Age-related site-specific muscle wasting of upper and lower extremities and trunk in Japanese men and women

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Abstract The purpose of this study was to examine the age-related site-specific muscle loss of the upper and lower extremities and trunk in men and women. Japanese nonobese adults aged 20–79 ($n=1559$, 52 % women) had muscle thickness (MTH) measured by ultrasound at nine sites on the anterior and posterior aspects of the body. An MTH ratio located in the anterior and posterior aspects of the upper arm, upper leg, lower leg, and trunk was calculated. Site-specific muscle loss was defined as a ratio of $MTH > 2$ standard deviations below the mean for young adults in each segment. Age was inversely correlated ($p < 0.001$) to upper-leg MTH ratio in men ($r = -0.463$) and women ($r = -0.541$). Age was correlated positively to upper-arm MTH ratio and inversely to trunk MTH ratio in men ($r = 0.191$ and $r = -0.238$, both $p < 0.001$) and women ($r = 0.102$, $p = 0.004$ and $r = -0.446$, $p < 0.001$). Weak correlations were observed between age and lower-leg MTH ratios in men ($r = 0.015$, $p = 0.682$) and women ($r = 0.086$, $p = 0.015$). The prevalence of site-specific upper-leg muscle loss showed an age-related increasing pattern in men (6 % for ages 30–39, 21 %

for ages 50–59, and 38 % for ages 70–79) and women (15 % for ages 30–39, 32 % for ages 50–59, and 50 % for ages 70–79). For other segments, however, the prevalence rate of site-specific muscle loss was relatively low throughout the age groups in men and women, although higher rates were observed in the older group. These results suggest that the anterior/posterior MTH ratio of the upper leg may be useful in providing an earlier diagnosis for site-specific muscle loss.

Keywords Aging · Thigh muscle thickness · Skeletal muscle mass · B-mode ultrasound

Introduction

A limited number of studies have reported that the electromyogram (EMG)-determined muscle activity patterns during daily life activities differ between muscle groups located in the anterior and posterior aspects of the limbs (Sawai et al. 2006; Shirasawa et al. 2009). Klein et al. (2010) examined muscle activity in the quadriceps during 24 h of daily activity using EMG and found that the anterior upper-leg muscle (vastus lateralis) was active for a short amount of time (1–3 h) and at relatively low intensities (3–12 % of maximal voluntary isometric strength), although only one muscle was measured. Recent studies have demonstrated that an age-related site-specific loss of muscle mass is observed in Japanese men and women (Abe et al. 2011a) and in German men (Abe et al. 2011b), especially for

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the anterior upper leg (Ogawa et al. 2012a). A follow-up observation of approximately 9 years also observed a significant reduction in anterior mid-thigh muscle cross-sectional area (CSA), while posterior muscle CSA did not change (Frontera et al. 2008). The age-related site-specific muscle loss of the anterior upper leg is inversely associated with zigzag walking performance, but not with maximal walking speed in middle-aged and older women (Abe et al. 2012a). In addition, this site-specific muscle loss of the anterior upper leg is positively correlated to one-leg standing balance in active healthy women before adjusting for physical activity level (Abe et al. 2013a). The site-specific upper-leg muscle loss may lead to increased functional impairment of specific task performance.

Recently, we defined site-specific upper-leg muscle loss using ultrasound-measured muscle thickness (MTH) at the anterior and posterior aspects of the upper leg (Abe et al. 2013b). The prevalence of site-specific upper-leg muscle loss displayed an age-related increasing pattern in both men and women, and it appears before it is able to be detected at the whole-body level. However, it is unclear whether the age-related site-specific muscle loss appears in other extremities and in the trunk in men and women. In the present study, we examined the age-related changes in anterior and posterior MTH ratios of the upper and lower extremities and trunk and compared the prevalence of site-specific muscle loss in those extremities and trunk across different age groups in men and women.

Methods

Subjects

Subjects were recruited from individuals who had received a community-based general health examination (age was ≥ 35 years, and the screening rate was approximately 50 %) as well as individuals who had taken culture classes at a community school. Younger adults (age 20–34 years) were recruited through printed advertisements and by word of mouth from the university campus and surrounding area. Prior to obtaining informed consent, a written description of the purpose of the study and its safety was distributed to potential subjects. All subjects were free of overt chronic disease (e.g., diabetes, angina, myocardial infarction, cancer, and stroke) as assessed by self-report. In addition, according

to the WHO (2000), obesity is defined as a body mass index of ≥ 30 kg/m², and subjects with a higher body mass index (BMI, ≥ 30 kg/m²) were also excluded in order to increase the similarity of BMIs between groups and limit the influence of adiposity on muscle mass. As a result, 746 men and 813 women aged 20–79 years were used for data analyses (Tables 1 and 2). This study was conducted according to the Declaration of Helsinki and was approved by the Ethics Committee for Human Experiments of the academic institute.

