Sarcopenia and increased adipose tissue infiltration of muscle in elderly African American women¹–³

Mi-Yeon Song, Else Ruts, Jaehee Kim, Isaiah Janumala, Steven Heymsfield, and Dympna Gallagher

ABSTRACT

Background: Aging is associated with metabolic, physiologic, and functional impairments, in part through age-related changes in body composition. During the later adult years, skeletal muscle mass decreases and body fat becomes centralized.

Objective: The goal of the study was to investigate body composition over time (x ± SD: 2.04 ± 0.6 y) in healthy, ambulatory, elderly African American women. The hypothesis that a reduction in total-body skeletal muscle (SM) and increases in visceral adipose tissue (VAT), subcutaneous adipose tissue (SAT), and intermuscular adipose tissue (IMAT) are ongoing in healthy, weight-stable elderly was tested.

Design: The study was a longitudinal evaluation of 26 women (age at baseline: 75.5 ± 5.1 y) with a body mass index (in kg/m²) of 27.0 ± 4.0. Body composition was measured by using whole-body magnetic resonance imaging for the quantification of SM, total adipose tissue (TAT), VAT, SAT, and IMAT.

Results: SM (P < 0.001) and bone (P < 0.05) masses decreased, and regional analyses showed a decrease in dual-energy X-ray absorptiometry–derived leg SM (P < 0.05). VAT (P = 0.011) and IMAT (P < 0.001) increased. No changes occurred in TAT (P = 0.45), SAT (P = 0.96), physical function, or food intake.

Conclusion: These data show an age-related remodeling of body composition with reductions in SM and corresponding increases in VAT and IMAT. Changes in the previously unstudied depot of IMAT may be involved in the deterioration of metabolic values frequently observed during aging. Am J Clin Nutr 2004;79:874–80.

KEY WORDS Aging, body composition, longitudinal study, African Americans, fat distribution

INTRODUCTION

Aging is associated with metabolic, physiologic, and functional impairments, in part through age-related changes in body composition. We previously reported that weight stability in a multiethnic group of elderly over a 5-y period was accompanied by a disproportionate loss of lean tissue, of which skeletal muscle (SM) was a primary component (1). In contrast, fat mass increased significantly in men, but our understanding of the location of this increase was limited by the method of measurement used.

It is well established that, during the later adult years, SM mass decreases (2, 3) and body fat becomes centralized (4, 5). Characterization of the effect of the aging process on SM has identified losses in muscle mass, force, and strength, which collectively are defined as sarcopenia (6, 7). In the elderly, the loss of SM is correlated with physical impairment and disability (8). Persons who are obese and sarcopenic are reported, independent of age, ethnicity, smoking, and comorbidity, to have worse outcomes—including functional impairment, disabilities, and falls—than do those who are nonobese and sarcopenic (9).

Increased central or truncal adiposity is another well-established phenomenon that accompanies increasing age, irrespective of sex (10) or race (11, 12). Middle-aged women have larger waist circumferences and visceral adipose tissue (VAT) areas than do younger women (13, 14). Excess VAT is recognized as an important risk factor in the development of coronary artery disease (15, 16) and non-insulin–dependent diabetes mellitus (17, 18). Even in nondiabetic and nonhypertensive postmenopausal women, large amounts of VAT are associated with less favorable metabolic profiles than are small amounts (19).

Adipose tissue infiltration of SM increases with age (20–22). As measured with the use of computerized tomography (CT), mid thigh low-density lean tissue—also referred to as reduced muscle attenuation—is directly related to age and adiposity in women (21). Accordingly, reduced muscle attenuation is considered to reflect a larger intermuscular adipose tissue (IMAT) content, and a larger amount of thigh IMAT is associated with poorer leg function in elderly (22). None of the aforementioned studies assessed total-body measures of adipose tissue distribution, including IMAT, or used a longitudinal design.

