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Skeletal muscle contractile and noncontractile components in young and older women and men

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Kent-Braun, Jane A., Alexander V. Ng, and Karl Young. Skeletal muscle contractile and noncontractile components in young and older women and men. *J. Appl. Physiol.* 88: 662–668, 2000.—To examine the influences of age, gender, and habitual physical activity level on human skeletal muscle composition, we developed a relatively simple magnetic resonance imaging method for the quantitation of leg anterior compartment contractile and noncontractile content. We studied 23 young (11 women and 12 men, 26–44 yr old) and 21 older (10 women and 11 men, 65–83 yr old) healthy adults. Analysis was by two-factor (age, gender) ANOVA. Physical activity, quantitated by three-dimensional accelerometer worn about the waist for 1 wk, was not different between groups. Men had larger contractile and noncontractile cross-sectional areas (cm^2) than women, with no gender effect on percent noncontractile area. Young subjects had larger contractile areas and smaller absolute (cm^2) and relative (percent total) noncontractile areas than older subjects. There was a significant linear relationship between physical activity and percent noncontractile area in older ($r = -0.68$, $P = 0.002$) but not young subjects. These data demonstrate a more than twofold increase in the noncontractile content of locomotor muscles in older adults and provide novel support for physical activity as a modulator of this age-related change in muscle composition.

muscle function; aging; physical activity; fat; gender

IN HUMANS, LEAN BODY MASS decreases with age, whereas fat mass may remain the same or increase (4). Loss of skeletal muscle tissue contributes significantly to the loss of lean body mass that occurs with aging (10). These age-related changes in body composition have important implications in large-scale epidemiologic studies of health and functional capacity and small-scale mechanistic studies of muscle function (7). For example, in addition to the association between body fat and risk factors for cardiovascular disease and diabetes (5, 17, 33), low muscle mass (3) and high percent body fat (34) were shown recently to be associated with increased disability in older adults. Likewise, lower muscle mass has been implicated as the primary factor in the significant loss of muscle strength of older adults (10).

Although the largest site of increased fat deposition with aging is generally the abdomen (4, 28), it has been demonstrated in some muscle groups that there is also a significant age-related increase in intramuscular fat (8, 9, 14, 22, 32). In addition, a biopsy study showed higher intramuscular fat content in the quadriceps muscle of women than of men (8). The possibility that men and women age differently with respect to the accumulation of intramuscular fat stores has not been fully explored.

Use of estrogen replacement therapy (ERT) by postmenopausal women has become commonplace in certain segments of the population. Some investigators have suggested that ERT preserves specific strength (strength per unit muscle mass) relative to postmenopausal women not using ERT (23). However, data concerning fat-free muscle mass were not reported in this previous study, nor was the intramuscular fat content examined. Thus the extent to which changes in muscle composition are associated with long-term ERT is not known.

It is reasonable to expect that habitual physical activity level may modify the changes in muscle and body composition that occur with aging (11, 29, 30). For example, exercise training has been shown in young men to increase the utilization of intramuscular fat stores during exercise (12). Presumably, this effect may alter muscle composition over time. However, the effects of physical activity level on muscle composition in healthy older men and women have not been fully clarified. Although questionnaires have been used in a number of studies to estimate activity level, some limitations in the sensitivity of questionnaire assessments (20) may render them less useful for small-scale mechanistic studies of muscle function. An objective measure of physical activity may be more appropriate in these types of studies.

The assessment of muscle quality (strength per unit muscle) requires an accurate assessment of the contractile content of muscle (22). In humans, anthropometric measures of muscle girth may not accurately reflect muscle mass or size, inasmuch as the contribution to girth from subcutaneous and intramuscular fat stores cannot be determined from these measures (27). Although subcutaneous fat content can be estimated using skinfold calipers, intramuscular fat content is best quantitated using computed tomography (22, 27) or magnetic resonance imaging (MRI) (19). MRI provides a safe, reliable method of noninvasively and

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repeatedly measuring the composition of human muscle compartments. This technique has become more accessible and simpler to use than in the past and, thus, can now be used to address a variety of experimental questions in the area of human muscle composition.