Skeletal muscle mass and muscle thickness ratio

Total skeletal muscle mass (SM) was estimated from an ultrasound-derived prediction equation that converted muscle thickness (MTH) to SM (Sanada et al. 2006). A strong correlation ($R^2=0.94$) has previously been observed between magnetic resonance imaging-measured total SM and ultrasound-predicted total SM (Sanada et al. 2006). Recently, we examined the relationship between dual-energy X-ray absorptiometry (DXA)-estimated appendicular lean tissue mass and ultrasound-predicted total SM and found that there is a strong correlation ($R^2=0.95$) between the two methods (Abe et al. 2013c). MTH was measured using a B-mode ultrasound (Aloka SSD-500, Tokyo, Japan) at nine sites on the anterior and posterior aspects of the body (forearm, upper arm, trunk, upper leg, and lower leg) as previously described (Abe et al. 1994). The measurements were taken while the subjects stood with their elbows and knees extended and relaxed because MTH for the prediction equation of SM was measured in a standing position. A 5-MHz scanning head was placed on the measurement site without depressing the dermal surface. The subcutaneous adipose tissue–muscle interface and the muscle–bone interface were identified from the ultrasonic image, and the distance between two interfaces was recorded as MTH. Test–retest reliability of MTH measurements using intraclass correlation coefficient ($ICC_{3,1}$), standard error of measurement (SEM), and mean difference was previously determined from 15 middle-aged subjects for anterior (0.88, 0.08 cm, and 0.00 cm) and posterior (0.96, 0.08 cm, and 0.04 cm) upper arm and anterior (0.98, 0.07 cm, and 0.01 cm) and posterior (0.95, 0.10 cm, and 0.04 cm) upper leg. To evaluate site-specific muscle loss of each segment, the anterior-to-posterior MTH ratios of the upper arm, trunk, upper leg, and lower leg were calculated.

Table 1 Body composition and muscle thickness of men ($n=746$) in each age group

	Age group (years)						<i>p</i> -value
	20–29	30–39	40–49	50–59	60–69	70–79	
<i>N</i>	103	108	180	167	125	63	
Age (year)	24 (3) ^{bcd}	35 (3) ^{ac}	44 (3) ^{ab}	55 (3) ^{ab}	65 (3) ^{ab}	73 (3) ^{ab}	<0.001
Height (cm)	171 (6) ^c	169 (6) ^d	167 (6) ^d	164 (5) ^{ab}	162 (6) ^{ab}	161 (5) ^{ab}	<0.001
Body mass (kg)	66.0 (9.1) ^e	67.6 (8.5) ^d	65.4 (8.0) ^e	63.9 (8.0) ^b	60.9 (7.9) ^{ab}	58.6 (8.4) ^{ab}	<0.001
Body mass index (kg/m ²)	22.7 (2.7) ^d	23.8 (3.0) ^a	23.5 (2.7)	23.7 (2.5) ^a	23.2 (2.5)	22.5 (2.7) ^b	0.002
Body fat (%)	18.9 (5.2)	20.3 (5.3)	19.7 (4.2)	19.3 (3.4)	18.7 (3.7)	19.8 (4.1)	0.042
Fat-free mass (kg)	53.2 (5.8) ^d	53.6 (5.0) ^d	52.4 (5.4) ^e	51.3 (5.0) ^{ab}	49.2 (5.3) ^{ab}	47.0 (5.2) ^{ab}	<0.001
Muscle thickness (cm)							
Forearm anterior	2.37 (0.31) ^c	2.28 (0.29) ^d	2.22 (0.29) ^a	2.16 (0.26) ^{ab}	2.08 (0.28) ^{ab}	1.90 (0.29) ^{ab}	<0.001
Upper-arm anterior	3.05 (0.35) ^f	3.11 (0.35) ^e	3.07 (0.35) ^e	3.07 (0.33) ^e	2.93 (0.36) ^b	2.77 (0.39) ^{ab}	<0.001
Upper-arm posterior	3.40 (0.63) ^e	3.47 (0.61) ^e	3.51 (0.54) ^e	3.39 (0.59) ^e	3.08 (0.56) ^{ab}	2.74 (0.63) ^{ab}	<0.001
Trunk anterior	1.42 (0.28) ^b	1.27 (0.21) ^a	1.20 (0.22) ^a	1.14 (0.19) ^{ab}	1.03 (0.18) ^{ab}	0.97 (0.16) ^{ab}	<0.001
Trunk posterior	2.35 (0.55) ^e	2.39 (0.46) ^d	2.27 (0.50) ^e	2.17 (0.41) ^b	2.10 (0.45) ^{ab}	1.98 (0.39) ^{ab}	<0.001
Upper-leg anterior	5.31 (0.67) ^c	5.09 (0.67) ^d	4.79 (0.64) ^{ab}	4.48 (0.63) ^{ab}	4.05 (0.63) ^{ab}	3.83 (0.77) ^{ab}	<0.001
Upper-leg posterior	5.90 (0.64) ^e	5.95 (0.59) ^e	5.76 (0.58) ^f	5.85 (0.64) ^f	5.63 (0.62) ^{ab}	5.47 (0.71) ^{ab}	<0.001
Lower-leg anterior	3.03 (0.29) ^d	2.96 (0.30) ^d	2.93 (0.30) ^d	2.81 (0.32) ^{ab}	2.72 (0.33) ^{ab}	2.74 (0.42) ^{ab}	<0.001
Lower-leg posterior	6.92 (0.48) ^c	6.86 (0.56) ^d	6.68 (0.51) ^a	6.52 (0.53) ^{ab}	6.22 (0.66) ^{ab}	6.17 (0.61) ^{ab}	<0.001