The present study was designed to evaluate body-composition changes over time in healthy, community-dwelling and independently living, elderly African American women. Body composition was measured by using whole-body magnetic resonance imaging (MRI) for the quantification of total-body SM mass, total adipose tissue (TAT), and components of TAT—VAT, subcutaneous adipose tissue (SAT), and IMAT. IMAT is defined

1 From the Department of Medicine, Obesity Research Center, St Luke’s–Roosevelt Hospital, New York (M-Y.S., ER, JK, II, SH, and DG); the Department of Oriental Rehabilitation Medicine, College of Oriental Medicine, Kyung Hee University, Seoul, Korea (M-Y.S.); and the Institute of Human Nutrition, Columbia University, New York (DG).
2 Supported by grant no. R29-AG14715 and grant no. PO1-DK42618 (Project 4) from the National Institutes of Health.
3 Reprints not available. Address correspondence to D Gallagher, Obesity Research Center, 1090 Amsterdam Avenue, New York, NY 10025. E-mail: dg108@columbia.edu.
Received June 13, 2003. Accepted for publication October 17, 2003.
as the adipose tissue that is visible within the muscle area. The hypothesis that there are ongoing reductions in SM and increases in VAT, SAT, and IMAT in healthy, weight-stable elderly was tested.

SUBJECTS AND METHODS

Subject recruitment

Subjects were required to be independent, community-dwelling African American women aged ≥ 65 y. Inclusion criteria were that subjects be ambulatory, nonexercising, and non-smoking and that, by self-report, their body weight has changed by ≤ 3 kg over the previous 3 y. Subjects with untreated diabetes mellitus, malignant or catabolic conditions, or any missing limb; who have undergone joint replacement; or who are taking estrogen replacement therapy or medications that could potentially influence body composition were excluded from the study. Recruitment occurred through advertisements in newspapers and flyers posted in the local community. The study was approved by the Institutional Review Board of St Luke’s—Roosevelt Hospital, and written informed consent was obtained from all participants.

Baseline and follow-up measures

Baseline data were collected for 43 women, of whom 31 returned for a follow-up evaluation. The mean (± SD) follow-up time was 2.04 ± 0.6 y (range: 19–35 mo). Of the 12 subjects who did not return, 1 died, 2 relocated, 3 did not respond to telephone or mail contacts, and 6 refused to be reevaluated.

During baseline and follow-up, each subject completed a medical examination that included screening blood tests after an overnight fast. Blood samples were sent to a commercial laboratory (Corning Clinical Laboratories and Quest Diagnostics, Teterboro, NJ) for screening for occult disease. Of the 31 medically evaluated subjects, 5 were excluded from the final analyses for the following reasons: intentional diet-related weight loss (≥ 6.6 kg; n = 1); hip replacement (n = 1); self-reported cancer (n = 1); stent implant (n = 1); and incomplete MRI scan (n = 1).

Body composition

Subjects reported in the morning in a fasted state to the Body Composition Laboratory. While each subject was wearing a hospital gown and foam slippers, body weight and height were measured to the nearest 0.1 kg (Weight Tronix, New York) and 0.5 cm (Holtain Stadiometer, Crosswell, United Kingdom), respectively.

Magnetic resonance imaging

SM and TAT, including total SAT, VAT, and IMAT, were measured by using whole-body multislice MRI. In our laboratory, IMAT is defined as intermuscular adipose tissue—ie, the adipose tissue visible between muscle groups and beneath the muscle fascia—as shown in Figure 1. The gray-level intensity (threshold value) of the adipose tissue in the SAT region was determined and used as a reference. This threshold value was reduced by 20% to identify the IMAT threshold. Subjects were placed on the 1.5 T scanner (6X Horizon; General Electric, Milwaukee) platform with their arms extended above their heads. The protocol involved the acquisition of ≈ 40 axial images of 10-mm thickness at 40-mm intervals across the whole body (23). SLICEOMATIC image analysis software (version 4.2; Tomovision, Montreal, Canada) was used to analyze images on a personal computer workstation (Gateway, Madison, WI). MRI estimates of volume were converted to mass with the use of an assumed density of 1.04 kg/L for skeletal muscle and 0.92 kg/L for adipose tissue (24). All scans were read by the same technician (IJ), who was blind to the scan sequence. The technical error for 3 repeated readings of the same scan by the same observer (IJ) for the MRI-derived SM, SAT, VAT, and IMAT volumes in our laboratory is 1.9%, 0.96%, 1.97%, and 0.65%, respectively.

