’s 4 π-whole body counter was used to measure $^{40}$K (27). The $^{40}$K raw counts accumulated over 9 min were adjusted for body size on the basis of a $^{40}$K calibration equation (29). The within-subject coefficient of variation in our laboratory for $^{40}$K counting is 4% (29). TBK was calculated as TBK (mmol) = $^{40}$K (mmol)/0.000118. BCM was calculated from TBK as BCM (kg) = 0.00833 × TBK (mmol) (23).

MRI. Adipose tissue and SM mass were measured using whole body multislice MRI. Subjects were placed on the 1.5 T scanner (General Electric, 6X Horizon, Milwaukee, WI) platform with their arms extended above their heads. The protocol involved the acquisition of ~40 axial images of 10-mm thickness and at 40-mm intervals across the whole body (15, 32). The technical errors for repeated measurements of the same scan by the same observer of MRI-derived SM and adipose tissue volumes in our laboratory are 0.7 and 1.1%, respectively. MRI volume estimates were converted to mass with assumed stable densities for fat and lean tissues (15).

Protein Metabolism

Protein turnover, quantified from the stable isotope $^{[13C]}$leucine, was evaluated at baseline and after 16 wk of weight loss treatment. A detailed description of the $^{[13C]}$leucine protein turnover method is provided by Matthews et al. (22). After an overnight fast, the subject was prepared for a 4-h continuous infusion of the stable isotope L-$^{[13C]}$leucine (99% $^{13C}$; Mass Trace, Woburn, MA). Tracer was priming through an antecubital vein, and arterialized-venous blood samples were acquired from a contralateral hand vein. Priming doses of sodium $^{[13C]}$bicarbonate (1.6 μmol/kg FFM) and $[1-^{13C}]$leucine (4.5 μmol/kg FFM) were administered intravenously, followed by the continuous 4-h infusion of [1-13C]leucine at 4.5 μmol · kg FFM$^{-1}·$h$^{-1}$ by use of a calibrated syringe pump at a rate of 13.2 ml/h. Blood and breath samples were obtained before the start of the tracer infusion and at 15-min intervals between hours 3 and 4 of the infusion. Each subject’s oxygen consumption and carbon dioxide production were measured periodically by indirect calorimetry for 10-min intervals (41).

Measurements of expired air CO$_2$, for $^{13}$C enrichment by isotope ratio mass spectrometry, and fF plasma leucine and α-ketoisocaproate (KIC) $^{13}$C enrichments, by gas chromatography-mass spectroscopy, were performed using methods previously described (21, 22). The measured plasma $[1-^{13C}]$leucine and [1-13C]KIC enrichments, by gas chromatography-mass spectroscopy, were performed using methods previously described (21, 22).

The only source of leucine appearance in the postabsorptive state is from protein breakdown; hence, leucine appearance reflects the rate of leucine release from whole body proteolysis (B). The rate of leucine oxidation was also calculated at steady state from the rate of $^{13}$CO$_2$ excretion (21, 22). The rate of nonoxidative disposal of leucine at steady state reflects the uptake of leucine for protein synthesis (S) and is the difference between the rates of proteolysis and oxidation (C) in the postabsorptive state: S = B − C. Leucine kinetic data were calculated on a whole body basis (μmol of leucine/h) and normalized for metabolic mass as micromoles of leucine per kilogram FFM per hour.

Statistical Methods

The mean ΔFFM/ΔBW, as reported by Ballor and Poehlman (1), was taken as the null hypothesis value (i.e., that the subject’s body composition remodels appropriately with weight loss). The alternative hypothesis (i.e., disproportionate losses or gains of FFM) would be represented, according to this approach, by a smaller or larger observed change in FFM than that reported on the basis of ΔBW. The significance of differences between reported and observed changes in FFM was evaluated by paired t-tests. Two time points were considered, the 16-wk and long-term follow-up evaluations.

Descriptive changes in the body composition and protein metabolic measures over time were evaluated in the obese women for significance using paired t-tests. Statistical significance was set at $P < 0.05$.

Data were analyzed using Microsoft Excel Version 5.0 (Microsoft, Redmond, WA). Group subject data are expressed as means ± SD in the text and as means ± SE estimate in Figs. 1 and 2.

