Leg Muscle Mass and Composition in Relation to Lower Extremity Performance in Men and Women Aged 70 to 79: The Health, Aging and Body Composition Study

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OBJECTIVES: The loss of muscle mass with aging, or sarcopenia, is hypothesized to be associated with the deterioration of physical function. Our aim was to determine whether low leg muscle mass and greater fat infiltration in the muscle were associated with poor lower extremity performance (LEP).

DESIGN: A cross-sectional study, using baseline data of the Health, Aging and Body Composition study (1997/98).

SETTING: Medicare beneficiaries residing in ZIP codes from the metropolitan areas surrounding Pittsburgh, Pennsylvania, and Memphis, Tennessee.

PARTICIPANTS: Three thousand seventy-five well-functioning black and white men and women aged 70 to 79.

MEASUREMENTS: Two timed tests (6-meter walk and repeated chair stands) were used to measure LEP. Muscle cross-sectional area and muscle tissue attenuation (indicative of fat infiltration) were obtained from computed tomography scans at the midthigh. Body fat was assessed using dual-energy x-ray absorptiometry.

RESULTS: Blacks had greater muscle mass and poorer LEP than whites. Black women had greater fat infiltration into the muscle than white women. After adjustment for clinic site, age, height, and total body fat, smaller muscle area was associated with poorer LEP in all four race-gender groups. (Regression coefficients, expressed per standard deviation (± 55 cm^2) of muscle area, were 0.658 and 0.519 in white and black men and 0.547 and 0.435 in white and black women, respectively, $P < .01$.) In addition, reduced muscle attenuation—indicative of greater fat infiltration into the muscle—was associated with poorer LEP, independent of total body fat and muscle area. (Regression coefficients per standard deviation (= 7 Hounsfield Units) of muscle attenuation were 0.292 and 0.224 in white and black men, and 0.193 and 0.159 in white and black women, respectively, $P < .05$). The most important body composition components related to LEP were muscle area in men and total body fat in women. Results were similar after additional adjustment for lifestyle factors and health status. No interactions between race and muscle area ($P > .7$) or between race and muscle attenuation ($P > .2$) were observed.

CONCLUSION: Smaller midthigh muscle area and greater fat infiltration in the muscle are associated with poorer LEP in well-functioning older men and women. **J Am Geriatr Soc 50:897–904, 2002.**

Key words: aging; body composition; computed tomography; fat infiltration; functional status; human; obesity; race; sarcopenia; skeletal muscle

The loss of muscle mass is one of the changes in body composition that occur with aging. Recent longitudinal studies using accurate methodology have confirmed the decline in muscle mass suggested by earlier cross-sectional studies. Using computed tomography (CT), a 14.7% decline in muscle cross-sectional area was observed in older men over a period of 12 years.[1] Using dual-energy x-ray absorptiometry (DXA), a 2% to 3% decline in appendicular skeletal muscle mass was observed in healthy older men and women over 4.7 years.[2] The loss of muscle mass with aging, or sarcopenia, is hypothesized to be associ-

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ated with the deterioration of physical function. However, studies investigating the association between low muscle mass and physical function have provided inconsistent results.[3–6]

Not only the quantity but also the composition of the muscle changes with age. An increasing amount of fat is deposited within the muscle,[7–9] but whether this affects the function of the muscle has not been thoroughly studied. A study in older women showed that a greater relative proportion of adipose fat within the quadriceps muscle was associated with poorer knee extension strength and slower walking speed.[10] A study in older men and women showed that lower muscle attenuation at the midthigh, measured with CT and indicating greater fat infiltration, was independently associated with poorer absolute and relative knee extension strength.[11] These studies suggest a relationship between muscle composition and physical function in older individuals.

Physical activity, specifically resistance training, is known to increase muscle mass in older persons.[12,13] Furthermore, recent studies have suggested that muscle attenuation can be positively modified through physical activity.[14,15] Physical activity may be a good strategy to reverse the loss of muscle mass and the increasing fat infiltration of the muscle, potentially resulting in a lower risk for functional decline and loss of independence in older men and women.

The main purpose of this study was to determine whether lower leg muscle mass and greater fat infiltration in the muscle were associated with poorer lower extremity performance (LEP) in a biracial sample of well-functioning older men and women. In addition, we investigated whether these associations were consistent in black and white men and women.