Dual-energy X-ray absorptiometry

Total-body bone mineral content (TBBMC), total body fat (TBF), and fat-free mass (FFM; calculated as body weight – TBF) were measured by using a whole-body dual-energy X-ray absorptiometry (DXA) scanner (DPX; GE Lunar, Madison, WI) and DPX software (version 3.6; GE Lunar). Appendicular lean soft tissue (ALST) mass was considered equivalent to the sum of lean soft tissue (ie, nonfat and nonbone mineral mass) in arms and legs (25, 26). The between-measurement technical errors for TBBMC, TBF, FFM, and ALST mass in the same subject are 0.9%, 3.4%, 1.2%, and 3.0%, respectively (27). Ethanol and water bottles with a volume of 8 L, simulating fat and fat-free soft tissues, respectively, were scanned weekly as soft-tissue quality-control markers. A spine bone phantom was scanned daily. The range in measured R values over the study period was 1.255–1.258 (CV: 0.127%) and 1.367–1.371 (CV: 0.103%) for ethanol and water, respectively.

DXA- and MRI-measured lower-limb SM masses have been shown to be highly correlated (r = 0.94, P < 0.001) in adults (28). Equally high correlations (r = 0.98) have been found between DXA-measured ALST mass and MRI-derived total-body SM mass in adults (29).

Physical function

To determine whether changes in body-composition variables would be reflected in changes in physical function, physical function was tested at baseline and follow-up. All tests were first demonstrated to the participants. Muscle strength (handgrip strength) and lower-extremity function—including agility and coordination (chair stand), gait (2-min walk), and balance
Muscle strength

The subject was instructed to exert a squeezing action and perform 2 trials alternately with each hand by using a hand-cable tensiometer (Pacific Scientific, Anaheim, CA). Grip strength was expressed in kilograms and has a reported reliability of 3–6% in older persons (30, 31).

Agility and coordination

Each subject was asked to stand up from a chair and sit back down 5 times as quickly as possible, with the arms folded across the chest. The entire session was timed for the span from the initial sitting position to the final standing position at the end of the fifth stand. These tests were previously reported to be highly predictive of subsequent disability in older persons with a preclinical stage of disability (32). The between-observer CV in the same subject was 0.73 for repeated rising from a chair (33).

Gait

The subject was asked to walk for 2 min at his or her usual pace, and the distance was recorded. This test is considered a simple and practical indicator of everyday disability, and it provides a useful, reproducible measure of exercise tolerance (34).

Balance

The balance walk tests were performed within 2 sets of colored lines 8 ft in length that were placed along a corridor floor. The green lines were 20 cm apart, and the orange lines were 30 cm apart. Each subject was instructed to walk within a given set of colored lines at a comfortable pace. Each walk was timed, and the number of steps was recorded from when the start and finish lines were crossed. Stepping onto or outside of the tape constituted a failure. An increase from baseline in the time taken to complete the walk gave a significantly worse score than that at baseline (35). For the semitandem stand test, the heel of one foot was placed to the side of the first toe of the other foot, with the subject choosing which foot to place forward. For the tandem stand test, the subject was required to place the heel of one foot directly in front of the toes of the other foot. The stand position was timed for 30 s. These walk, semitandem stand, and tandem stand tests provide information on balance. The between-observer CV for the same subject was 0.97 for semitandem and tandem standing balances (36).