RESULTS

Subjects

Obese postmenopausal women. Sixteen women met the study entry criteria and began weight loss treat-
were calorically restricted for 11.1 weeks and on average lost 10.6 kg of weight. This group consisted of 14 women, 6 African-American, and 8 Caucasian, who ranged in age from 56 to 76 yr (mean, 63.4 ± 8.5 yr) at baseline. The group was moderately obese, with a mean baseline body weight and BMI of 90.1 ± 10.4 kg and 35.2 ± 4.3 kg/m², respectively. Six subjects completed the MRI portion of the protocol, and 10 subjects successfully completed protein turnover studies.

The percentage of fat for the group as a whole, as estimated by DEXA, was 47.6 ± 3.5%. Adipose tissue mass measured by MRI was similar in magnitude (39.6 ± 8.3 kg) and highly correlated with total fat mass (40.3 ± 7.8 kg) estimated by DEXA (r = 0.97, P = 0.002) (Table 2). Of total adipose tissue, 94.3% was subcutaneous and 5.1% was located within the visceral compartment.

Reference women. Forty studies involving a diet restriction-only approach to weight loss were reported in the meta-analysis of Ballor and Poehlman (1). Subjects were on average young [36.8 ± 1.2 (SE) yr] and obese (88.7 ± 1.9 kg; 42.2 ± 0.8 %fat) women who on average were calorically restricted for 11.1 ± 0.8 wk. The group on the whole lost 10.6 ± 0.9 kg of body mass, 2.5 ± 0.3 kg of which was FFM. The ratio ΔFFM/ΔBW for the group was 0.238 ± 0.022 kg.

### Weight Loss Treatment Effects

**Body weight and adiposity.** The 14 subjects successfully completed 16 wk of treatment, with a mean weight loss of 9.6 ± 3.0 kg (P = 0.0001) (Table 1) or 10.7% of initial BW. There were large between-individual differences in weight loss (Fig. 1), ranging from a minimum of 6.5% to a maximum of 16.7% of initial BW. None of the subjects experienced any adverse effects or clinically important changes over the 16 wk in blood pressure, serum electrolytes, and serum liver tests; serum lipid levels remained stable or improved in relation to cardiovascular risk.

A significant reduction in fat mass was observed in the group as a whole (7.4 ± 2.3 kg, 78% of weight loss, P < 0.0001). There was also a significant lowering of total body adipose tissue by 6.7 kg (78% of weight loss) in the six patients who completed MRI studies (Table 2). A strong correlation was present between the observed changes in total body adipose tissue and fat in this group (r = 0.92, P = 0.01). Of the 6.7 kg mean loss of adipose tissue, 6.2 kg or 93% was subcutaneous and 0.5 kg or 7% was visceral adipose tissue. On a relative

### Table 1. Characteristics for all subjects at baseline and after 16-wk weight loss

<table>
<thead>
<tr>
<th></th>
<th>Baseline</th>
<th>After Weight Loss</th>
<th>Change</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Body weight, kg</td>
<td>90.1 ± 10.4</td>
<td>80.5 ± 9.7</td>
<td>−9.6 ± 3.0</td>
<td>0.0001</td>
</tr>
<tr>
<td>Body mass index, kg/m²</td>
<td>35.2 ± 4.2</td>
<td>31.5 ± 3.8</td>
<td>−3.8 ± 1.3</td>
<td>0.0001</td>
</tr>
<tr>
<td>Circumference, cm</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Waist</td>
<td>98.8 ± 10.9</td>
<td>90.8 ± 10.9</td>
<td>−7.9 ± 3.9</td>
<td>0.0001</td>
</tr>
<tr>
<td>Hip</td>
<td>121.5 ± 9.1</td>
<td>112.9 ± 9.9</td>
<td>−8.5 ± 4.2</td>
<td>0.0001</td>
</tr>
<tr>
<td>Waist/Hip</td>
<td>0.81 ± 0.08</td>
<td>0.81 ± 0.1</td>
<td>−0.01 ± 0.02</td>
<td>NS</td>
</tr>
</tbody>
</table>