METHODS

Study Population

The Health, Aging and Body Composition (Health ABC) Study cohort includes 3,075 black and white men and women. Whites were recruited from a random sample of Medicare beneficiaries residing in ZIP codes from the metropolitan areas surrounding Pittsburgh, Pennsylvania, and Memphis, Tennessee. Blacks were recruited from all age-eligibles in these geographic areas. After receiving information describing the study, potential participants were screened for eligibility. Eligibility criteria included: aged 70 to 79 in the recruitment period from March 1997 to July 1998; self-report of no difficulty walking one-quarter of a mile or climbing 10 steps without resting; no difficulty performing basic activities of daily living; no reported use of a cane, walker, crutches or other special equipment to ambulate; no history of active treatment for cancer in the prior 3 years; and no plan to move out of the area in the next 3 years. Participants with missing data on muscle mass ($n = 53$), LEP ($n = 33$), or total body fat ($n = 10$) were excluded, leaving 2,979 participants (913 white men, 529 black men, 839 white women, 698 black women) available for the statistical analyses (96.9%).

Lower Extremity Performance

LEP was measured during a clinic visit using two timed performance tests. The first test consisted of walking 6 meters at a usual pace. Two trials were performed, and the fastest time was used in the analyses. For the second test, participants were asked to stand up and sit down five times from a chair as quickly as possible with their arms folded across their chest.[16] Participants who were not able to complete a test were scored 0 for that test. Participants who successfully completed the test were given a score of 1 to 4 based on the quartiles of time for that test (1 = slowest quartile, 4 = fastest quartile). The cutpoints for these quartiles were created based on the distribution of the complete Health ABC Study cohort. An overall measure of LEP was created by summing up the score of the walk test and the repeated chair stands test (range 0–8).

Muscle Area and Muscle Attenuation

The cross-sectional area of muscle in both thighs was measured using CT (at Memphis clinic site: Siemens Somatom Plus 4, Siemens Corp., Erlangen, Germany, and Picker PQ 2000S, Marconi Medical Systems, Cleveland, OH; at Pittsburgh clinic site: GE 9800 Advantage, General Electric, Milwaukee, WI). To locate the midthigh scan position, an anterior-posterior scout scan of the entire femur was obtained. The femoral length was measured in cranial-caudal dimension, and the scan position was determined as the midpoint of the distance between the medial edge of the greater trochanter and the intercondyloid fossa of the right leg. A single, 10-mm-thick axial image (120 kVp, 200–250 mAs) of both thighs was obtained. All CT scans were transferred to one center and analyzed by a single observer on a SUN Workstation (SPARCstation II, Sun Microsystems, Mountain View, CA) using interactive-data language-development software (RSI Systems, Boulder, CO). Areas were calculated by multiplying the number of pixels of a given tissue type by the pixel area. Density values were determined by averaging the CT number (pixel density) values of the regions outlined on the images. CT numbers were defined on a Hounsfield Unit (HU) scale where 0 equals the HU of water and −1,000 equals the HU of air. The external contours of the thigh were determined using a threshold of −224 HU, and the external bone contours were derived at 150 HU. For each participant, the determination of soft tissue type was made using the bimodal image distribution histogram resulting from the distribution numbers in adipose tissue and muscle tissue.[17] Intermuscular and visible intramuscular adipose tissue was separated from subcutaneous adipose tissue by drawing a line along the deep fascial plane surrounding the thigh muscles. The total area of nonadipose, nonbone tissue within the deep fascial plane was used as a measure of muscle area. The mean attenuation (HU) of thigh muscle tissue, excluding intermuscular and intramuscular adipose tissue lying interior to the deep fascial plane surrounding the muscle, was also assessed and was used as an indicator of fat infiltration in the muscle. The validity of this noninvasive measure has been shown before.[18] In 45 men and women with a body mass index ranging from 18.5 to 35.9 kg/m^2 and aged between 25 and 49 years, the correlation between muscle attenuation and muscle fiber fat content determined with histological oil red O staining was −0.43 ($P < .01$).[18] In a subset of 19 volunteers, the correlation between muscle attenuation and triglyceride content in percutaneous biopsy specimens from vastus lateralis was −0.58 (P = .02).[18] Reproducibility of muscle area and muscle attenuation was assessed by reanalyzing a 5% convenience sample of the study cohort and showed a coefficient of variation of less than 5%.