Food-frequency questionnaire

Usual dietary intake was estimated with the use of a self-administered food-frequency questionnaire (FFQ: Fred Hutchinson Cancer Research Center, Seattle; 37) at baseline and follow-up. The FFQ was completed by the subject during the center visit. Completed FFQs were analyzed by Fred Hutchinson Cancer Research Center, and results were provided in an unadjusted format for energy, percentage of energy from macronutrients, absolute amounts of macronutrients and dietary fiber (in g), and absolute amount of dietary cholesterol (in mg). Total intake, protein, carbohydrate, fat, and calcium consumptions were used in the analyses.

<table>
<thead>
<tr>
<th>TABLE 1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Characteristics of subjects (n = 26) at baseline and follow-up</td>
</tr>
<tr>
<td>Baseline</td>
</tr>
<tr>
<td>---</td>
</tr>
<tr>
<td>Age (y)</td>
</tr>
<tr>
<td>Height (m)</td>
</tr>
<tr>
<td>BMI (kg/m&lt;sup&gt;2&lt;/sup&gt;)</td>
</tr>
<tr>
<td>&lt;sup&gt;1&lt;/sup&gt; All values are x ± SD.</td>
</tr>
<tr>
<td>&lt;sup&gt;2&lt;/sup&gt; Significantly different from follow-up, P &lt; 0.001.</td>
</tr>
</tbody>
</table>

Lipids

Blood samples were drawn in the morning after an overnight fast and were sent to a commercial laboratory (Corning Clinical Laboratories and Quest Diagnostics) for analysis. All samples were analyzed for triacylglycerols, total and HDL cholesterol, and glucose.

Data analysis

Longitudinal changes in each body-composition component, physical activity and function, and food intake were tested by using paired t tests. Pearson’s correlation coefficients were used to quantify bivariate correlations between baseline body-composition components obtained with the use of MRI and DXA. The relation between change over time in each body-composition measurement and its baseline value was tested by using regression analysis in which the observed change was set as the dependent variable and its baseline value was set as an independent variable. Length of follow-up was treated as an independent variable. In all analyses, a two-tailed α level of 0.05 was used. Data were analyzed by using SPSS software (version 8.0; SPSS Institute, Chicago). Results are presented as means (± SDs) in the text and as means (± SEs) in the figures.

RESULTS

Subject characteristics

A comparison of the baseline characteristics of all persons who returned for follow-up evaluation (n = 31) with those of persons who did not return (n = 12) found no significant differences in age, height, weight, FFM, or fat mass measurements obtained by using DXA. The baseline and follow-up descriptive characteristics of persons included in the final analysis (n = 26) are summarized in Table 1. The mean follow-up interval for the study population was 2.0 ± 0.6 y. No significant changes occurred in body weight, height, or BMI.

Longitudinal body-composition changes

The changes observed in the body-composition components from baseline to follow-up evaluations, expressed as absolute values and rates per year, are shown in Table 2. Length of follow-up was not a significant predictor in any of the analyses.

Fat-free mass and skeletal muscle

There was no significant change in FFM measurements obtained by using DXA (0.03 ± 1.18 kg; P = 0.89). Significant losses occurred in total SM measurements obtained by using MRI (−0.72 ± 0.72 kg; P < 0.001; Figure 2A), and the difference was not significantly correlated with baseline SM (r = 0.23, P = 0.26). Regional analyses showed a significant decrease in
DXA-derived leg skeletal muscle (LSM; \(-0.30 \pm 0.66\) kg; \(P = 0.03\); Figure 2B) and no significant change in DXA-derived arm skeletal muscle (ASM; \(0.06 \pm 0.30\) kg; \(P = 0.33\)).

Of the total sample of 26 women, 21 (81%) had a decrease (\(\Delta < 2.0\) kg) or no change in SM from baseline to follow-up. The remaining 5 women (19%) had an increase (\(\Delta > 0.5\) kg) in SM.