Baseline After Weight Loss Change P Value

<p>| | | | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
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<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Fat-free body mass</td>
<td>46.8 ± 4.4</td>
<td>44.8 ± 3.3</td>
<td>−2.1 ± 2.6</td>
<td>0.006</td>
</tr>
<tr>
<td>Appendicular LST</td>
<td>20.4 ± 2.0</td>
<td>19.1 ± 2.1</td>
<td>−1.2 ± 1.2</td>
<td>0.001</td>
</tr>
<tr>
<td>Total body water</td>
<td>35.8 ± 4.0</td>
<td>34.0 ± 2.3</td>
<td>−1.8 ± 3.4</td>
<td>0.03</td>
</tr>
<tr>
<td>Bone mineral</td>
<td>2.43 ± 0.31</td>
<td>2.44 ± 0.33</td>
<td>0.02 ± 0.10</td>
<td>0.28</td>
</tr>
<tr>
<td>Cellulol level</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Body cell mass</td>
<td>19.8 ± 2.4</td>
<td>19.2 ± 1.9</td>
<td>−0.6 ± 2.3</td>
<td>0.16</td>
</tr>
</tbody>
</table>

Data are means ± SD of 14 subjects. LST, lean soft tissue; NS, not significant.

### Table 2. Characteristics for 6 subjects by longitudinal MRI studies at baseline and after weight loss

<table>
<thead>
<tr>
<th></th>
<th>Baseline</th>
<th>After Weight Loss</th>
<th>Change</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Body weight, kg</td>
<td>86.2 ± 8.7</td>
<td>77.6 ± 9.2</td>
<td>−8.6 ± 2.9</td>
<td>0.0001</td>
</tr>
<tr>
<td>Body mass index, kg/m²</td>
<td>33.8 ± 2.9</td>
<td>30.5 ± 3.3</td>
<td>−3.3 ± 1.3</td>
<td>0.0001</td>
</tr>
<tr>
<td>Body composition, kg</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Molecular level</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fat-free mass</td>
<td>45.7 ± 2.9</td>
<td>44.2 ± 2.0</td>
<td>−1.5 ± 1.8</td>
<td>0.001</td>
</tr>
<tr>
<td>Fat</td>
<td>40.3 ± 7.8</td>
<td>33.5 ± 8.1</td>
<td>−6.8 ± 2.9</td>
<td>0.0001</td>
</tr>
<tr>
<td>Appendicular LST</td>
<td>20.0 ± 0.75</td>
<td>19.3 ± 0.93</td>
<td>−0.8 ± 0.94</td>
<td>0.98</td>
</tr>
<tr>
<td>Tissue-system level</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Adipose tissue</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>39.6 ± 8.3</td>
<td>32.9 ± 7.8</td>
<td>−6.7 ± 3.2</td>
<td>0.002</td>
</tr>
<tr>
<td>Subcutaneous</td>
<td>37.3 ± 7.8</td>
<td>31.2 ± 7.6</td>
<td>−6.2 ± 2.8</td>
<td>0.001</td>
</tr>
<tr>
<td>Visceral</td>
<td>2.0 ± 0.7</td>
<td>1.5 ± 0.6</td>
<td>−0.5 ± 0.7</td>
<td>0.06</td>
</tr>
<tr>
<td>Adipose tissue free mass</td>
<td>46.6 ± 2.4</td>
<td>44.7 ± 1.8</td>
<td>−1.9 ± 1.4</td>
<td>0.0001</td>
</tr>
<tr>
<td>Skeletal muscle</td>
<td>21.8 ± 0.5</td>
<td>20.1 ± 0.0</td>
<td>−1.5 ± 0.8</td>
<td>0.002</td>
</tr>
</tbody>
</table>

Data are means ± SD.
basis, the reductions in subcutaneous and visceral adipose tissue were 16.6 and 25%, respectively. Both waist and hip circumferences were significantly reduced with weight loss, although the change in waist-to-hip ratio was not statistically significant.

**Lean tissue.** Of the molecular body composition level components, FFM decreased significantly in the 14 subjects by 2.1 \(\pm\) 2.6 kg \((P = 0.006)\) or 19% of weight loss over the 16-wk study interval (Table 1). The reported relative change with weight loss treatment for FFM was 2.3 \(\pm\) 0.7 kg on the basis of the Ballor-Poehlman ratio of 0.238. The reported and observed \(\Delta\)FFM values were not significantly different \((P = 0.19)\) and are presented in Fig. 2.