Significance set at $p<0.05$ ^a Significant group difference from age 20–29^b Significant group difference from age 30–39^c Significant group difference from age 40–49^d Significant group difference from age 50–59^e Significant group difference from age 60–69^f Significant group difference from age 70–79

Body composition and anthropometry

Subcutaneous fat thickness was measured using an ultrasound at nine sites, as described previously (Abe et al. 1994). Body density was estimated from subcutaneous fat thickness using an ultrasound-derived prediction equation (Abe et al. 1994). Percent body fat (%fat) was calculated from body density using the method of Brozek et al. (1963). We have reported previously that the standard error of the estimate (SEE) of body density calculated using the ultrasound equations is approximately 0.006 g/ml (or an error of about 2.5 % fat) in a nonobese Japanese population (Abe et al. 1994). Fat-free mass (FFM) was estimated as total body mass minus fat mass. Body mass and standing height was measured to the nearest 0.1 kg and 0.1 cm, respectively, by using an electronic weight scale and a stadiometer. Body

mass index (BMI) was defined as body mass/height² (kg/m²).

Definition of age-related severe muscle loss detected by whole-body muscle mass

Age-related severe muscle loss was defined as a skeletal muscle mass index (SM/height², SM index) value of 2 standard deviations (SD) below the mean for young adults. In a previous study, we reported a SM index of Japanese men (8.6 [SD 0.9] kg/m²) and women (6.0 [SD 0.9] kg/m²) aged 20–30 years as the reference values for men and women (Abe et al. 2013b). Therefore, the reference values for severe muscle loss (2 SD below the sex-specific means) in men and women were 6.8 and 4.2 kg/m², respectively.

Table 2 Body composition and muscle thickness of women ($n=813$) in each age group

