Longitudinal changes in body composition in older men and women: role of body weight change and physical activity

Virginia A Hughes, Walter R Frontera, Ronenn Roubenoff, William J Evans, and Maria A Fiatarone Singh

ABSTRACT
Background: Estimates of body-composition change in older adults are mostly derived from cross-sectional data.
Objective: We examined the natural longitudinal patterns of change in fat-free mass (FFM) and fat mass (FM) in older adults and explored the effect of physical activity, weight change, and age on these changes.
Design: The body composition measured by hydrodensitometry and the level of sports and recreational activity (SRA) of 53 men and 78 women with a mean (±SD) initial age of 60.7 ± 7.8 y were examined on 2 occasions separated by a mean (±SD) time of 9.4 ± 1.4 y.
Results: FFM decreased in men (2.0% per decade) but not in women, whereas FM increased similarly in both sexes (7.5% per decade). Levels of SRA decreased more in men than in women over the follow-up period. Baseline age and level of SRA were inversely and independently associated with changes in FM in women only. Neither age nor level of SRA was associated with changes in FFM in men or women. Weight-stable subjects lost FFM. FFM accounted for 19% of body weight in those who gained weight, even in the presence of decreased levels of SRA. Loss of FFM (33% of body weight) was pronounced in those who lost weight, despite median SRA levels > 4184 kJ/wk.
Conclusions: On average, FM increased; however, the increase in women was attenuated with advancing age. The decrease in FFM over the follow-up period was small and masked the wide interindividual variation that was dependent on the magnitude of weight change. The contribution of weight stability, modest weight gains, or lifestyle changes that include regular resistance exercise in attenuating lean-tissue loss with age should be explored. Am J Clin Nutr 2002;76:473–81.

KEY WORDS Aging, weight change, sarcopenia, fat mass, fat-free mass, sports, recreational activity

INTRODUCTION
Sarcopenia and increasing body fat are both hallmarks of the aging process (1). However, most of our knowledge regarding age-related patterns of change is derived from cross-sectional studies, few of which include elderly subjects. Lean mass peaks in the third to fourth decade of life, followed by a steady decline with advancing age (2, 3). This decline in muscle mass is associated with weakness, disability, and morbidity (4–6). In contrast, body weight increases until ≈60 y of age; thereafter, ≥60% of the population experiences a decrease in weight (7–11). Therefore, an accumulation of fat mass (FM) occurs during midlife. Obesity is a major public health problem in the general population, although weight loss in the elderly has a more detrimental effect on health or physical function than does an equivalent amount of weight gain (12–15). Understanding the pattern of weight and body-composition change in the elderly and the factors that influence it will further our potential to develop appropriately timed and effective strategies to optimize body composition for health and function in the latter years of life.

Longitudinal studies of body composition have generally agreed with the cross-sectional observations of the pattern of weight gain. Weight gain, characterized by a greater percentage of fat than lean tissue, has been reported in men and women < 60 y of age (16–21). Longitudinal studies of body composition in men > 60 y of age are consistent in their finding of weight loss, and the studies generally found a greater loss of fat than lean tissue (22–26). There are fewer longitudinal observations in older women, and a consistent pattern has not yet been described (18, 25, 27, 28).

Because leisure time physical activity can be a significant proportion of total energy expenditure, it is important in the regulation of body weight. Prospective studies have shown the protective effects of physical activity in preventing weight gain in middle-aged persons (10, 29, 30). There is less evidence that sarcopenia can be attenuated by maintaining moderate or high levels of physical activity in older individuals. Furthermore, exercise in attenuating lean-tissue loss with age should be explored. Am J Clin Nutr 2002;76:473–81.

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activity. To our knowledge, there are no reports that assessed both physical activity patterns and body-composition changes over an extended period in a diverse older adult population.

Therefore, the purpose of the present study was to document the body-composition changes over 5–12 y in a cohort of men and women aged 46–80 y and to explore the effect of trends in leisure time physical activity, body weight, and age on these changes. We hypothesized that 1) on average, men and women would lose lean mass and gain FM over the follow-up period; 2) there would be no difference in the composition of weight change over time between the sexes; 3) weight gain would protect against lean-tissue loss; and 4) higher levels of physical activity would attenuate losses of lean tissue and gains of adipose tissue over time.