**Adipose tissue**

There was an increase in VAT (0.19 \(\pm 0.35\) kg; \(P = 0.011\)) over the 2-y period. This increase was dependent on baseline VAT, so that the smaller the baseline VAT, the greater the change in VAT with follow-up (\(P < 0.05\)). There was no significant change in SAT (\(-0.02 \pm 1.64\) kg; \(P = 0.96\)). IMAT increased significantly (0.14 \(\pm 0.17\) kg; \(P < 0.001\); Figure 2C).

**Bone mineral content**

TBBMC decreased significantly (0.03 \(\pm 0.06\) kg; \(P = 0.03\)), and the change was independent of its baseline value (\(r = 0.05\), \(P = 0.82\)). The observed overall longitudinal changes in body weight and body-composition components are shown in Figure 3. The observed (0.24 kg) increase in body weight consisted of gains in VAT (0.19 kg) and IMAT (0.14 kg) and a loss in SM (0.72 kg). Whereas there was no significant change in FFM (0.03 kg), within the SM compartment, a loss of LSM (0.30 kg) and a nonsignificant change in ASM (0.06 kg) were observed. The observed change in TBBMC was \(-0.03\) kg.

**Lipid measurements**

No significant changes were observed in total cholesterol (\(P = 0.21\)), HDL cholesterol (\(P = 0.19\)), triacylglycerols (\(P = 0.20\)), or glucose (\(P = 0.16\)). The observed changes in VAT and IMAT did not correlate significantly with changes in any of the metabolic variables measured. Changes in VAT showed a trend (\(P = 0.09\)) toward predicting changes in triacylglycerols, which suggested that there was inadequate power to detect a relation, if indeed it existed at all.

### Bivariate correlations

Baseline measurements of SM by MRI and of ALST mass by DXA were highly correlated (\(r = 0.84\), \(P < 0.001\)), as were those of TAT by MRI and of TBF by DXA (\(r = 0.99\), \(P < 0.001\)). Changes in measurements of SM by MRI and of ALST by DXA were poorly correlated (\(r = 0.10\), \(P < 0.62\), and changes in measurements of TAT by MRI and of TBF by DXA were highly correlated (\(r = 0.85\), \(P < 0.001\)).

**Physical function and food-frequency questionnaires**

Completed baseline and follow-up physical function tests (\(n = 23\)) and FFQs (\(n = 25\)) were analyzed. No significant differences were found between baseline and follow-up values (Table 3).

### DISCUSSION

The findings of this study of a sample of independently living, healthy, African American women support the hypothesis that a reduction in SM and increases in IMAT and VAT occur with advancing age, despite no detectable changes in physical function or dietary intake. Additional observations include significant losses of LSM and TBBMC over the 2-y study period.

### Skeletal muscle loss

We are unaware of any previous study longitudinally that assesses changes in SM mass in African American women of a similar age with which we can compare our data. In the current study, the rate of total-body SM loss by MRI was 0.37 kg/y and the rate of LSM loss by DXA was 0.11 kg/y. We previously reported longitudinal changes in ASM and LSM mass in a multiethnic group of healthy, ambulatory, weight-stable women and men aged \(\geq 65\) y who were followed for 5 y (1). Rates of ALST mass loss (arm and leg combined) of 0.60 kg/decade were reported in women. Assuming that ALST mass accounts for \(\approx 75\%\) of total-body SM in adults (24), an estimated 0.08-kg/y loss of

#### Table 2

Results of longitudinal body-composition studies in 26 subjects[^1]