	Age group (years)						<i>p</i> -value
	20–29	30–39	40–49	50–59	60–69	70–79	
<i>N</i>	124	83	146	195	189	76	
Age (years)	23 (3) ^{bcdef}	35 (3) ^{acdef}	44 (3) ^{abdef}	55 (3) ^{abcef}	64 (3) ^{abcdf}	73 (3) ^{abcde}	<0.001
Height (cm)	159 (5) ^{bcdef}	156 (5) ^{adef}	155 (5) ^{adef}	151 (6) ^{abcf}	150 (6) ^{abcf}	148 (6) ^{abcde}	<0.001
Body mass (kg)	52.0 (6.0) ^d	52.0 (6.2) ^d	54.0 (6.6) ^f	54.6 (8.4) ^{abf}	53.7 (7.2) ^f	49.7 (8.5) ^{cde}	<0.001
Body mass index (kg/m ²)	20.5 (2.1) ^{bcdef}	21.4 (2.3) ^{acde}	22.5 (2.6) ^{abde}	23.8 (3.2) ^{abc}	23.9 (3.0) ^{abc}	22.8 (3.7) ^a	<0.001
Body fat (%)	24.2 (4.0) ^{de}	24.3 (4.1) ^{de}	25.6 (4.1) ^d	27.3 (4.7) ^{abc}	26.9 (4.6) ^{ab}	25.2 (6.5)	<0.001
Fat-free mass (kg)	39.2 (3.8) ^f	39.2 (3.5) ^f	40.0 (3.7) ^f	39.4 (4.6) ^f	39.2 (4.3) ^f	36.7 (4.1) ^{abcde}	<0.001
Muscle thickness (cm)							
Forearm anterior	1.70 (0.21) ^{de}	1.73 (0.24)	1.75 (0.24) ^f	1.81 (0.28) ^{af}	1.79 (0.26) ^{af}	1.60 (0.33) ^{cde}	<0.001
Upper-arm anterior	2.05 (0.29) ^{bcdef}	2.24 (0.30) ^{ad}	2.25 (0.29) ^{ad}	2.38 (0.36) ^{abcf}	2.32 (0.37) ^{af}	2.18 (0.30) ^{ade}	<0.001
Upper-arm posterior	2.33 (0.50) ^{cd}	2.35 (0.52) ^c	2.62 (0.58) ^{abf}	2.53 (0.57) ^{af}	2.46 (0.53)	2.28 (0.61) ^{cd}	<0.001
Trunk anterior	1.06 (0.17) ^{bcdef}	0.90 (0.15) ^{adef}	0.91 (0.16) ^{adef}	0.82 (0.14) ^{abcf}	0.79 (0.15) ^{abc}	0.74 (0.20) ^{abcd}	<0.001
Trunk posterior	1.71 (0.37) ^d	1.69 (0.36) ^d	1.70 (0.33) ^d	1.84 (0.38) ^{abcf}	1.81 (0.39) ^f	1.63 (0.35) ^{de}	<0.001
Upper-leg anterior	4.68 (0.59) ^{bcdef}	4.38 (0.57) ^{adef}	4.37 (0.57) ^{adef}	3.99 (0.67) ^{abcef}	3.69 (0.59) ^{abcdf}	3.28 (0.66) ^{abcde}	<0.001
Upper-leg posterior	5.19 (0.55) ^d	5.34 (0.52) ^f	5.38 (0.56) ^f	5.43 (0.61) ^{af}	5.35 (0.65) ^f	5.02 (0.66) ^{bcde}	<0.001
Lower-leg anterior	2.58 (0.28) ^{bdef}	2.41 (0.28) ^{ac}	2.54 (0.28) ^{bef}	2.46 (0.28) ^a	2.45 (0.28) ^{ac}	2.38 (0.29) ^{ac}	<0.001
Lower-leg posterior	6.06 (0.49) ^{def}	5.92 (0.46) ^{ef}	5.91 (0.47) ^{ef}	5.79 (0.50) ^{af}	5.71 (0.50) ^{abcf}	5.49 (0.56) ^{abcde}	<0.001

Significance set at $p<0.05$ ^a Significant group difference from age 20–29^b Significant group difference from age 30–39^c Significant group difference from age 40–49^d Significant group difference from age 50–59^e Significant group difference from age 60–69^f Significant group difference from age 70–79

Definition of age-related site-specific muscle loss

Age-related site-specific muscle loss was defined as an MTH ratio value of 2 SD below the mean for young adults. In a previous study, we reported an upper-leg (thigh) MTH ratio of Japanese men (0.91 [SD 0.12]) and women (0.91 [SD 0.11]) aged 20–29 years as the reference values for men and women (Abe et al. 2013b). Because there are no published site-specific reference values for other segments, we used the mean and SD from the current study (aged 20–29 years) for diagnostic criteria of site-specific muscle loss in the upper arm (0.92 [0.15] for men and 0.92 [0.22] for women), trunk (0.62 [0.13] for men and 0.64 [0.15] for women), and lower leg (0.44 [0.04] for men and 0.43 [0.04] for women). Therefore, the reference values for site-specific muscle loss (2 SD below the sex-specific means) in men and women were, respectively, 0.67 and 0.69 in the

upper leg, 0.62 and 0.48 in the upper arm, 0.36 and 0.34 in the trunk, and 0.36 and 0.35 in the lower leg.

Statistical analysis

Results are expressed as means and SD. The differences between age groups for age, height, body mass, BMI, body fat percent, fat-free mass, MTH, SM index, and MTH ratio were tested for significance by one-way analysis of variance (ANOVA), followed by pairwise comparisons using Tukey's multiple comparison procedure if a significant *F* test was obtained. If variances were unequal, Dunnett's *C* procedure was performed. Pearson product correlations were performed to determine the relationships between age and MTH ratio in each segment. Subjects were classified as having severe muscle loss based on the SM index as well as

having site-specific muscle loss based on the MTH ratio. P -values <0.05 were considered statistically significant.