Here, we report a relatively simple method for using MRI to quantitate contractile and noncontractile areas of the ankle dorsiflexor muscles of healthy young and older volunteers. Using a cross-sectional design, we tested the hypotheses that older women and men would have *1*) smaller contractile cross-sectional areas (CSA) and *2*) more intramuscular noncontractile tissue (e.g., fat) than young women and men of similar physical activity levels. Secondary purposes of this study were to examine gender-related differences in muscle composition and to explore the effects of long-term ERT on muscle composition and size in postmenopausal women.

METHODS

Subjects. Healthy young (25–45 yr old) and older (65–85 yr old) adults were recruited for this study, with an attempt to recruit a balanced number of men and women in each group. Aside from those women using ERT, all subjects were free from disease or medication that might be expected to affect our measurements. All older subjects were nonedematous. Edema was checked using the standard clinical assessment of firmly palpating the soft tissue at the ankle and observing the presence or absence of pitting (residual impression of the thumb). In addition to the measures described below, maximal leg circumference was obtained using a tape measure, with the subject seated and the knee extended.

All women in the older group were ≥10 yr postmenopause. Five of the postmenopausal women were using ERT [72 ± 5 (SD) yr, 165 ± 9 cm, 62 ± 12 kg], and five women were not (75 ± 6 yr, 162 ± 11 cm, 65 ± 16 kg). The ERT group had been using ERT for ≥7 yr. Three women were on conjugated estrogens (Premarin), one woman was on conjugated estrogens and progestin (Premarin and Provera), and one woman was on esterified estrogens and methyltestosterone (Estratest).

All volunteers were screened and selected to be relatively sedentary (no more than ~2 exercise periods of <20 min/wk in the previous 3 mo). To account for any remaining differences in habitual physical activity patterns, as well as to obtain quantitative information regarding activity, each subject's daily activity was measured for 7 days with a three-dimensional accelerometer (Tritrac, Professional Products, Madison, WI). Briefly, the monitor was worn at the waist for 7 days during waking hours, the vector magnitude of acceleration in all three dimensions was recorded continuously, and the data were averaged over the 7-day period and reported as average daily activity, as described previously (20). Specifically, the data were averaged for all 168 h (7 days for 24 h) and divided by 7 to obtain the daily average. For ease of presentation, the vector magnitude average was then divided by 1,000 and reported as arbitrary units (AU). All subjects provided informed consent in accordance with university requirements. Portions of the physical activity and contractile CSA data have been reported previously (15).

Muscle compartment contractile and noncontractile measurements. Proton T1-weighted magnetic resonance axial images of the anterior compartment of the leg were acquired using a 31-cm-diameter extremity coil in a 1.5-T whole body magnet with a Siemen spectrometer, as performed previously (16). The right leg was studied in all cases, and data were acquired with the subject in a supine position. The belly of the tibialis anterior muscle (primary dorsiflexor in the anterior compartment) was located using a sagittal scout image, and the grid for the transverse (axial) slices was centered at the belly of this muscle. This procedure ensured inclusion of the maximal anterior compartment CSA in our image acquisitions.

The image parameters were as follows: echo time of 14 ms, field of view equal to 210 mm^2, matrix equal to 256 × 256, slice thickness of 4 mm, 33 slices, 1 acquisition, total acquisition time of ~5 min. These parameters were selected to optimize differences in signal intensity between contractile and noncontractile tissue. Slices were acquired in two passes, with a 4-mm gap between slices on each pass and the second pass offset by 4 mm relative to the first pass. This procedure allowed acquisition along the entire length of the muscle belly while cross talk between adjacent slices was prevented. Before analysis, the 33 slices were arranged anatomically (total length 132 mm), and the single slice with the largest anterior compartment was selected (with a fixed outline of the compartment as a guide) for full analysis. All image analyses were performed by the same investigator, who was blinded as to the subject's age and gender.

Software written in Interactive Data Language (Research Systems, Boulder, CO) allowed for the separate quantitation of contractile (muscle) and noncontractile (mainly fat) components of the anterior compartment of the leg, which contains the ankle dorsiflexor muscles. This method is illustrated in Fig. 1. The distinction between components was achieved on the basis of the signal intensity of the individual pixels. The software first displayed the MRI of the leg in cross section. The investigator then drew a roughly rectangular region of interest containing ~50% muscle and 50% subcutaneous fat (Fig. 1*A*). The software calculated and displayed an intensity histogram for the selected region, which typically contained two distinct peaks separated by a region of very low signal (Fig. 1*B*). The peak with the lower signal intensity reflects muscle, and the higher intensity peak reflects fat. The investigator then placed an intensity threshold just to the right of the muscle peak; everything below this threshold was considered "contractile" tissue and everything above it "noncontractile" tissue. The investigator then outlined the anterior compartment by using anatomic guidelines (Fig. 1*C*), which were clearly discernible on the computer monitor.