SUBJECTS AND METHODS

Subjects

The subjects in this study were recruited from 1985 to 1988 for studies at the Jean Mayer USDA Human Nutrition Research Center on Aging at Tufts University. The subjects were recruited as previously described (6). Of the 223 original volunteers, 148 (66%) returned for testing. To control for possible seasonal influences on body composition (31), baseline and follow-up testing were done at approximately the same time of year (for 85% of the subjects, the time of year for follow-up testing was within 6 wk of that of baseline testing).

A medical history, physical examination, standard analysis of blood and urine constituents, and an electrocardiogram were performed at baseline and follow-up. Subjects were excluded at baseline if they had a medical condition that would influence neuro-muscular function, if they were taking medications that could alter body composition or muscle function, if they had joint arthroplasty, if they were living in an institutional setting, or if cognitive impairment prevented informed consent. Subjects were not excluded on the basis of body mass index or physical activity habits, and all subjects agreed to perform the underwater weighing test. The only criteria for excluding subjects at follow-up were cognitive impairment that would prevent informed consent or terminal illness. The study procedures were approved by the Human Investigation Review Committee of the Tufts-New England Medical Center, and written, informed consent was obtained at both time points.

Body composition

The same hydrodensitometry system was used to measure underwater weight at baseline and follow-up. All tests were performed after subjects had fasted overnight and voided. Body weight (out of water) and height were measured to the nearest 0.1 kg and 0.25 cm, respectively. While subjects were coached to expire maximally, their underwater weight to the nearest 10 g was measured with the use of a Sauter scale (model K120; Mettler Instruments, Highstown, NJ). The underwater weight of each subject was measured 5–10 consecutive times. Underwater weights for each trial were chosen by a computer algorithm that averaged the 5 highest weights after excluding outliers by using a 3-point running median. Analog data from the scale were converted with the use of a multimeter (model 34401A; Hewlett Packard, Palo Alto, CA). The average of 3 trials with the highest underwater weights and lowest between-trial variability were chosen for further data analysis. Densities of fat and fat-free tissues of 0.9 and 1.1, respectively, were used to calculate FM and FFM from the total body density obtained from the underwater weight measurements after correction for estimated residual volume (32). Four subjects, whose underwater weight was measured twice within 14 d, showed a CV for FFM of 1.4%.

Physical activity

Energy expenditure in sports and recreational activity (SRA) during the previous year was estimated by using a questionnaire developed for the Harvard Alumni Health Study (33). Subjects were queried in an open-ended manner at baseline and follow-up, and one hundred six subjects completed the questionnaire at both time points. The total energy expended per year for each activity was calculated by using the total number of minutes, body weight, and MET (metabolic equivalent unit) levels from standard tables (34). The CV for repeated assessments 2 wk apart was 2%. Physical inactivity was defined as expending < 2092 kJ/wk (500 kcal/wk) over the past year. This level was chosen because of its association with an increased prevalence of chronic disease (35).

Health history

One physician classified medical conditions and medication use by reviewing information obtained during the physical exams and from health-history questionnaires. Regular medication use was defined as ≥ 1 time/wk. Postmenopausal status was defined as a cessation of menses for ≥ 1 y.

Data analysis

At follow-up, subjects who were taking medications that could influence body composition (n = 6) or who had had a knee or hip arthroplasty (n = 6) were excluded from the analysis because either condition could preclude a meaningful interpretation of body-weight change or invalidate the FFM-density assumption used in the underwater-weighing algorithms. An additional 5 subjects refused to participate in or were unable to participate in the underwater-weighing procedure at follow-up. Therefore, 17 subjects were excluded from the analysis.