Results

Age-related change in body composition

In men, BMI was similar among the youngest (ages 20–29) and older (ages 60–69 and 70–79) groups and was higher in both ages 30–39 and 50–59 compared with the youngest group. In women, BMI was higher in middle-aged (ages 40–49 and 50–59) and older (ages 60–69 and 70–79) groups compared with younger (ages 20–29 and 30–39) groups. Percent body fat was similar among age groups in men, while in women, percent body fat was higher in ages 50–59 and 60–69 compared with younger groups. FFM gradually decreased with age for men and was lower in older men (ages 60–69 and 70–79) compared with the younger and middle-aged men. On the other hand, FFM was similar among age groups in women, except ages 70–79 where it was lower (Tables 1 and 2).

Age-related change in muscle thickness and its ratios

Age-related changes in MTH were a site-specific manner in both men and women. For instance, upper-leg anterior MTH gradually decreased with age in both sexes, while upper-leg posterior MTH was similar among younger (ages 20–29 and 30–39) and middle-aged (ages 40–49 and 50–59) groups and was lower in ages 70–79 compared with the younger and middle-aged groups in men and women. In both sexes, trunk anterior and lower-leg posterior MTH also gradually decreased with age, while trunk posterior and lower-leg anterior MTH were similar among ages 20–29, 30–39, and 40–49 and were lower in older (ages 60–69 and 70–79) groups compared with the youngest three groups, except ages 30–39 in the lower-leg anterior. Upper-arm anterior and posterior MTH were similar among younger (ages 20–29 and 30–39) and middle-aged (ages 40–49 and 50–59) groups in men and were lower in older groups compared with the younger and middle-aged groups. In women, upper-arm anterior and posterior MTH were higher in middle-aged (ages 40–49 and 50–59) groups compared with the youngest (ages 20–29) group. In addition, MTH was similar among younger and older groups in posterior upper arm and was higher in the older groups

compared with the younger groups in the anterior upper arm (Tables 1 and 2).

The upper-leg anterior-to-posterior MTH ratio gradually decreased with age in men and women. The trunk anterior-to-posterior MTH ratio was higher in ages 20–29 compared with other age groups in both sexes and was lower in ages 50–59 and older compared with the younger groups in women. The lower-leg anterior-to-posterior MTH ratio was similar among age groups in men and women, except ages 30–39 in women where it was lower. Because the age-related change in MTH was greater in the posterior, the upper-arm anterior-to-posterior MTH ratio was higher in ages 70–79 compared with younger and middle-aged groups in men. The upper-arm anterior-to-posterior MTH ratio was similar between younger and older groups (Table 3).

Age-related change in SM index

The SM index gradually decreased with age in men, and the mean value of ages 70–79 (6.7 kg/m^2) was lower than that of the reference values for severe muscle loss (2 SD below, 6.8 kg/m^2) in men. On the other hand, the SM index was similar among younger (ages 20–29 and 30–39) and middle-aged (ages 40–49 and 50–59) groups in women and was lower in older (ages 60–69 and 70–79) groups compared with the younger and middle-aged groups (Table 3).

Relationship between age and muscle thickness ratio

Age was inversely correlated ($p<0.001$) to the upper-leg MTH ratio in men ($r=-0.463$) and women ($r=-0.541$). Age was also correlated positively to the upper-arm MTH ratio and inversely to the trunk MTH ratio in men ($r=0.191$ and $r=-0.238$, both $p<0.001$) and women ($r=0.102$, $p=0.004$ and $r=-0.446$, $p<0.001$). Weak correlations were observed between age and lower-leg MTH ratios in men ($r=0.015$, $p=0.682$) and women ($r=0.086$, $p=0.015$).