<table>
<thead>
<tr>
<th></th>
<th>Baseline</th>
<th>Change</th>
<th>(P^2)</th>
<th>Change[^4]</th>
<th>(P^4)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Body weight (kg)</td>
<td>66.2 ± 10.2[^3]</td>
<td>0.24 ± 2.4</td>
<td>0.62</td>
<td>0.28 ± 1.5</td>
<td>0.69</td>
</tr>
<tr>
<td>MRI (kg)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SM</td>
<td>18.6 ± 2.0</td>
<td>-0.72 ± 0.72</td>
<td>0.001[^5]</td>
<td>-0.37 ± 0.4</td>
<td>0.002</td>
</tr>
<tr>
<td>TAT</td>
<td>26.8 ± 7.97</td>
<td>0.28 ± 1.99</td>
<td>0.45</td>
<td>0.17 ± 1.0</td>
<td>0.37</td>
</tr>
<tr>
<td>SAT</td>
<td>24.0 ± 7.53</td>
<td>-0.02 ± 1.64</td>
<td>0.96</td>
<td>0.00 ± 0.9</td>
<td>0.99</td>
</tr>
<tr>
<td>VAT</td>
<td>1.87 ± 1.01</td>
<td>0.19 ± 0.35</td>
<td>0.011</td>
<td>0.10 ± 0.2</td>
<td>0.016</td>
</tr>
<tr>
<td>IMAT</td>
<td>1.08 ± 0.42</td>
<td>0.14 ± 0.17</td>
<td>0.001[^5]</td>
<td>0.07 ± 0.1</td>
<td>0.001</td>
</tr>
<tr>
<td>DXA (kg)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>FFM</td>
<td>41.1 ± 4.57</td>
<td>0.03 ± 1.18</td>
<td>0.89</td>
<td>0.07 ± 0.8</td>
<td>0.42</td>
</tr>
<tr>
<td>ASM</td>
<td>4.25 ± 0.54</td>
<td>0.06 ± 0.30</td>
<td>0.33</td>
<td>0.05 ± 0.2</td>
<td>0.20</td>
</tr>
<tr>
<td>LSM</td>
<td>13.1 ± 1.73</td>
<td>-0.30 ± 0.66</td>
<td>0.03</td>
<td>-0.11 ± 0.3</td>
<td>0.08</td>
</tr>
<tr>
<td>TBF</td>
<td>24.8 ± 7.73</td>
<td>0.09 ± 2.3</td>
<td>0.84</td>
<td>0.13 ± 1.3</td>
<td>0.61</td>
</tr>
<tr>
<td>TBBMC</td>
<td>2.18 ± 0.29</td>
<td>-0.03 ± 0.06</td>
<td>0.03</td>
<td>-0.01 ± 0.03</td>
<td>0.03</td>
</tr>
</tbody>
</table>

[^1]: SM, skeletal muscle; TAT, total adipose tissue; SAT, subcutaneous adipose tissue; VAT, visceral adipose tissue; IMAT, intermuscular adipose tissue; FFM, fat-free mass; ASM, arm skeletal muscle; LSM, leg skeletal muscle; TBF, total body fat; TBBMC, total-body bone mineral content; MRI, magnetic resonance imaging; DXA, dual-energy X-ray absorptiometry.

[^2]: For the test of change between baseline and follow-up.

[^3]: Changes are per year and do not equal absolute change because the follow-up period varied between 1 and 3 y (\(\pm 2.04 \pm 0.6\) y; range: 19–35 mo).

[^4]: For the test of change per year.

[^5]: \(\pm \) SD (all such values).

[^6]: Adjusted Bonferroni values for significance within MRI and DXA, \(P < 0.01\).
total-body SM would have occurred in these women. The latter derived changes would therefore greatly underestimate (0.08 kg/y instead of 0.37 kg/y) the rate of change observed in the current study. A lack of change in FFM in the current study suggests a 1.2-kg/decade loss of ALST mass (41), which translates into a 0.16-kg/y loss of total-body SM mass. FFM in men decreased with age at approximately twice the rate (0.22 kg/y) found in the women (0.10 kg/y) (42), a finding supported by others (1). More recently, Janssen et al (43) reported on a cross-sectional investigation of a multiethnic group in whom the loss of SM mass with age was significantly greater in the lower body than in the upper body. Longitudinal rates of decline in leg muscle strength in men aged 46–78 y were ~60% greater than were cross-sectional estimates in the same population (44). A longitudinal investigation of muscle cross-sectional area (CSA) by CT in men (aged 65.4 y at baseline) followed for 12 y found CSA reductions of 1.4%/y (45). Cross-sectional studies may underestimate actual rates of SM loss, and the losses in SM with aging may not be linear because they accelerate as age increases (2).