Potential Confounders

Covariates included clinic site, age, education, body height, total body fat, physical activity, health status, and smoking. Based on the highest grade or year of school completed, low education was defined as an education less than high school. Body height was measured to the nearest millimeter using a wall-mounted stadiometer. Because taller persons have more muscle, height was included in the regression models to normalize leg muscle mass. Previous studies have shown that high body fat and high body mass index are associated with greater muscle mass[3,5] and greater fat infiltration in the muscle (lower muscle attenuation as measured by CT).[14,19] Furthermore, these studies have shown that high body fat is associated with poorer physical performance.[3,5] Therefore, we included total body fat as assessed by using fan beam DXA (Hologic QDR4500A, software version 8.21, Waltham, MA) as a potential confounder. We used total body fat and not percentage of body fat because the regression between body fat mass (numerator) and body mass (denominator) has a nonzero intercept[20] and could introduce spurious correlations between percentage body fat and other variables.[21] Physical activity of the past 7 days was assessed by questionnaire during a home interview. The time spent on climbing stairs, walking for exercise, walking for other purposes, aerobics, weight or circuit training, high-intensity exercise activities, and moderate-intensity exercise activities was obtained as was information on the intensity level at which each activity was performed. A metabolic equivalent value was assigned to each activity/intensity combination and was used to calculate the number of kilocalories per week per kilogram of body weight spent on that activity.[22] For each participant, the scores of all performed activities were summed and multiplied by body weight to create an overall physical activity score in kilocalories per week. Disease history was assessed using self-reported information on physician-diagnosed diseases including heart disease, stroke, lung disease, diabetes mellitus, arthritis, and hip fracture. The total number of diseases (range 0–6) was used as an indicator of health status. Participants who reported smoking cigarettes, pipes, or cigars were categorized as current smokers and contrasted with never/former smokers.

Statistical Analyses

Analyses were performed stratified by gender and race using SAS software (SAS Institute, Inc., Cary, NC). Multivariate regression analysis was used to test the association of muscle area and attenuation with LEP. Because it was unclear whether the relationships were linear or had a certain threshold, we first investigated the nature of the relationships. Using gender and race-specific quintiles or deciles of muscle area and muscle attenuation, we did not observe a potential nonlinear relationship or threshold with LEP. Therefore, muscle area and attenuation were used as continuous variables in the regression models. To facilitate interpretation of the results, the coefficients were expressed per population standard deviation of muscle area (±55 cm^2) and muscle attenuation (±7 HU). All analyses were adjusted for clinic site, height, and age (for muscle area) or for clinic site and age (for muscle attenuation). In a second set of models, we additionally adjusted for total body fat. In the final models, we additionally adjusted for potential confounders known to be associated with muscle mass, muscle attenuation, and LEP, including physical activity, health status, education, and smoking status. Potential racial differences in the relationship between muscle area and attenuation and LEP were assessed in the stratified analyses and were tested using product-terms in additional analyses stratified by gender only. To compare the independent associations of each body composition measure (muscle area, muscle attenuation, and total body fat) with LEP, we included these three measures and potential confounders in a single model and calculated standardized regression coefficients.

RESULTS

Characteristics of the study population are shown in Table 1. Black persons had greater muscle mass, as indicated by greater muscle area at the midthigh, than white persons. Black women had lower muscle attenuation than white women, indicating more fat infiltration into the muscles of the midthigh. In men, no racial differences in muscle attenuation were observed. Black men had less total body fat than white men, whereas black women had more total body fat than white women.

Table 2 shows the results of the two performance tests and the overall LEP of the study population. For each of the tests and the overall LEP, black men and women had poorer performance than whites ($P < .05$). The conclusions of the statistical analyses were similar when the results of each individual performance test were used or when the results of both tests were combined in the overall LEP score. Therefore, only the results for the overall LEP score are presented in the paper.

The association between muscle area and LEP is shown in Table 3. In men, after adjustment for clinic site, age, and body height, those with a lower muscle area had a poorer LEP, which was maintained after adjustment for total body fat. The association between muscle area and LEP became significant in women after adjustment was made for total body fat (Model 2). Additional adjustment for lifestyle parameters, education, and health status only slightly reduced the strength of the associations in men and women. No interactions were observed between race and muscle area in men or women ($P > .7$), indicating that, in all four race-sex groups, lower muscle area was similarly associated with poorer LEP.