Appendicular LST decreased by 1.2 \(\pm\) 1.2 kg \((P < 0.001)\) and accounted for 57% of the FFM loss. TBW decreased by 1.8 \(\pm\) 3.4 kg, \(P = 0.03\), and accounted for 86% of \(\Delta\)FFM. The change in bone mineral mass \((0.02 \pm 0.10\ kg)\) was not statistically significant.

At the cellular body composition level (Table 1), the decrease in BCM \((0.6 \pm 2.3\ kg, \ P = 0.16,\) or 26% of the \(\Delta\)FFM) was not statistically significant.

The tissue-system level component of total body SM mass declined in the six subjects with MRI studies by 1.5 \(\pm\) 0.8 kg \((P = 0.002)\), or 6.9% below the baseline level (Table 2). SM mass accounted for 78.0 and 17.8% of adipose tissue-free mass and BW losses, respectively.

**Protein metabolism.** The results of \([^{13}\text{C}]\)leucine kinetic studies are presented in Table 3. No significant changes in the rates of leucine flux, oxidation, or synthesis were observed at the end of the 16-wk weight loss treatment phase.

**Long-Term Follow-Up**

Eleven women returned for follow-up evaluation. The mean follow-up duration was 23.7 \(\pm\) 5.7 mo with a range of 16–32 mo.

The 11 reevaluated women (Table 4) had a mean body weight at follow-up of 83.0 \(\pm\) 10.6 kg, which represents a loss of 3.0 \(\pm\) 4.9 kg, or a reduction of 3.5% below their initial body weight \((P = 0.033)\). Of the 11 women, 3 (27%) maintained a weight loss \(\geq\)5% below their baseline level, and 8 (73%) were at weights that ranged between 97 and 104% of their respective baseline levels. None of the women reported intervening weight loss treatment. The group’s mean weight increased by 5.4 \(\pm\) 4.3 kg between the second and third follow-up visits.

Fat mass in the reevaluated group was 2.4 \(\pm\) 4.2 kg \((6.0\%)\) below baseline values \((P = 0.043)\) and represented 78% of weight loss.

FFM, appendicular LST mass, and BCM were non-significantly changed from their baseline levels by 0.7 \(\pm\) 1.6 kg \((P = 0.09), 0.3 \pm 0.8\ kg \((P = 0.12), and 0.02 \pm 2.1\ kg \((P = 0.49),\) respectively (Table 4). There was a nonsignificant change in bone mineral mass of
Table 3. Protein kinetic studies at baseline and after weight loss

<table>
<thead>
<tr>
<th>Leucine Kinetic Measure</th>
<th>Baseline</th>
<th>After Weight Loss</th>
<th>Change</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flux</td>
<td>89.4 ± 15.1</td>
<td>86.3 ± 11.7</td>
<td>-3.1 ± 14.1</td>
<td>0.26</td>
</tr>
<tr>
<td>Oxidation</td>
<td>8.5 ± 2.3</td>
<td>8.1 ± 1.5</td>
<td>-0.4 ± 1.6</td>
<td>0.23</td>
</tr>
<tr>
<td>Synthesis</td>
<td>80.9 ± 13.1</td>
<td>78.2 ± 10.6</td>
<td>-2.7 ± 13.9</td>
<td>0.28</td>
</tr>
</tbody>
</table>

Data are means ± SD of 10 subjects expressed in μmol · kg FFM⁻¹ · h⁻¹.

0.043 ± 0.145 kg. The loss of FFM (0.7 ± 1.6 kg) was not significantly different from that reported (0.7 ± 1.1) (P = 0.41).

DISCUSSION

Composition of Weight Loss

The principal finding of this study was that prescribed weight loss in obese postmenopausal women consisted of a small and appropriate amount of FFM relative to that in young dieting women. This observation, based on a small but thoroughly evaluated cohort, fails to support any adverse effect of dieting on LSTs in postmenopausal women. Our study also provides two additional observations in support of this conclusion on the basis of FFM. First, we quantitatively explored losses of other related components, such as SM, appendicular LST, BCM, and TBW. Although all of these components were lost to varying degrees with weight loss, none changed in a manner contradictory to known body composition relationships. Second, we did not observe any relative changes in leucine metabolism suggestive of undue catabolic weight loss effects. This observation supports the minimal LST effects of dieting in the postmenopausal women whose relatively small losses of protein-containing tissues, such as SM mass, fail to support a large weight loss-induced period of negative nitrogen balance. Thus, taken collectively, weight loss with a hypocaloric diet in our postmenopausal obese women was not accompanied by unduly large or disproportionate losses of functionally important body composition compartments (40).