The software provided the following output: total compartment CSA (cm^2), contractile tissue CSA (cm^2), noncontractile CSA (cm^2), percent contractile tissue (contractile CSA/total CSA), percent noncontractile tissue (noncontractile CSA/total CSA), signal intensity threshold value, and total number of pixels. The output was downloaded directly into a spreadsheet for statistical analysis. For the purposes of this study, the data reported are *1*) total compartment CSA, *2*) contractile CSA, *3*) noncontractile CSA, and *4*) percent noncontractile tissue. Each subject's image was analyzed three times, and the average values for each variable were recorded. The within-subject variabilities (SD/mean) were established using the data from the three analyses: total compartment area = 1.8%, contractile CSA = 3.4%, percent noncontractile content = 24.3%. The higher variability of the noncontractile measure is consistent with its relatively small area. This variability emphasizes the importance of performing analyses such as these several times to obtain an accurate representation of the true value for each measure.

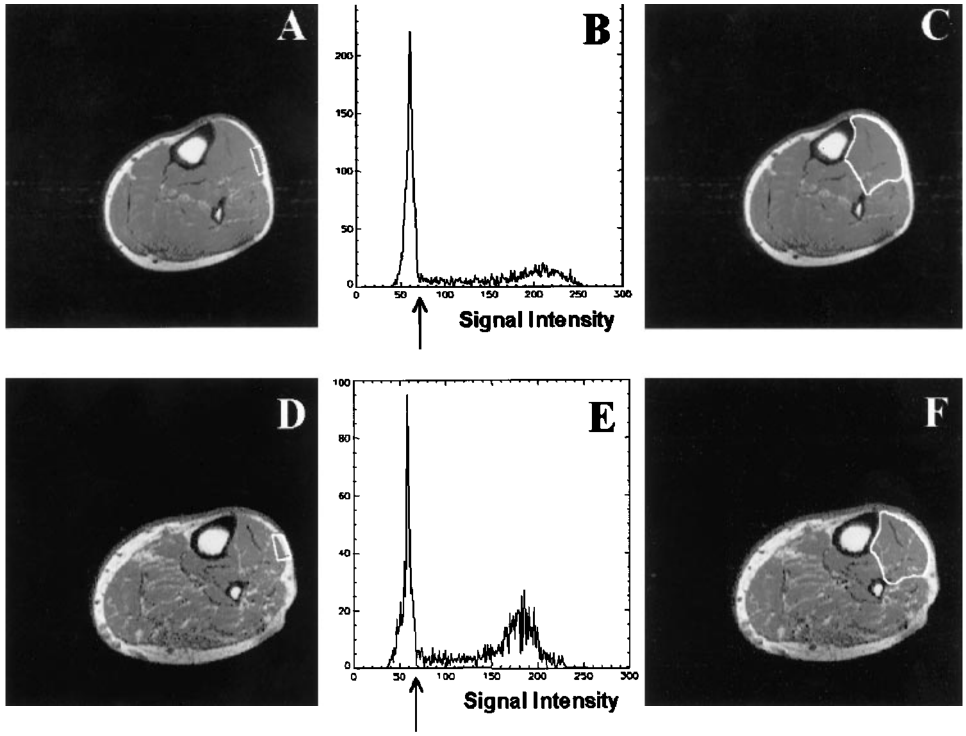

Fig. 1. Method for determining contractile and noncontractile components of muscle compartment in representative young (*A–C*) and older (*D–F*) men. *A*: outline of region of interest (ROI) consisting of ~50% subcutaneous fat and 50% muscle compartment. *B*: signal intensity histogram of ROI from *A*. Peak on *left* corresponds to contractile tissue (muscle); everything above that signal intensity (including broad peak from fat, *right*) corresponds to noncontractile tissue. Arrow, signal intensity threshold. *C*: outline of anterior compartment of leg. All pixels with signal intensity greater than threshold for noncontractile content (as assigned in *B*) are subsequently subtracted from total compartment area to provide contractile and noncontractile areas. *D*, *E*, and *F* correspond to *A*, *B*, and *C*, respectively. Noncontractile content was 4.8% in a young (38-yr-old) man and 15.5% in an older (73-yr-old) man.