To specifically investigate the effect of total body fat on the association between midthigh muscle area and LEP, we performed an additional analysis. For each gender and race group, the population was divided into tertiles of total body fat and midthigh muscle area. Clear trends in LEP across tertiles of total body fat (P = .0001) and across tertiles of midthigh muscle area (P = .0001) were observed (Figure 1). Among persons in the highest tertile of total body fat, those with smaller midthigh muscle area had poorer performance than those with larger muscle area (P = .007). Similar results were obtained in persons in the medium tertile of total body fat (P =

Table 1. Characteristics of Participants in the Health, Aging and Body Composition Study (1997/98)

	Men		Women	
Characteristic	White (n = 913)	Black (n = 529)	White (n = 839)	Black (n = 698)
Age, years, mean ± SD	73.9 ± 2.9	73.5 ± 2.8‡	73.6 ± 2.8	73.4 ± 3.0
Body mass index, kg/m², mean ± SD	27.0 ± 3.7	27.1 ± 4.2	26.0 ± 4.6	29.6 ± 5.8‡
Body weight, kg, mean ± SD	81.4 ± 12.4	81.0 ± 14.3	66.2 ± 12.2	75.5 ± 15.6‡
Height, meters, mean ± SD	1.73 ± 0.06	1.73 ± 0.07	1.60 ± 0.06	1.59 ± 0.06
Total body fat, kg, mean ± SD	21.6 ± 6.7	20.0 ± 7.2‡	24.9 ± 7.7	29.2 ± 9.8‡
Mid-thigh muscle area, cm², mean ± SD	255 ± 38	277 ± 49‡	170 ± 28	202 ± 33‡
Mid-thigh muscle attenuation, HU, mean ± SD	37.4 ± 6.4	37.1 ± 6.4	34.7 ± 6.7	32.4 ± 7.1‡
Number of diseases, mean ± SD*	1.1 ± 0.9	1.1 ± 1.0	1.0 ± 0.8	1.3 ± 0.9‡
Physical activity, kcal/week, mean ± SD	1,910 ± 3,358	1,174 ± 2,119‡	948 ± 1,501	652 ± 976‡
Memphis clinic site, %	50.9	49.4	54.0	45.7‡
Current smoking, %	9.1	24.7‡	7.5	12.8‡
Low education, %†	12.8	48.1‡	9.4	37.5‡

*Self-reported physician-diagnosed heart disease, lung disease, stroke, diabetes mellitus, arthritis, or hip fracture.
†Less than high school.
‡Significantly different from whites within gender, $P < .05$.
HU = Hounsfield Unit scale, where 0 equals the HU of water and −1,000 equals the HU of air; SP = standard deviation.

.0008) and the lowest tertile of total body fat ($P = .005$). These results confirm the previous analyses and show that midthigh muscle area and total body fat are independently associated with LEP.

Table 4 shows the association between muscle composition and LEP. Higher muscle attenuation (indicating less fat infiltration into muscle tissue) was associated with better LEP in men and women (Model 1). Because high total body

Table 2. Lower Extremity Performance of Participants in the Health, Aging and Body Composition Study: Distribution and Mean of Walking, Repeated Chair Stands, and Lower Extremity Performance Score

	Men		Women	
Test	White	Black	White	Black
Six-meter walking score, %				
0 (unable)	0	0	0	0
1 (>5.8 sec)	10.4	28.6	20.2	48.8
2 (5.2–5.8 sec)	19.5	26.8	23.9	27.7
3 (4.6–5.1 sec)	27.8	25.0	32.9	13.9
4 (<4.6 sec)	42.3	19.6†	23.0	9.6†
Repeated (5x) chair-stand score, %				
0 (unable)	1.4	3.2	2.6	4.7
1 (>16.1 sec)	14.2	28.2	23.6	36.0
2 (13.8–16.1 sec)	22.8	28.7	23.4	23.2
3 (11.6–13.7 sec)	26.5	20.6	27.9	19.8
4 (<11.6 sec)	35.1	19.3†	22.5	16.3†
Lower extremity performance score, %*				
0	0	0	0	0
1	0.6	1.7	1.0	4.2
2	3.7	12.6	9.4	22.1
3	6.7	16.2	12.4	19.2
4	11.5	19.2	15.9	19.1
5	17.4	17.0	18.9	16.2
6	20.2	15.4	17.4	10.2
7	19.8	11.0	16.0	5.4
8	20.1	6.9†	9.0	3.6†
Walking score, mean ± SD	3.0 ± 1.0	2.4 ± 1.1†	2.6 ± 1.1	1.8 ± 1.0†
Chair stands score, mean ± SD	2.8 ± 1.1	2.2 ± 1.2†	2.4 ± 1.2	2.1 ± 1.2†
Lower-extremity score, mean ± SD	5.8 ± 1.7	4.6 ± 1.8†	5.0 ± 1.8	3.9 ± 1.8†

*Sum of walking score and repeated chair-stand score.
†Significantly different from whites within gender, $P < .05$.
SD = standard deviation.