Currently available MRI and DXA methods allow for both whole-body and regional muscle measurements, which are essential to the monitoring of potentially small changes in tissue mass. Decreases in bone and SM are thought to contribute to increased disability (22, 46), and less leg muscle mass is related to poor low-extremity performance (22). Studies have shown that increasing the SM mass can improve functional status (47, 48), which suggests that muscle mass loss with age may increase the risk of functional decline. Studies that attempted to assess muscle strength in relation to mass often used insufficiently sensitive muscle mass—measurement techniques.

The reason or reasons for a reduction in SM mass in the current

### TABLE 3
Summary of physical function and dietary intake at baseline and follow-up

<table>
<thead>
<tr>
<th>Physical function</th>
<th>Baseline</th>
<th>Follow-up</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grip strength (kg)</td>
<td>25.4 ± 3.6</td>
<td>25.0 ± 5.3</td>
</tr>
<tr>
<td>Chair stand, n = 23 (s)</td>
<td>13.2 ± 4.3</td>
<td>13.1 ± 3.4</td>
</tr>
<tr>
<td>2-min walk, n = 18 (m)</td>
<td>144.6 ± 23.2</td>
<td>154.8 ± 33.6</td>
</tr>
<tr>
<td>Standing balance (s)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>30-cm narrow walk, n = 23</td>
<td>5.2 ± 1.0</td>
<td>5.6 ± 0.9</td>
</tr>
<tr>
<td>20-cm narrow walk, n = 22</td>
<td>5.2 ± 1.1</td>
<td>5.8 ± 1.1</td>
</tr>
<tr>
<td>Semitandem stand test, n = 24</td>
<td>28.0 ± 6.9</td>
<td>28.3 ± 5.8</td>
</tr>
<tr>
<td>Tandem stand test, n = 23</td>
<td>25.8 ± 9.5</td>
<td>27.3 ± 7.2</td>
</tr>
<tr>
<td>FFQ, n = 25</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total energy intake (kcal/d)</td>
<td>1126.4 ± 734.0</td>
<td>1326.6 ± 869.4</td>
</tr>
<tr>
<td>Fat (g/d)</td>
<td>44.4 ± 35.2</td>
<td>49.6 ± 46.8</td>
</tr>
<tr>
<td>Carbohydrate (g/d)</td>
<td>157.8 ± 90.8</td>
<td>160.6 ± 83.7</td>
</tr>
<tr>
<td>Calcium (mg/d)</td>
<td>433.6 ± 398.5</td>
<td>499.7 ± 406.8</td>
</tr>
</tbody>
</table>

1 All values are x ± SD. FFQ, food-frequency questionnaire. There were no significant differences between baseline and follow-up values; however, the difference from baseline for the 30-cm narrow walk was nearly significant (P = 0.06).
cohort are unknown. One theory has linked reductions in FFM to increases in cytokines and increases in mortality (49). Higher concentrations of inflammatory cytokines including interleukin 6 are found in the elderly (50) and are reported to be associated with low lean mass in the elderly. Although the mechanisms involved in age-related body-composition changes remain unclear, hormonal and cytokine mediators may play a role (49). The relation of the immune system, declines in sex hormones and physical activity, and incident disease with body composition should be investigated further.

Adipose tissue changes

In the present study, the mean yearly increases in VAT and IMAT were 0.10 kg and 0.07 kg, respectively. Data from carefully controlled clinical investigations are lacking on the metabolic implications of increases in these depots. DeNino et al (13) investigated whether increasing abdominal adiposity with adipocytic implications of increases in these depots. DeNino et al (13) investigated whether increasing abdominal adiposity with advancing age in women from 20 to 78 y old was a strong predictor of the deterioration in the metabolic profile in white women. A progressive increase in VAT (single L4–L5 slice by CT) with increasing age was observed, and the group aged 61–78 y had 28% less glucose disposal than did younger groups. Unfavorable changes in plasma lipids (triaclylglycerols, total cholesterol, and LDL cholesterol) were strongly associated with the age-related increase in VAT, but the study did not include African American women and was not longitudinal in design (13).