Data were visually inspected for normality before analyses. The data are reported as means ± SDs or as medians and interquartile ranges for nonnormally distributed data. Because of their nonnormal distribution, values for exercise energy expenditure (kJ/wk) at baseline and follow-up were log-transformed before use in the analysis. The characteristics of the subjects who did and did not return for baseline testing were compared by using analysis of variance with adjustment for sex. The McNemar test was used to analyze the change in the percentage of subjects rated as being sedentary over time. Multiple regression analysis was used to assess the effects of age, physical activity, and health status on body composition at the baseline and follow-up assessments. Changes in body composition over the follow-up period were assessed by using repeated-measures analysis of covariance with sex and follow-up time as cofactors. Differences between the sexes in physical activity at baseline and follow-up were compared by using the Kruskal-Wallis test. Significant predictors of changes in body weight and body composition were calculated by using regression analysis with adjustment for follow-up period and sex. Weight-change was defined as a gain or loss > 5% because of the clinical relevance of that amount of weight change (14). Subjects who did not have that amount of weight change were classified as weight stable. Weight-change groups were compared by using analysis of covariance with adjustment for initial age, follow-up period, and sex. Post hoc tests were performed by using Tukey’s
The subjects who returned for follow-up testing reported taking fewer medications and had fewer medical conditions at baseline than did the subjects who did not return for testing [0.3 ± 0.6 compared with 0.6 ± 0.8 (P < 0.007) and 1.5 ± 0.7 compared with 1.8 ± 0.8 (P < 0.014), respectively]. Eighteen women took estrogen replacement medications at follow-up only (n = 18) or both at baseline and follow-up (n = 3).

RESULTS

Subject characteristics

At baseline and follow-up, all subjects were community dwelling. Ninety-seven percent of the subjects were white. The characteristics of the subjects (n = 131) at baseline and follow-up are shown in Table 1. The mean (±SD) follow-up period was 9.4 ± 1.4 y (range: 4.9–12.6 y). The subjects who were tested at follow-up were similar in initial age, body mass index, percentage of body fat, FFM, and physical activity levels to those who did not return for testing. The subjects who returned for follow-up testing reported taking significantly higher (16.9 ± 0.9 kg; P < 0.0001) in the men than did the women and increased significantly with age in both the men and the women (0.16 ± 0.06 kg/y; P < 0.01). Similar associations were observed for FFM at follow-up only, ie, it was significantly higher (16.1 ± 0.9 kg; P < 0.0001) in the men compared to baseline and follow-up are shown in Table 2. After the data were fitted to a multiple regression model, mean (±SD) FFM at baseline was significantly higher (16.9 ± 0.9 kg; P < 0.0001) in the men than in the women and decreased significantly with age in both the men and the women (0.16 ± 0.06 kg/y; P < 0.01). Similar associations were observed for FFM at follow-up only, ie, it was significantly higher (16.1 ± 0.9 kg; P < 0.0001) in the men compared to baseline.

TABLE 1

Characteristics of subjects at baseline and follow-up

<table>
<thead>
<tr>
<th></th>
<th>Men (n = 53)</th>
<th>Women (n = 78)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Age (y)</strong></td>
<td>61.1 ± 8.11</td>
<td>60.0 ± 7.41</td>
</tr>
<tr>
<td><strong>BMI (kg/m²)</strong></td>
<td>25.2 ± 2.8</td>
<td>25.3 ± 3.4</td>
</tr>
<tr>
<td><strong>Physical inactivity (%)</strong></td>
<td>21</td>
<td>30</td>
</tr>
<tr>
<td><strong>Medication use (n)</strong></td>
<td>0.2 ± 0.5</td>
<td>0.4 ± 0.7</td>
</tr>
<tr>
<td><strong>Medical conditions (n)</strong></td>
<td>1.4 ± 0.7</td>
<td>1.5 ± 0.8</td>
</tr>
<tr>
<td><strong>Heart disease (%)</strong></td>
<td>9</td>
<td>1</td>
</tr>
<tr>
<td><strong>Hypertension (%)</strong></td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td><strong>Osteoarthritis (%)</strong></td>
<td>26</td>
<td>12</td>
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<tr>
<td><strong>Diabetes (%)</strong></td>
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<td>1</td>
</tr>
<tr>
<td><strong>Cancer (%)</strong></td>
<td>6</td>
<td>1</td>
</tr>
<tr>
<td><strong>Stroke (%)</strong></td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