Table 3. Regression Coefficients Per Standard Deviation Increase in Mid-Thigh Muscle Area (cm^2) in Relation to Lower Extremity Performance by Gender and Race of Participants in the Health, Aging and Body Composition Study

	Men		Women	
	White	Black	White	Black
Model	mean ± standard error			
1[†]	0.401 ± 0.086**	0.381 ± 0.090**	0.009 ± 0.133	0.125 ± 0.115
2[‡]	0.658 ± 0.090**	0.519 ± 0.103**	0.547 ± 0.145**	0.435 ± 0.122**
3[§]	0.590 ± 0.090**	0.457 ± 0.101**	0.509 ± 0.141**	0.427 ± 0.118**

[†]Adjusted for clinic site, age and body height.
[‡]Additionally adjusted for total body fat.
[§]Additionally adjusted for education, physical activity, health status and smoking.
**$P < .01$.

fat is associated with lower muscle attenuation[14,19] and poorer LEP,[3,5,6] it was considered an important confounder in the relationship between muscle attenuation and LEP. In Model 2, we therefore adjusted for total body fat. As expected, the association between muscle attenuation and LEP was reduced in most groups after additional adjusting for total body fat but remained statistically significant (Model 2). The association also remained statistically significant after additional adjustment for education, health status, and lifestyle variables (Model 3). The final model (Model 4) shows that the association between muscle attenuation and LEP is independent of the amount of muscle at the midthigh. No interaction between race and muscle attenuation was observed in men ($P = .27$) or women ($P = .17$).

An additional analysis, in which differences in LEP were investigated across gender- and race-specific tertiles of midthigh muscle attenuation and total body fat, showed clear trends for midthigh muscle attenuation ($P = .0001$) and total body fat ($P = .0001$, Figure 2). Moreover, among the persons in the highest tertile of total body fat, those with low midthigh muscle attenuation had a poorer LEP than those with high midthigh muscle attenuation ($P = .0005$). A similar association was observed among persons in the medium ($P = .2$) and lowest tertile of total body fat ($P = .009$).

To investigate which body composition measure (muscle area, muscle attenuation, or total body fat) was most strongly associated with LEP, we included these variables and potential confounders in a single regression model (similar to Model 4 of Table 4) and calculated the standardized regression coefficients (Table 5). The advantage of standardized regression coefficients is that they are unitless and allow a direct comparison between different independent variables. In men, muscle area was most strongly associated with LEP, followed by muscle attenuation and total body fat. Total body fat was not an independent determinant of LEP in black men ($P = .20$). In women, a different result was obtained. Total body fat was most strongly associated with LEP, followed by muscle area and muscle attenuation.

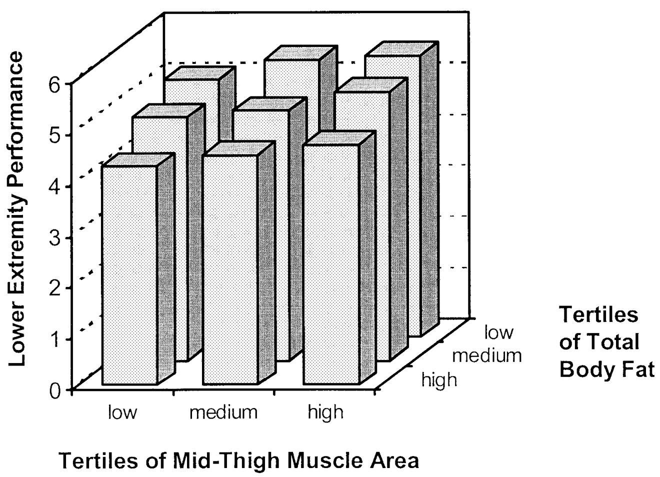

Figure 1. Lower extremity performance, adjusted for potential confounders, by gender- and race-specific tertiles of midthigh muscle area (cm^2) and total body fat (kg) in participants of the Health, Aging and Body Composition study. A trend was observed across muscle groups ($P = .0001$) and across fat groups ($P = .0001$).