Statistical analyses. Anterior compartment total area, contractile and noncontractile CSAs, and noncontractile percent area of the ankle dorsiflexor muscles were analyzed using two-factor (age, gender) ANOVAs. Physical activity was also analyzed with a two-factor ANOVA. The influence of ERT was examined using two-sample *t*-tests within the group of older women. Linear regression was used to examine the associations between physical activity level and anterior compartment contractile (cm^2) and noncontractile (percent area) components. The data are presented as means ± SD, with exact *P* values provided (6). To assist in interpretation of the results and to aid in comparison to other studies, all data are presented by age and gender groups.

RESULTS

Subjects. Twenty-three young and 21 older healthy women and men completed the study. Characteristics of the 33 Caucasian, 6 Asian, 3 Hispanic, 1 African-American, and 1 Native American subjects, including physical activity level, are summarized in Table 1. Leg circumferences were not different between groups, although there was a tendency toward smaller leg girths in the women than in the men ($P = 0.09$). There were no gender or age main effects in mean physical activity level ($P = 0.71$ and 0.16, respectively), although there was a tendency toward an age-by-gender interaction ($P = 0.10$), presumably due to the average values for the young and older women. The ranges in activity (in AU/day) for each group were as follows: 20.7–262.9 for young men, 104.5–317.7 for young women, 86.9–213.0 for older men, and 60.7–198.6 for older women. Thus the young subjects had an approximately twofold greater range in activity than the older adults. Activity data were missing because of subject noncompliance (1 young man and 1 young woman), instrument failure (3 older men), or loss of instrument (1 young woman).

Muscle compartment contractile and noncontractile components. Anterior compartment CSA data are summarized in Table 2. Men had larger total ($P < 0.001$), contractile ($P < 0.001$), and noncontractile ($P = 0.03$) CSAs (cm^2) than women. There was no gender effect on percent noncontractile area. Young subjects had larger contractile ($P < 0.01$) and smaller absolute (cm^2) and relative (percent total) noncontractile areas ($P < 0.001$) than older subjects. There was no age effect on total compartment area ($P = 0.61$). We detected no significant age-by-gender interactions. The range in contractile CSA values was similar in the young women (6.5–10.9 cm^2), older women (4.8–10.3 cm^2), and older men (7.6–13.1 cm^2), whereas the range was somewhat greater in the young men (9.0–17.7 cm^2). In contrast,

Table 1. *Subject characteristics*

Measure	Young Women ($n = 11$)	Older Women ($n = 10$)	Young Men ($n = 12$)	Older Men ($n = 11$)
Age, yr	29.4 ± 4.0	73.2 ± 5.6	33.7 ± 5.3	72.2 ± 5.9
Height, cm	166.7 ± 5.1	163.3 ± 9.6	177.5 ± 10.1	175.0 ± 9.7
Weight, kg	74.0 ± 26.9	63.5 ± 13.3	80.6 ± 15.4	80.4 ± 16.2
Leg circumference, cm	36.9 ± 3.1	37.3 ± 3.8	38.5 ± 3.5	39.0 ± 1.9
Physical activity, AU	185.4 ± 68.4	124.0 ± 50.1	144.9 ± 61.0	150.0 ± 59.2

Values are means ± SD; *n*, no. of subjects. AU, arbitrary units. Men were taller and heavier than women, with no interactions. There were no significant gender or age effects or interactions for leg circumference or physical activity. Group sizes for activity measurement were 9 young women, 10 older women, 11 young men, and 8 older men (see text for details).