When the mean 2-yr follow-up results in these women are considered, there likely exists the additional small aging-related lean tissue loss anticipated from previous cross-sectional (5, 14, 25, 26) and longitudinal (10) aging studies. The observed FFM reduction over 2 yr in these older women undoubtedly includes an aging-related portion in addition to that accounted for solely by body mass change. Although these two separate portions of ΔFFM cannot be identified in the present study, the actual ΔFFM was relatively modest (0.7 kg) and equivalent to that reported for weight loss alone.

There was an absence of significant bone mineral change over 16 wk of weight loss treatment or 2 yr of follow-up, even though there were weight and age changes in a direction associated with gradual depletion of bone mass (31). None of our subjects was actively engaged in physical activity programs or was taking estrogen replacement therapy, measures that might prevent loss of bone mineral (18, 24). The 16-wk post-weight-loss evaluation may have been too short a period, and a sample of 14 women may not have been large enough to detect the expected small changes in bone mineral mass (31).

The phenomenon of separate changes in bone mineral and other LSTs requires a careful consideration of our developed FFM and other prediction models. For example, the fraction of FFM as water is usually reported as ranging between 0.70 and 0.75. However, the FFM hydration of ~0.70 assumes that the fraction of FFM as bone mineral is also relatively stable (37). On the other hand, the water fraction of most fat-free soft tissues approximates ~0.80 (17, 35). This may partly explain why our observed change in water relative to FFM was higher than expected (0.86). Subtle effects, such as those noted with a lack of bone mineral loss, may cause small deviations from the change expected.

An intentional aspect of our protocol was to evaluate the effects on body composition of a nutritionally adequate hypocaloric diet. Physical activity as part of treatment was discouraged. To what extent exercise regimens might reduce lean tissue losses remains unclear (34). A small positive increment in the fraction of

Table 4. Baseline, post-16-wk weight loss, and follow-up results

<table>
<thead>
<tr>
<th></th>
<th>Baseline</th>
<th>Post-16-Wk Weight Loss</th>
<th>Change</th>
<th>Post-24-Mo Weight Loss</th>
<th>Change</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Body weight, kg</td>
<td>86.0 ± 8.1</td>
<td>77.4 ± 8.9</td>
<td>-8.6 ± 2.8</td>
<td>83.0 ± 10.6</td>
<td>-3.0 ± 4.9</td>
<td>0.033</td>
</tr>
<tr>
<td>Body mass index, kg/m²</td>
<td>33.6 ± 2.7</td>
<td>30.2 ± 3.0</td>
<td>-3.4 ± 2.0</td>
<td>32.3 ± 3.6</td>
<td>-1.4 ± 2.1</td>
<td>0.028</td>
</tr>
<tr>
<td>Circumference, cm</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Waist</td>
<td>97.2 ± 8.7</td>
<td>89.1 ± 9.8</td>
<td>-8.1 ± 3.7</td>
<td>96.7 ± 11.7</td>
<td>-0.5 ± 7.0</td>
<td>0.41</td>
</tr>
<tr>
<td>Hip</td>
<td>118.2 ± 6.2</td>
<td>109.9 ± 8.8</td>
<td>-8.3 ± 4.5</td>
<td>116.8 ± 7.5</td>
<td>-1.4 ± 4.1</td>
<td>0.15</td>
</tr>
<tr>
<td>Waist/Hip</td>
<td>0.82 ± 0.07</td>
<td>0.81 ± 0.08</td>
<td>-0.01 ± 0.02</td>
<td>0.83 ± 0.08</td>
<td>0.004 ± 0.04</td>
<td>0.39</td>
</tr>
<tr>
<td>Body composition, kg</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Molecular level</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fat mass</td>
<td>40.3 ± 6.0</td>
<td>33.2 ± 6.5</td>
<td>-7.1 ± 2.4</td>
<td>37.9 ± 8.4</td>
<td>-2.4 ± 4.2</td>
<td>0.043</td>
</tr>
<tr>
<td>Fat-free body mass</td>
<td>45.7 ± 5.0</td>
<td>44.3 ± 3.1</td>
<td>-1.5 ± 1.3</td>
<td>45.1 ± 3.4</td>
<td>-0.7 ± 1.6</td>
<td>0.09</td>
</tr>
<tr>
<td>Appendicular LST</td>
<td>19.8 ± 1.5</td>
<td>18.8 ± 1.8</td>
<td>-1.0 ± 0.6</td>
<td>19.4 ± 2.0</td>
<td>-0.3 ± 0.8</td>
<td>0.12</td>
</tr>
<tr>
<td>Bone mineral</td>
<td>2.44 ± 0.35</td>
<td>2.45 ± 0.38</td>
<td>0.004 ± 0.11</td>
<td>2.49 ± 0.40</td>
<td>0.04 ± 0.15</td>
<td>0.12</td>
</tr>
<tr>
<td>Cellular level</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Body cell mass</td>
<td>19.5 ± 2.2</td>
<td>18.7 ± 1.3</td>
<td>-0.8 ± 2.2</td>
<td>19.5 ± 1.9</td>
<td>0.02 ± 2.1</td>
<td>0.49</td>
</tr>
</tbody>
</table>