Prevalence rates of site-specific muscle loss and severe muscle loss detected by SM index

The prevalence of site-specific upper-leg muscle loss indicated an age-related increasing pattern in both men and women. The prevalence rate of site-specific upper-leg muscle loss was 6 % for ages 30–39, 21 % for ages 50–59, and 38 % for ages 70–79 in men and was 15 %

Table 3 Skeletal muscle mass (SM) index and anterior-to-posterior muscle thickness (AP MTH) ratio of men and women in each age group

	Age group (years)						
	20–29	30–39	40–49	50–59	60–69	70–79	<i>p</i> -value
Men (<i>n</i> =760)							
SM index (kg/m ²)	8.51 (1.07) ^{cdef}	8.43 (1.02) ^{def}	8.11 (0.95) ^{aef}	7.84 (0.94) ^{abef}	7.19 (1.01) ^{abcdf}	6.69 (1.17) ^{abcde}	<0.001
Upper-arm AP MTH ratio	0.92 (0.15) ^f	0.92 (0.17) ^f	0.89 (0.16) ^{ef}	0.94 (0.20) ^f	0.99 (0.22) ^c	1.06 (0.27) ^{abcd}	<0.001
Trunk AP MTH ratio	0.62 (0.13) ^{bcd^{ef}}	0.54 (0.11) ^a	0.55 (0.14) ^a	0.54 (0.12) ^a	0.51 (0.12) ^a	0.51 (0.11) ^a	<0.001
Upper-leg AP MTH ratio	0.91 (0.12) ^{cdef}	0.86 (0.12) ^{def}	0.84 (0.12) ^{adef}	0.77 (0.13) ^{abcef}	0.73 (0.12) ^{abcd}	0.70 (0.12) ^{abcd}	<0.001
Lower-leg AP MTH ratio	0.44 (0.04)	0.43 (0.04)	0.44 (0.04)	0.43 (0.05)	0.44 (0.05)	0.45 (0.06)	0.235
Women (<i>n</i> =826)							
SM index (kg/m ²)	5.74 (0.87) ^{ef}	5.61 (0.80) ^f	5.80 (0.84) ^{ef}	5.66 (0.95) ^{ef}	5.39 (0.92) ^{acdf}	4.69 (1.03) ^{abcde}	<0.001
Upper-arm AP MTH ratio	0.92 (0.22)	1.00 (0.28)	0.91 (0.25) ^d	0.99 (0.30) ^c	0.99 (0.27)	1.03 (0.35)	0.002
Trunk AP MTH ratio	0.64 (0.15) ^{bcd^{ef}}	0.56 (0.13) ^{adef}	0.55 (0.14) ^{adef}	0.46 (0.10) ^{abc}	0.45 (0.11) ^{abc}	0.47 (0.14) ^{abc}	<0.001
Upper-leg AP MTH ratio	0.91 (0.12) ^{bcd^{ef}}	0.83 (0.12) ^{adef}	0.82 (0.13) ^{adef}	0.74 (0.12) ^{abcef}	0.70 (0.13) ^{abcd}	0.66 (0.14) ^{abcd}	<0.001
Lower-leg AP MTH ratio	0.43 (0.04)	0.41 (0.05) ^{cdef}	0.43 (0.05) ^b	0.43 (0.04) ^b	0.43 (0.05) ^b	0.44 (0.06) ^b	0.003

Significance set at *p*<0.05^a Significant group difference from age 20–29^b Significant group difference from age 30–39^c Significant group difference from age 40–49^d Significant group difference from age 50–59^e Significant group difference from age 60–69^f Significant group difference from age 70–79^g Significant group difference from age 80–89

for ages 30–39, 32 % for ages 50–59, and 50 % for ages 70–79 in women. For other segments, however, the prevalence rate of site-specific muscle loss was relatively low throughout the age groups in both men and women, although higher rates were observed in the older group (Table 4).

The prevalence of severe muscle loss markedly increased after age 60 in men and women. The prevalence rate of severe muscle loss was less than 10 % for men under the age of 50 and for women under the age of 60, and 52 % in men and 30 % in women for ages 70–79 (Table 4).

Discussion

Approximately a quarter century ago, many researchers were interested in the age-related loss of SM and function and also how it was influenced by physical disability and metabolic disorders (Rosenberg 1997;

Janssen 2010). Now, it is known that the prevalence of age-related severe muscle loss dramatically increases after the age of 60 (Baumgartner et al. 1998; Abe et al. 2013b) and that severe muscle loss leads to increased risk of physical disability (Baumgartner et al. 1998), cognitive decline (Burns et al. 2010), metabolic disorders (Park et al. 2009; Abe et al. 2012b), and mortality (Bunout et al. 2011). Additionally, recent studies demonstrate that the prevalence of age-related severe muscle loss is highly dependent on the diagnostic criteria (Bijlsma et al. 2013). On the other hand, it was recently reported that site-specific muscle loss appears in the upper leg (Abe et al. 2013b); however, it is unclear whether site-specific muscle loss appears in the upper and lower extremities and trunk in men and women. In the present study, our results indicated that the prevalence rates of site-specific muscle loss in men and women markedly differed in each segment. An age-related increasing pattern of the site-specific muscle loss was observed in the upper leg. On the other hand, the