Efforts are ongoing at quantifying SM composition and fatty infiltration or lipid content. Goodpaster et al (51) observed that reduced SM attenuation (as measured by using CT) was associated with increased SM lipid content (r = −0.43, P < 0.01). A cross-sectional investigation using the needle-biopsy technique in subjects aged ≥60 y found significantly greater muscle fat content in the women than in the men (52). Low-density lean tissue within midthigh muscle as measured by using CT was reported to be correlated with age (r = 0.52, P < 0.005), insulin, (r = 0.34, P < 0.005), triacylglycerol (r = 0.41, P < 0.005), cholesterol (r = 0.50, P < 0.005), and LDL cholesterol (r = 0.53, P < 0.005) in women aged 18–69 y (21). Higher muscle attenuation values in the elderly are reported to be associated with greater strength independent of muscle cross-sectional area (20). These investigators also found that adipose tissue located beneath the fascia lata (IMAT) and therefore adjacent to skeletal muscle was significantly correlated negatively with insulin sensitivity, whereas adipose tissue above the fascia lata (SAT) and removed from skeletal muscle was not (51).

To our knowledge, the current longitudinal study is the first to report on MRI-derived whole-body IMAT changes with age. It is not known whether changes in the IMAT depot are related to the deterioration in metabolic values frequently observed during aging.

Influence on physical performance

The performance measures acquired have been shown to be powerful predictors of incident disability, even in high-functioning elderly (33), but they may not have been sufficiently sensitive to small changes in function. No detectable changes in physical performance were found in the present study that could help explain the observed losses of SM. Data on the relation between muscle mass and physical function in the elderly are limited. It was reported that, after adjustment for several behavioral measurements and physiologic and psychological health measurements, leg muscle mass measured by DXA was not associated with leg function in women > 65 y old (53). Recently, Sternfeld (54) reported that poor physical performance, functional limitation, and disability and mortality are related to body fat loss more than to muscle mass loss in women > 55 y old.

Measuring body composition

Advances in our laboratory (27) and that of others (23) strongly support the use of whole-body MRI as a reference method for evaluating and monitoring changes over time in whole and regional body composition. In addition, we have supported the use of DXA as a means of quantifying appendicular skeletal mass (29). DXA provides a useful means of quantifying total-body and regional bone mineral mass and density, which are important measurements that parallel SM mass.

Study limitations

The current study population is limited in size and does not represent a random sample of older women but rather a convenient sample of urban-dwelling, healthy African Americans. This group cannot be considered representative of the aging population in general. The presence of undiagnosed medical conditions that could affect body composition cannot be ruled out. However, the unequivocal finding of SM mass loss over time in a healthy cohort suggests that the extent of muscle loss in a randomly selected sample would be greater than that observed in our study. The study sample consisted of African American women. Extrapolation of these findings to men and women of other racial or ethnic groups should be made with caution.

Conclusions

Over a 2-y period, a loss of SM and gains in IMAT and VAT occurred in independently living, healthy, African American women, despite no detectable changes in physical function. These data are the first reported on increases in IMAT and VAT in elderly African American women, and they suggest that, in the short term, changes in body composition may be more sensitive to aging than are changes in physical function. These findings provide further support for the hypothesis that dynamic remodeling of soft tissues occurs even in healthy, ambulatory, weight-stable elderly subjects.

M-YS was involved in data analysis and manuscript writing. ER coordinated the study. JK participated in the study setup and protocol design. H analyzed all magnetic resonance imaging scans. SH provided advice and consultation on study design and grant writing. DG was involved in study design, data collection, data analysis, and manuscript writing and provided administrative support, supervision, and advice. None of the authors declared any conflict of financial or personal interests.

REFERENCES