DISCUSSION

The results of our study show that lower leg muscle mass and lower muscle attenuation, indicative of greater fat infiltration in the muscle, are associated with poorer LEP in older men and women. Moreover, the observed associations were similar between blacks and whites and independent of overall body fatness. Our results are based on a large population-based study that incorporated state-of-the-art methods to determine muscle area and muscle attenuation and used objective performance tests to determine physical functioning.

A previous study using DXA to assess appendicular skeletal muscle mass showed an inverse relationship between muscle mass and self-reported disability. Older men and women with low muscle mass were three to four times more likely to report disability, and older men with low muscle mass were more likely to have balance abnormalities and to use a walker or cane.[4] Our study extends these findings to a well-functioning population by showing that low muscle area is associated with poor LEP. These results support the hypothesis that the loss of muscle mass with aging, also called sarcopenia, is associated with a decline in physical function and disability.

Table 4. Regression Coefficients Per Standard Deviation Increase in Mid-Thigh Muscle Attenuation (HU) in Relation to Lower Extremity Performance by Gender and Race of Participants in the Health, Aging and Body Composition Study

	Men		Women	
	White	Black	White	Black
Model	mean ± standard error			
1†	0.392 ± 0.061**	0.286 ± 0.086**	0.419 ± 0.065**	0.365 ± 0.065**
2‡	0.305 ± 0.073**	0.346 ± 0.102**	0.242 ± 0.075**	0.232 ± 0.073**
3§	0.283 ± 0.072**	0.279 ± 0.100**	0.204 ± 0.074**	0.179 ± 0.072*
4‖	0.292 ± 0.071**	0.244 ± 0.100*	0.193 ± 0.073**	0.159 ± 0.072*

†Adjusted for clinic site and age.
‡Additionally adjusted for total body fat.
§Additionally adjusted for education, physical activity, health status and smoking.
‖Additionally adjusted for thigh muscle area.
$^{*}P < .05$; $^{**}P < .01$.
HU = Hounsfield Unit scale, where 0 equals the HU of water and −1,000 equals the HU of air.

A unique aspect of the study was the inclusion of in vivo measurements to determine the composition of the muscle in addition to the total muscle area. We observed that lower muscle attenuation, indicative of greater fat infiltration in the muscle, was associated with poorer LEP. Our results support the findings of a small study in older women showing that a greater relative proportion of adipose fat within the quadriceps muscle was inversely associated with walking speed.[10] Because our data were cross-sectional, we cannot address whether there is a causal relationship between fat infiltration in muscle and physical function. Low muscle attenuation has been associated with poor knee extensor strength.[11] Whether fat in the muscle may directly affect muscle contractility (cellular function), muscle fiber recruitment (nerve function), or muscle metabolism (energy utilization), thereby affecting muscle strength and physical function is unknown. An indirect relationship between muscle attenuation and physical function can also be hypothesized. Several studies have shown that greater fat content in the muscle is associated with glucose intolerance and diabetes mellitus[23,24] and that diabetes mellitus may lead to poor physical performance and disability.[25,26] In our analyses, adjustment for self-reported physician-diagnosed diseases, including diabetes mellitus, did not markedly effect the observed associations. However, we cannot exclude the possibility that low muscle attenuation is associated with subclinical disease that may affect physical function of older persons.

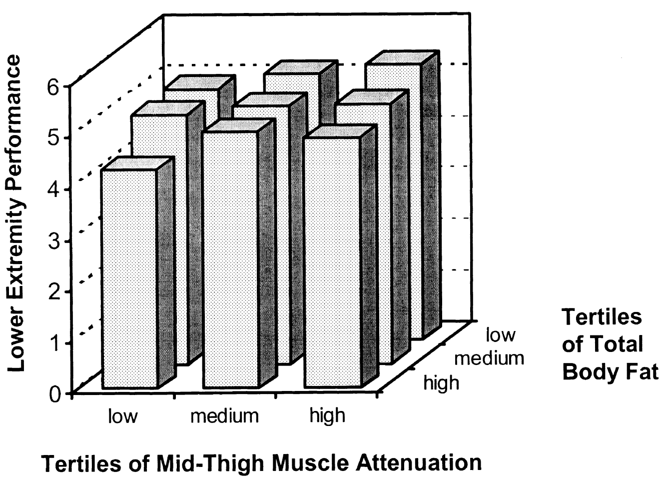

Figure 2. Lower extremity performance, adjusted for potential confounders, by gender- and race-specific tertiles of midthigh muscle attenuation (HU) and total body fat (kg) in participants of the Health, Aging and Body Composition study. A trend was observed across attenuation groups ($P = .0001$) and across fat groups ($P = .0001$).