Table 4 The prevalence rates (number and percent in parenthesis) of site-specific sarcopenia of upper and lower extremities and trunk and of severe sarcopenia detected by SM index in men and women

	Age group (years)						Overall
	20–29	30–39	40–49	50–59	60–69	70–79	
Men	(<i>n</i> =103)	(<i>n</i> =108)	(<i>n</i> =180)	(<i>n</i> =167)	(<i>n</i> =125)	(<i>n</i> =63)	(<i>n</i> =746)
Women	(<i>n</i> =124)	(<i>n</i> =83)	(<i>n</i> =146)	(<i>n</i> =195)	(<i>n</i> =189)	(<i>n</i> =76)	(<i>n</i> =813)
Men							
Upper arm	3 (2.9)	8 (7.4)	5 (2.8)	15 (9.0)	14 (11.2)	14 (22.2)	59 (7.9)
Upper leg	1 (1.0)	6 (5.6)	10 (5.6)	35 (21.0)	41 (32.8)	24 (38.1)	117 (15.7)
Lower leg	2 (1.9)	2 (1.9)	4 (2.2)	3 (1.8)	6 (4.8)	8 (12.7)	25 (3.4)
Trunk	1 (1.0)	5 (4.6)	12 (6.7)	7 (4.2)	10 (8.0)	4 (6.3)	39 (5.2)
SM index	5 (4.9)	4 (3.7)	15 (8.3)	20 (12.0)	46 (36.8)	33 (52.4)	123 (16.5)
Women							
Upper arm	5 (4.0)	8 (9.6)	6 (4.1)	18 (9.2)	17 (9.0)	8 (10.5)	62 (7.6)
Upper leg	0 (0)	12 (14.5)	16 (11.0)	63 (32.3)	86 (45.5)	38 (50.0)	215 (26.4)
Lower leg	4 (3.2)	2 (2.4)	5 (3.4)	12 (6.2)	8 (4.2)	9 (11.8)	40 (4.9)
Trunk	0 (0)	3 (3.6)	5 (3.4)	16 (8.2)	21 (11.1)	11 (14.5)	56 (6.9)
SM index	3 (2.4)	1 (1.2)	2 (1.4)	8 (4.1)	19 (10.1)	23 (30.3)	56 (6.9)

prevalence rate was relatively low throughout the age groups in other segments. Over 20 % of men and women aged 50–59 and approximately 40 % of men and 50 % of women aged 70–79 were classified as having site-specific upper-leg muscle loss. These results are consistent with a previous study in both men and women (Abe et al. 2013b). The main reason for the site-specific upper-leg muscle loss (decrease in anterior-to-posterior MTH in the upper leg) would be the lower anterior upper-leg (quadriceps) MTH, because the posterior upper-leg (hamstring) MTH was not significantly decreased among age groups under the age of 60 in men and under the age of 70 in women (Tables 1 and 2).

The reasons for the gradual decrease in MTH of the anterior upper leg with age are not well known. Considering the relatively constant posterior upper-leg MTH with age, one of the possible factors may be the decline in intensity and duration of weight-bearing physical activity with increasing age. Physiological evidences concerning the intensity/duration of muscle activity in different muscles during 24 h of normal daily activities are lacking (Tikkanen et al. 2013). A limited number of studies have reported that the EMG activity patterns during ambulation differed among upper- and lower-leg muscles (Sawai et al. 2006; Shirasawa et al. 2009). Muscle activation levels while walking on a

downward slope and jogging are greater in the posterior upper-leg muscle compared with those in the anterior upper leg (Sawai et al. 2006). In addition, a recent study reported that the ratio of anterior to posterior upper-leg MTH was inversely correlated to duration of vigorous physical activity in middle-aged and older women (Ogawa et al. 2012b). Furthermore, we recently examined whether chronic vigorous exercise (master athletes) prevents site-specific upper-leg muscle loss experienced in sedentary adults and found that the anterior/posterior MTH ratio was similar between master athletes (cyclists and swimmers) and young active men (unpublished observation). Interestingly, this is supported by research that has observed site-specific losses in motor units with advancing age (Aagaard et al. 2010). A recent study demonstrated that the lifelong running can provide a localized maintenance of motor units in exercising muscle but not systemically (Power et al. 2012).