TABLE 2

Changes in body composition and physical activity in men (n = 53) and women (n = 78)

<table>
<thead>
<tr>
<th></th>
<th>Baseline</th>
<th>Follow-up</th>
<th>Change</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Weight (kg)</strong></td>
<td>77.6 ± 9.5</td>
<td>77.8 ± 11.6</td>
<td>0.1 ± 4.4</td>
</tr>
<tr>
<td><strong>Fat-free mass (kg)</strong></td>
<td>41.9 ± 4.4</td>
<td>41.8 ± 4.3</td>
<td>−0.1 ± 2.1</td>
</tr>
<tr>
<td><strong>Fat mass (kg)</strong></td>
<td>18.8 ± 6.4</td>
<td>20.1 ± 7.8</td>
<td>1.2 ± 3.5</td>
</tr>
<tr>
<td><strong>Fat mass (% of body weight)</strong></td>
<td>33.9 ± 7.1</td>
<td>35.1 ± 7.4</td>
<td>1.2 ± 4.7</td>
</tr>
<tr>
<td><strong>Physical activity (kJ/wk)</strong></td>
<td>6527 (2992, 11954)</td>
<td>4628 (1130, 7644)</td>
<td>−2171 (−7815, 1280)</td>
</tr>
</tbody>
</table>

/SD.

< 0.01.

< 0.014).

< 0.0001.

< 0.007.

< 0.01.)

< 0.0001.)

< 0.0001.)

< 0.01.)

< 0.0001.)

< 0.0001.)

< 0.0001.)
than in the women and decreased significantly with age (0.15 ± 0.06 kg/y; P < 0.02). Neither energy expenditure in SRA nor health status (represented as the total number of medical conditions) added any significant predictive ability to these equations. Multiple regression equations also showed that the percentage of fat was significantly higher (9.85 ± 1.10%; P < 0.0001) in the women than in the men and increased significantly with age (0.34 ± 0.07% per year; P < 0.0001). As for FFM, neither energy expenditure in SRA nor health status added any significant predictive capabilities. At follow-up, the difference between the sexes in the relation between the percentage of fat and age was nearly significant (P < 0.06 for interaction). The percentage of fat increased significantly with age in the men (0.30 ± 0.11% per year; P < 0.01) but not in the women. Neither physical activity estimates nor the number of chronic medical conditions significantly improved predictive abilities for the percentage of fat in the men, nor were they significantly related to the percentage of fat in the women at follow-up. At baseline or follow-up, energy expenditure in SRA was not significantly associated with age in the men or the women.

**Longitudinal changes in body composition**

Mean body weight did not change significantly over the follow-up period, although absolute changes ranged from −9.9 to 19.4 kg. Mean FFM decreased in the men but not in the women (P < 0.01). This change in FFM represented a 2.0% decrease per decade in the men. In contrast, mean FM and percentage of body fat increased to the same extent in both sexes (P < 0.01). This change in FM represented a 7.5% increase per decade. Absolute changes in FM and FFM ranged from −6.4 to 5.3 kg and −7.0 to 15.8 kg, respectively.

**Physical activity**

The men reported significantly higher energy expenditure levels in SRA than did the women at baseline (P < 0.04) but not at follow-up because of a greater decrease in energy expenditure over the follow-up period in the men than in the women (P < 0.01 for time-by-sex interaction) (Table 2). The change in energy expenditure in physical activity was not related to baseline age in the men or the women.

**Predictors of change in body weight and body composition**

Multiple regression equations showed that weight change was independently and inversely predicted by baseline age (−0.14 ± 0.06 kg/y; P < 0.02) and by the log of weekly baseline physical activity (−0.49 ± 0.23 kg/log SRA; P < 0.05). Together they explained 12% of the variability in weight change over the follow-up period after adjustment for sex and follow-up period. Weight change was not significantly associated with baseline health status, as indicated by medication use or medical conditions reported, or with the change in these variables. Nor was the initial level of body fatness (percentage of body weight) associated with the magnitude or direction of weight change. Neither physical activity assessed at follow-up nor the change in physical activity was significantly related to weight change.