Table 2. *Leg anterior compartment total, contractile, and noncontractile CSA, and percent noncontractile area in young and older women and men*

Measure	Young Women (*n* = 11)	Older Women (*n* = 10)	Young Men (*n* = 12)	Older Men (*n* = 11)
CSA, cm^2				
Total	9.3 ± 1.5	9.0 ± 2.1	13.8 ± 2.7	12.5 ± 1.7
Contractile	8.7 ± 1.4	7.7 ± 1.7	13.0 ± 2.3	10.5 ± 1.8
Noncontractile	0.6 ± 0.3	1.3 ± 0.7	0.9 ± 0.5	2.0 ± 1.1
Noncontractile area, %total area	6.0 ± 2.6	13.9 ± 6.6	6.0 ± 2.2	15.6 ± 8.4

Values are means ± SD; *n*, no. of subjects. Total ($P < 0.001$), contractile ($P < 0.001$), and noncontractile ($P = 0.032$) cross-sectional areas (CSAs) were larger in men than in women. There was no gender effect on percent noncontractile area. Contractile CSA ($P = 0.004$) was larger in young than in older subjects, and absolute and relative noncontractile areas ($P < 0.001$) were smaller in young than in older subjects. There was no effect of age on total compartment area, and there were no age-by-gender interactions.

the young men and women had similar, small ranges in values for percent noncontractile area (3.8–10.8 and 3.3–12.5%, respectively), whereas older men and women had a markedly higher range in these values (4.5–30.1 and 4.6–25.7%, respectively).

The older women were grouped by ERT status, and comparisons of physical activity, contractile and noncontractile CSAs, and percent noncontractile area were performed. These data are summarized in Table 3. Contractile CSA was greater with than without ERT, whereas there was no difference in absolute (cm^2) or percent noncontractile areas.

Muscle composition and physical activity. Figure 2 illustrates the relationships between percent noncontractile area and physical activity for the young and older subjects. In the young men and women ($n = 21$), there was no relationship between noncontractile content and activity. In contrast, these variables were inversely related in the older subjects ($n = 18$, $r = -0.68$, $P < 0.01$). For the young and older groups, there was no apparent effect of gender on this analysis (Fig. 2). There was no significant relationship between contractile CSA and physical activity for the young ($r = 0.19$) or older ($r = 0.30$) group.

The percent noncontractile area was inversely related to physical activity in the postmenopausal women ($n = 10$, $r = -0.69$, $P = 0.03$), with no apparent effect of ERT status on this relationship. Physical activity was

Table 3. *Physical activity and muscle compartment contractile and noncontractile content in postmenopausal women with and without ERT*

Measure	Non-ERT	ERT	*P*
Physical activity, AU	97 ± 54	151 ± 30	0.09
CSA, cm^2			
Contractile	6.6 ± 1.6	8.9 ± 1.0	0.03
Noncontractile	1.4 ± 0.6	1.2 ± 0.8	0.67
Noncontractile area, %total area	16.5 ± 7.1	11.4 ± 5.5	0.24

Values are means ± SD of 5 women in each group. ERT, estrogen replacement therapy. Contractile CSA was significantly smaller in non-ERT than in ERT.

not associated with contractile CSA in the postmenopausal women ($r = 0.26$).

DISCUSSION

The primary findings of this study are smaller leg anterior compartment contractile CSAs in older than in young subjects and a two- to threefold increase in intramuscular noncontractile content in older compared with young subjects. In addition, we show that the increase in noncontractile content in older women and men is associated with their habitual physical activity level. Although the men had larger absolute contractile and noncontractile CSAs than the women, there was no gender effect on the percent noncontractile content in this muscle group. The significant inverse association between dorsiflexor muscle percent noncontractile area and habitual physical activity level measured by accelerometer in the older, but not young, adults supports the concept that activity may modify the intramuscular fat deposition observed with aging. Preliminary data concerning the effects of ERT suggest that postmenopausal women using ERT may have larger contractile CSAs than age-matched women not using ERT and noncontractile areas similar to those of age-matched women not using ERT.

Muscle size and composition. As expected, there was a significantly lower contractile area in older than in young women and men. In contrast, there was no effect of age on total compartment area, which was consistent with the lack of difference in the anthropometric measure of leg circumference. Our data indicate that the age-related loss of anterior compartment contractile area was associated with a quantifiable increase in the absolute and relative amounts of intramuscular noncontractile tissue in both genders. Approximately 6% of the anterior compartment of our young men and women was noncontractile tissue compared with ∼15% in the older adults. The magnitude of our observed difference in noncontractile content (∼2.5-fold increase) is in good agreement with previous studies of several muscle groups in older adults. These previous reports indicated the following increases in intramuscular noncontractile content in older adults compared with young subjects: a 2- to 3-fold increase in the quadriceps (8, 14, 22), a 2.5-fold increase in the hamstrings (22), 2- and 2.6-fold increases in the elbow extensors and flexors, respectively (26), and a ∼7-fold increase in the calf muscles (26). Some, but not all, of these studies included men and women. We now provide information related to the absolute and relative noncontractile content of the leg anterior compartment in young and older women and men.