Our findings showed that the anterior trunk (rectus abdominis) MTH gradually decreased with advancing age, while the posterior trunk MTH decreased significantly over the age of 60 in men and women; as a result, a few middle-aged and older adults were classified as having site-specific trunk muscle loss. Along with the age-related change in anterior upper-leg MTH, a gradual

decrement of the anterior trunk MTH with age may also be associated with the change in intensity and duration of daily physical activity. Together with the lateral abdominal muscles, the rectus abdominis forms the abdominal wall. Continuous muscle activity of the abdominal wall occurs to hold the viscera as well as to assist in regulating intra-abdominal pressure during breathing. Additionally, the activity of the abdominal wall contributes to spinal stability during exercise. To illustrate, during daily physical activity tasks (e.g., sitting and standing, squatting, and walking), the rectus abdominis muscle is active at very low intensities (approximately 2–3 % of MVC) (Sawai et al. 2006). On the other hand, greater trunk stability may benefit performance by providing a foundation for greater force production in the upper and lower extremities. Trunk muscle activity has been examined during upper-limb exercises performed in the sitting or standing position, and greater EMG activity in the rectus abdominis was observed in the standing position than in the sitting position, while EMG activity in the erector spinae was similar between the two positions (Saeterbakken and Fimland 2012).

In the present study, age-related declines in anterior and posterior upper-arm MTH were rarely observed in women, or in men over the age of 60. Surprisingly, middle-aged women had greater upper-arm anterior and posterior MTH compared with younger women. The reasons for this appearance are uncertain. Considering the lifestyle between generations, however, one of the possible factors may be the difference in daily physical activity levels. The subjects in this study included many younger women who were office workers while many older women were involved in domestic tasks and work in the fields near their homes. If necessary, this work also includes taking care of grandchildren for younger generations who work on a daily basis. Higher BMI values in older women may also be an influencing factor.

A higher prevalence rate of site-specific upper-arm muscle loss was found only in men aged 70–79. Similarly, the prevalence rate of site-specific lower-leg muscle loss was low and relatively constant (~4 %) throughout age groups under the age of 70 in men and women. However, the prevalence rate increased (about threefold) in the oldest men and women (ages 70–79). Thus, the reason for the site-specific decrease in muscle mass with age may differ between the upper-leg segment and upper-arm and lower-leg segments. As

described above, the change in intensity and duration of weight-bearing physical activity may be a main factor for the decreasing anterior upper-leg MTH with age. On the other hand, site-specific upper-arm muscle loss may be associated with a combination of age-related declines in physical activity and systemic etiologic factors (i.e., circulating anabolic hormones and cytokines, chronic low-grade inflammation, insulin resistance, and nutrition) for age-related muscle loss (Ryall et al. 2008; Beyer et al. 2012; Mitchell et al. 2012). For example, anterior and posterior upper-arm MTH were lower in older men (ages 60–69 and 70–79) than in younger and middle-aged men. The percent decrements of MTH between ages 50–59 and 70–79 were 10 % in the anterior site and 19 % in the posterior site. Since the age-related muscle loss of the upper arm begins around the age of 60, the magnitude of those changes differ between anterior and posterior sites. The systemic factors may be mainly related to muscle mass loss of the upper arm while physical activity or exercise may be related to the magnitude of change between anterior and posterior MTH.

Our results indicate that approximately 6 % of nonobese men and 2 % of nonobese women under the age of 50 were classified as having severe muscle loss. A previous study reported that ~2 % of men and ~3 % of women under the age of 50 met the criteria for severe muscle loss (Janssen et al. 2002). In other studies, the prevalence rate of age-related severe muscle loss for subjects between the ages of 70 and 80 years ranged from 10 to 50 % in men and women (Baumgartner et al. 1998; Abe et al. 2013b). It is known that the prevalence rate of severe muscle loss in men and women is higher in those with a low BMI than in those with higher BMI values (Newman and Kupelian 2003). The subjects in the present study were nonobese adults ($\text{BMI} < 30 \text{ kg/m}^2$), and the prevalence of severe muscle loss was within the range of previous studies with a higher percentage.

In conclusion, our results demonstrated that the prevalence of site-specific upper-leg (thigh) muscle loss showed an age-related increasing pattern in both men and women. For other segments, however, the prevalence rate of site-specific muscle loss was relatively low throughout the age groups in both men and women, although higher rates were observed in the older group. These results suggest that the anterior and posterior MTH ratios of the upper-leg may be useful in providing an earlier diagnosis for site-specific muscle loss.

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