The relation between the change in FFM and the change in weight is shown in Figure 1. The equation describing the relation between changes in FFM and weight indicates that with weight maintenance of body weight) associated with the magnitude or direction of variables. Nor was the initial level of body fatness (percentage of body weight) associated with the magnitude or direction of weight change. Neither physical activity assessed at follow-up nor the change in physical activity was significantly related to weight change.

![Figure 1](https://example.com/figure1.png)

**FIGURE 1.** Association between changes in body weight (Δwt) and changes in fat-free mass (ΔFFM) in older men (●, n = 53) and women (○, n = 78). The dashed lines indicate ΔFFM or Δwt = 0. The regression lines are as follows: ΔFFM = 0.32 (Δwt) − 1.16, r² = 0.38, SEE = 1.76 kg, P < 0.001 (men); ΔFFM = 0.22 (Δwt) − 0.38, r² = 0.27, SEE = 1.86 kg, P < 0.001 (women).
inversely associated with age in the women only (Figure 2; $P < 0.001$). For the women, significant and independent predictors of the change in FM in a multiple regression model were baseline age ($-0.10 \pm 0.03$ kg/y; $P < 0.0001$), change in body weight ($0.70 \pm 0.04$ kg/Δkg body wt; $P < 0.0001$), and log of baseline weekly physical activity ($-0.29 \pm 0.12$ kg/log SRA; $P < 0.02$), and together these predictors explained 88% of the change in FM after adjustment for follow-up period. The log of follow-up weekly physical activity was also a significant and independent predictor of the change in FM with age and of the change in body weight. In the men, body weight and the number of reported medical conditions at baseline were significant independent predictors of the change in FM [0.67 ± 0.06 kg/Δkg body wt ($P < 0.0001$) and $-0.91 \pm 0.45$ kg per medical condition ($P < 0.05$), respectively] and explained 79% of the variance. The change in FM was not associated with a change in physical activity in the men or the women.

Menstrual status or hormone replacement therapy and changes in body composition

Nine women were premenopausal at the baseline assessment. All women were postmenopausal at the follow-up assessment. The body-composition variables of the 9 women who were premenopausal at baseline (49.2 ± 2.7 y) were compared with those of the 10 women < 55 y of age (52.3 ± 2.2 y) who were postmenopausal at baseline because it was not possible to pair-match these subjects by age. At baseline the premenopausal women had significantly lower body weight, significantly less FM, and a significantly lower percentage of body fat than did the postmenopausal women (58.1 ± 6.0 compared with 64.7 ± 6.6 kg, 15.1 ± 4.7 compared with 21.4 ± 6.4 kg, and 25.7 ± 6.8% compared with 32.7 ± 6.7%, respectively; $P < 0.05$ for all). However, the premenopausal and postmenopausal women did not differ significantly in height (163.6 ± 5.4 compared with 166.3 ± 6.2 cm, respectively) or FFM (43.0 ± 4.4 compared with 43.3 ± 3.0 kg, respectively). At the follow-up assessment, the women who were premenopausal at baseline had gained more weight and FM over a similar follow-up period than had the women who were postmenopausal at baseline (Figure 3). As a result, the previously premenopausal women reached the same weight and percentage of body fat by the time of the follow-up assessment as those of the women who were postmenopausal at baseline. Fat-free mass and energy expenditure in SRA did not change significantly in either group.

FIGURE 2. Change in fat mass ($\Delta$FM) as a function of baseline age. There was no significant association in the men ($\bullet$, $n = 53$). ○, women who were premenopausal at baseline and postmenopausal at follow-up ($n = 9$); ●, women who were postmenopausal at baseline and follow-up. The regression line for the women ($n = 78$) is as follows: $\Delta$FM = $-0.19$ (baseline age) + 13.00, $r^2 = 0.11$, SEE = 4.07 kg, $P < 0.001$. The horizontal dashed lines indicate that $\Delta$FM = 0.