Our results provided no indication for racial differences, nonlinearity, or a threshold effect for any of the relationships under study in this cohort. This suggests that an increase in muscle mass or muscle attenuation would be beneficial to LEP, regardless of race and baseline level. Fortunately, both muscle mass and muscle attenuation have been shown to be modifiable even in old age. An increase in muscle mass after exercise training, specifically resistance training, has been reported in several studies in older persons.[12,13] In addition, weight loss or a combina-

Table 5. Standardized Regression Coefficients of Mid-Thigh Muscle Area, Mid-Thigh Muscle Attenuation, and Total Body Fat in Relation to Lower Extremity Performance by Gender and Race of Participants in the Health, Aging and Body Composition Study

	Men		Women	
Measurement	White	Black	White	Black
Muscle area, cm²	0.242**	0.208**	0.135**	0.138**
Muscle attenuation, HU	0.156**	0.114*	0.101*	0.088*
Total body fat, kg	−0.153**	−0.075	−0.255**	−0.194**

Note: Adjusted for clinic site, age, body height, education, physical activity, health status, and smoking.
$^{*}P < .05$; $^{**}P < .001$.
HU = Hounsfield Unit scale, where 0 equals the HU of water and −1,000 equals the HU of air.

tion program of walking and weight loss has been shown to increase muscle attenuation.[14,24] The positive effect of physical activity on physical function in older men and women may be partly mediated by its effect on muscle mass and muscle attenuation.

Previous studies from our group have consistently shown an association between high body fat content and poor performance.[3,5,6] Whether muscle characteristics have a relatively greater effect on LEP than on total body fat is not known. We therefore investigated which body composition component (muscle mass, muscle composition, or total body fat) was most strongly associated with LEP. Muscle mass and muscle attenuation were positively associated with LEP, whereas total body fat was inversely associated with LEP. A clear gender difference was observed. Although muscle area was most strongly associated with LEP in men, in women, total body fat was most strongly associated. These results may suggest that interventions to improve LEP through changes in body composition should have a different emphasis in men and women.

Work by our group and others suggests that the calibration of the QDR4500A DXA scanner produces lower total fat mass estimates than previous generations of Hologic whole body scanners[27] and lower total fat mass estimates than those based on alternative methods for assessing body composition.[28–30] We repeated our analyses using a preliminary correction factor for fat-free mass and fat mass derived from comparison of the QDR4500A with a four-compartment model.[28] Our results did not differ materially using this correction factor.

Several limitations of the study should be addressed. First, participants of the Health ABC study had to report no mobility disability at the baseline of the study. Therefore, our results are obtained in a well-functioning cohort and will not be generalizable to all persons aged 70 to 79. This selection bias may have caused an underestimation of the observed associations, because disabled persons (who are likely to have poorer muscle strength and lower muscle mass) were excluded from the study. However, older persons comparable with our study participants are most likely to be included in intervention studies focussing on the prevention of mobility loss. Second, we have used muscle attenuation as measured in vivo with CT as an indicator of fat infiltration in the muscle. No muscle biopsies were available in our study to directly determine the fat content of muscle tissue. However, the fat and triglyceride content of muscle tissue measured in percutaneous biopsy specimens from the vastus lateralis has been shown to be negatively correlated with midthigh muscle attenuation.[18] In addition, good correlations between tissue attenuation measured by CT and histological or chemical assessment of tissue fat content has been observed for other organs.[31]

In conclusion, smaller midthigh muscle area and lower midthigh muscle attenuation are associated with poorer LEP in well-functioning black and white men and women aged 70 to 79 years. These results suggest that that loss of muscle mass and greater fat infiltration in the muscle with aging may contribute to poor physical performance and subsequent disability. Future studies using longitudinal data are needed to further investigate whether change in muscle mass and change in muscle attenuation are predictive of change in LEP in older persons and to establish causality.

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