Although there was a greater absolute noncontractile CSA in the men than in the women, we observed no effect of gender on the relative (percent) noncontractile area of the leg anterior compartment (Table 2). Previous studies of gender effects have reported divergent results concerning the relative amount of intramuscular noncontractile tissue: Forsberg et al. (8) found a 2.5-fold higher fat content per kilogram of quadriceps muscle in biopsy samples from women than from men.

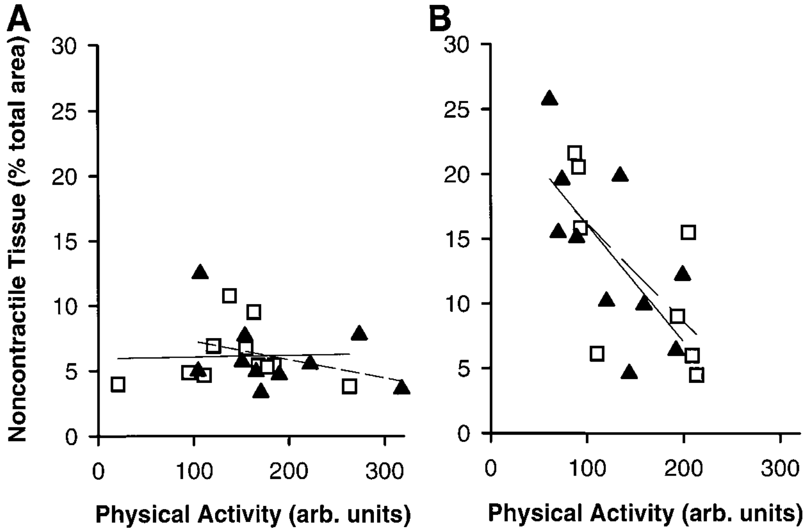

Fig. 2. Relationship between noncontractile tissue content (percent total compartment area) and physical activity in young (*A*) and older (*B*) men (□) and women (▲). arb, Arbitrary. There was no relationship between noncontractile content and physical activity in the young adults ($n = 21$), whereas there was a significant linear relationship between these variables in older adults ($n = 18$, $r = -0.68$, $P = 0.002$). For each plot, dashed lines represent regression for men and solid lines represent regression for women. There was no apparent gender effect on this relationship.

In contrast, Jubrias et al. (14) observed no difference in the noncontractile content of this muscle group, measured using MRI. The differences between these two studies may have been due to the different methods used, volumes sampled, or subjects examined. Our data from the ankle dorsiflexor muscles support a lack of influence of gender on the amount of intramuscular noncontractile content.

Seventy-five percent of the subjects in our study were Caucasian. Although separate analysis of the data with an accounting of ethnic background is beyond the scope of this study, information regarding ethnicity of the subjects is included to provide a point of comparison to epidemiologic studies of body composition and aging (3, 25). As suggested by these and other population-based studies, further information is needed concerning changes in muscle size and composition in persons of different ethnic backgrounds and about the relevance of intramuscular fat accumulation to health and functional capacity in various ethnic groups.

Physical activity. The average physical activity levels for each group (Table 1) were within the range of those observed in a previous study (20) of sedentary control subjects (mean 186 AU/day) and individuals with multiple sclerosis (mean 121 AU/day). Thus our screening procedure successfully provided relatively sedentary groups of similar physical activity levels. By way of comparison, a physically "active" group from the previous study had an average activity of 286 AU/day (20). In this group, activities of 300–340 AU/day corresponded to ~25–30 miles of running per week. Although there are limitations to measuring physical activity with a three-dimensional accelerometer (e.g., level vs. uphill walking is not distinguished, activities such as cycling are underestimated), it has been shown to be a reliable and valid instrument for overall activity assessment (21).