FIGURE 3. Mean (± SEM) changes in fat mass (■) and fat-free mass (●) by baseline menstrual status in 9 women who were premenopausal at baseline and in 10 women who were postmenopausal and <55 y of age at baseline. The horizontal lines indicate baseline weights. *$P < 0.01$. 

FIGURE 2. Change in fat mass ($\Delta$FM) as a function of baseline age. There was no significant association in the men ($\bullet$, $n = 53$). ○, women who were premenopausal at baseline and postmenopausal at follow-up ($n = 9$); ●, women who were postmenopausal at baseline and follow-up. The regression line for the women ($n = 78$) is as follows: $\Delta$FM = $-0.19$ (baseline age) + 13.00, $r^2 = 0.11$, SEE = 4.07 kg, $P < 0.001$. The horizontal dashed lines indicate that $\Delta$FM = 0.
Composition of weight changes in subjects who gained or lost weight

A comparison of the body-composition changes of the subjects who gained or lost > 5% of body weight with those of the subjects who were weight stable is shown in Figure 4, top. In the weight-loss group, 44% and 26% of the weight loss was attributed to changes in FFM in the men and the women, respectively (mean for all subjects: 33%). The subjects who were weight stable had a significant loss of FFM and a significant fat gain (P < 0.05). Among those subjects who gained weight, changes in FFM accounted for 10% and 23% of the weight gain in the men and the women, respectively (mean for all subjects: 19%).

Energy expenditure in SRA (Figure 4, bottom) varied across weight-change groups. The men and the women who gained weight over the follow-up period had significantly lower levels of energy expenditure at baseline and follow-up than did those who were weight stable or lost weight (P < 0.05).

DISCUSSION

In this study we assessed the pattern of changes in fat and lean tissue over an average of 9.4 y in an older adult cohort and documented the effects of physical activity, age, and body weight on these changes. Different patterns of change were observed in the men and the women: mean FFM and energy expenditure in SRA decreased in the men but remained constant in the women. Although not directly influenced by age or level of physical activity, the change in lean tissue was associated with a change in body weight. Therefore, even with overall lower activity levels, a lean-tissue gain was observed in the subjects who gained weight, whereas the higher activity levels of those who lost weight were not sufficient to prevent a lean-tissue loss over the follow-up period. Our longitudinal data also describe an attenuation of the increase in fat or even a loss of fat in the aging female.

Change in fat-free mass

The lack of change in FFM in the women did not support our hypothesis regarding expected decreases with advancing age. However, there are few reports on the changes in body composition in older women with which we can compare our data (18, 25, 27, 36). A decline in lean tissue, estimated from total-body potassium measurements, of about 0.4 kg/y has been documented in women aged > 50 y, but this rate was not significant (27). Data from cross-sectional and longitudinal studies suggest that the greatest rate of decline in lean tissue may occur in the perimenopausal years, followed by a more gradual decline thereafter (37, 38). The women who ceased menstrual function between assessments did not have significant losses in fat-free tissue, which was most likely because of their substantial gains (almost 12%) in weight. A decline in weight was seen in the oldest subjects of this cohort, but the change in FFM did not follow this age-related pattern. Therefore, our data do not support a nonlinear or age-dependent decline in fat-free tissue in weight-stable women aged 45–80 y followed on average for 9.4 y.

There are more reports on the pattern of changes in lean tissue in men than in women. A study in which methodology similar to ours was used and in which subjects were 10 y younger than our cohort noted no significant changes over time or between men (~1.3 kg FFM per decade) and women (0.0 kg FFM per decade) (21).
estimates are strikingly similar to our findings: −1.2 kg FFM per decade in men and −0.1 kg FFM per decade in women. A recent publication on weight-stable, healthy, elderly subjects confirms our finding of a sex difference in the age-related decline in lean tissue (36). The longitudinal reduction in appendicular muscle area or in whole-body muscle mass in older men supports the idea that the changes in fat-free tissue that we observed are primarily due to changes in muscle mass (23, 36, 39).