Data are means ± SD of 11 subjects.
weight loss as fat is recognized with weight loss treatment combined with structured exercise programs (1, 12). Moreover, strength training of elderly women results in small increases in SM mass and large relative improvements in strength (9, 24). The addition of an aerobic exercise program to a hypocaloric diet in obese older men failed to attenuate the loss in FFM (6, 7).

In addition to monitoring component changes over time, our analysis included baseline and 16-wk follow-up assessment of leucine kinetics. No significant changes at the 16th wk of dieting were detected in fasting leucine flux, synthesis, or oxidation, an observation consistent with the relatively small FFM and other nonosseous component (i.e., protein) losses. Our sample size was small, and thus our power to detect subtle changes in protein metabolism with weight loss was limited. Future studies with larger numbers of subjects and age distributions are needed to extend the present study observations.

The nonlean tissue components of body mass change with dieting included substantial losses of both subcutaneous (−16.6%) and visceral adipose tissue (−25%). Adipose tissue and closely related fat mass accounted for 79 and 80% of the observed weight loss at 16 wk of treatment and 2 yr of follow-up, respectively. The diet-induced weight loss of −8.2 kg corresponded to a 25% reduction in visceral adipose tissue in this sample. Given that a strong association has been reported in a similarly aged cohort between abdominal adiposity and risk of stroke (11) in terms of body composition, the goal of losing body fat, particularly in the visceral compartment, was accomplished in these elderly women.

Weight Loss Program

Our subjects lost ~10% of their baseline BW after 16 wk of treatment and, of those reevaluated at 2 yr of follow-up (11/14 subjects), 35% of the mean weight loss was maintained. This level of weight maintenance is within the range reported for other 1- and 2-yr diet-behavioral studies (2, 19). Our findings of primarily loss of body fat (i.e., −80% of weight loss) with dieting in elderly women provides strong support for advancing obesity studies in this population from an exploratory to an intensive analysis level.

Prescribing weight loss treatment for older individuals raises an important and unresolved question of efficacy. A recent study reported increased associations between higher body weights/adiposity and lower levels of physical functioning (e.g., climbing stairs and moderate activities), lower feelings of well being, and a greater burden of pain among middle-aged and older women (4). However, a growing literature reports a failure to clearly link higher levels of BMI in older individuals with greater morbidity and mortality risk (3, 36). Thus, it remains unclear whether older subjects, even if successful weight losers and maintainers, would experience any clinical or health benefits from their efforts.

Conclusion

The focus of this study was to quantify body composition effects in an elderly cohort of obese women after ingestion of a hypocaloric diet. The present investigation provides a comprehensive analysis of weight loss composition observed in nonexercising obese dieting elderly women who were subsequently followed for a mean of 2 yr. Our findings suggest that a small and appropriate fraction of weight loss consists of soft lean tissues including FFM and SM, whereas the majority of observed weight loss is fat. Elderly women who diet, even in the absence of vigorous exercise training, experience body composition changes that are generally recognized as beneficial. Important functional and clinical issues await resolution on the basis of larger, possibly longer, and appropriately controlled prospective studies.

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REFERENCES