The novel observation of a relationship between percent noncontractile area and physical activity in our older, but not young, subjects suggests that habitual physical activity level plays an important role in the age-related accumulation of intramuscular fat. In other studies, older (66–85 yr) male and female athletes had lower quadriceps intramuscular fat than age- and gender-matched nonathletes (29, 30). A relative decrease in intramuscular fat content, believed to be due mainly to an increase in contractile area, was observed in response to strength-training programs in older women (31). Our results are noteworthy, in that the association between noncontractile content and activity was observed in a group of healthy, although relatively sedentary, older individuals. Furthermore, this association, which was not observed in the young subjects, despite their twofold greater range in activity, was similar in older men and women. Although we have not established causality between fat content and activity level, this observation may have implications related to health, disability, and the risk factors associated with fat accumulation during aging.

We observed no association between contractile CSA and physical activity in our subjects. The tibialis anterior muscle, which is the largest dorsiflexor, is composed of ~75% type I fibers, which have a parallel orientation (13, 16). Inasmuch as the dorsiflexor muscles are primarily used for locomotion, they do not typically perform the type of high-intensity contractions needed to induce muscle hypertrophy. Thus it would appear that, for the anterior compartment of the leg, regular physical activity may be more important in slowing the accumulation of intramuscular fat than in preserving contractile mass as we age.

ERT. These preliminary data indicate that the postmenopausal women using ERT had larger contractile CSAs than those not using ERT, whereas there was no difference in absolute or relative noncontractile areas (Table 3). Although it is perhaps surprising that the increased contractile area in the women using ERT was not associated with a decrease in relative noncontractile area, the small numbers in this preliminary study may have precluded this observation. A post hoc sample size estimate indicated that 25 subjects per group would afford an 80% chance of detecting a difference between women using ERT and those not using ERT in percent noncontractile content of the magnitude indicated in Table 3.

Interestingly, the contractile CSA of the ERT group was similar to that of the young women (Table 2). These data provide some support for the possibility that long-term (≥7 yr) ERT use ameliorates the age-associated loss of muscle mass in postmenopausal women. However, this result must be viewed with caution, inasmuch as other factors may have influenced the observations in this small group of women. For example, Poehlman et al. (24) observed that perimenopausal women who had an accelerated loss of fat-free mass reported reduced physical activity. Others have shown that postmenopausal women using ERT reported greater physical activity than those not using ERT (2). In the present study the lack of association between contractile CSA and physical activity level in the postmenopausal women argues against activity as an important factor in the observed CSA difference. However, full clarification of this issue awaits further study. Overall, our preliminary results suggest that physical activity may be more important in controlling fat deposition in postmenopausal women, whereas ERT may be more important in preserving contractile CSA.

Methodology. Cadaver studies have indicated that MRI is a valid means of quantitating human body and muscle composition (1, 18). In a previous study we observed a strong correlation ($r = 0.82$) between anterior compartment contractile CSA by MRI and average tibialis anterior muscle single-fiber CSA by biopsy (16). Narici et al. (19) argued that MRI is superior to computed tomography, because it is able to vary the orientation of the image plane and distinguish different tissue types and does not expose the subject to X-rays. In the present study the variability of the small, noncontractile component was higher than that of the large, contractile CSA. Although this is understandable because of the relatively small proportion of the total area that comprised the noncontractile component, this result emphasizes the need to perform the analysis multiple times.

Advancements in hardware and methodology should soon make MRI an even more valuable tool. Increasing the acquisition number beyond that used in the present study will also improve image quality. Further differentiation of the noncontractile component into fat, connective tissue, blood vessel, and nerve bundles may also prove possible. The method described here is a safe and relatively simple technique and is now widely available on clinical MRI machines.

Conclusion. We conclude that, in addition to a smaller contractile area in older women and men than in gender-matched young subjects, ~6% of the anterior compartment of the leg is noncontractile tissue in men and women aged 26–44 yr and that this value is ~15% in healthy adults >65 yr of age. The lack of influence of gender on percent noncontractile content suggests that intramuscular fat stores accumulate with age in the same manner in men and women. In the older group, habitual physical activity level was significantly associated with the percentage of noncontractile tissue, indicating that physical activity must be treated as an important covariant in studies of aging human skeletal muscle composition and function.

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