In theory, an age-associated decline in the density of FFM could have exaggerated the results that we obtained from hydrodensitometry, in which we assumed a constant density of FFM over time. If the density of fat-free tissue decreased significantly over the follow-up period and we did not make the appropriate adjustment, we would have overestimated the decline in the lean tissue over time (40). However, Visser et al (41) suggested that age-related, qualitative changes in lean tissue are not a significant factor in estimating body composition from total body density.

Age and sex differences in the pattern of change in fat mass

Our data support observations of an overall increase in adipose tissue in an older cohort. However, in the women this increase was attenuated with increasing age, whereas there was no apparent age-related effect in the men. Previous cross-sectional studies by us and other researchers also suggest different patterns of change in FM in aging men and women (40, 42–44). In those studies, after ≈65 y of age, women had less FM than did younger subjects, whereas comparably aged men had an equal or greater amount of FM than did younger subjects. These observations in women may be because of selective recruitment of older survivors who have less body fat. The current study, however, provides longitudinal data to support this pattern of change in aging women. The younger women in our cohort, especially those who were premenopausal at the baseline assessment, gained fat, whereas the women who were >70 y of age lost fat as they aged. The apparent loss of fat in the older subjects in our study may also be the result of a selection bias or may represent a survival adaptation.

Effect of body weight and physical activity on changes in body composition

Changes in fat and FFM should be examined in light of the varying patterns of weight and physical activity in this older cohort. Analysis of these associations, however, is complicated by the facts that physical activity can influence body weight (29, 30, 45–47) and that the level of obesity itself may modulate physical activity behaviors (46, 48, 49). In turn, as others and we have seen, changes in body weight strongly influence changes in fat and FFM (50).

The inverse relation between physical activity and body fatness in different populations and the change in fat stores resulting from structured physical activity are well documented (51, 52). There is also some evidence to suggest that people who regularly engage in aerobic-type exercise have more lean mass and lose less of it with age than do their sedentary counterparts (19, 24, 53). In the present study, we found that higher levels of physical activity over the follow-up period, although effective in decreasing body weight and body fat, were not sufficient to prevent a decline in lean tissue in an older population. By contrast, recent evidence indicates that the level of physical activity influences lean-tissue changes in women 15 y younger than those in our cohort who gain weight (16). Although resistance-type exercise is effective in augmenting muscle mass in short-term intervention studies, it remains to be seen whether individuals who include habitual resistance training in their exercise regimens over extended periods can attenuate age-related declines in muscle. However, as we have shown, weight changes will also have a large effect on the ability to maintain lean tissue. On the basis of our data, resistance training was not an independent predictor of changes in lean tissue (data not shown), although this conclusion is limited because of the small number of practitioners (8% of the cohort). However, evidence from one cross-sectional study indicates that resistance training practiced over many years by elderly men may prevent the lean-tissue declines seen in their sedentary or aerobically active counterparts (54).

Age-associated weight changes

Our observation of greater weight loss (or less weight gain) with increasing age is in agreement with findings reported from the National Health and Nutrition Examination Survey (10). Given the general recommendations for increased physical activity for all individuals regardless of age and given the findings of this study, which document that weight loss is associated with consistently higher levels of physical activity in an older cohort, we must consider resistance-type exercise, with its relatively low rates of energy expenditure, to be of prime importance for nonobese elderly persons, who tend to lose weight.

In summary, we found that in subjects initially aged 46–80 y, declines in lean tissue and physical activity were greater in the men than in the women over an average of 9.4 y. Changes in body weight had the strongest influence on FFM, whereas age and activity level had no effect. This latter finding may be the result of the relatively high activity levels and the narrow age range in this cohort. The increase in fat tissue that is generally thought to be marked by, aging was attenuated in the oldest women. Weight-stable subjects who remained active still tended to lose lean tissue, a finding that points to the importance of encouraging resistance-type exercise to prevent the loss of lean tissue. Because of the variability in body weight and the variety of environmental factors that influence physical activity behaviors, it may be necessary to study more individuals more frequently and over a longer period of time to understand the specific recommendations required for maintaining optimal body composition.


