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Characteristics of Body Composition and Relationship between Muscle Mass and Muscle Strength among Elderly Women in Different Age Groups

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Abstract

Age-related changes in the body composition of older adults differ among age groups. The purpose of the present study was to clarify the characteristics of body compositions in young (age, 65 - 74 years; yE group) and old (age, ≥75 years; oE group) elderly women, and compare the relationship between muscle mass and strength in elderly women with that in young women for preventing motor function loss in older adults. A total of 30 elderly and 45 young women aged ≥ 65 and 19 - 22 years, respectively, participated in this study. The participants underwent body composition measurement via bioelectrical impedance analysis and examinations of handgrip and leg muscle strength. The age-related body composition changes varied among age groups. Compared with young women, fat-free mass (FFM) in the yE group did not decrease significantly; however, fat mass (FM) and waist-hip ratio (WHR) were significantly greater. Compared with the yE group, decreases in FFM, FM, and WHR in the oE group were significant; furthermore, the decrease in FM measurements was attributed to the loss of FM in the trunk and limbs (upper and lower). The measurement results suggested that the greater FM decrease in the oE group was characterized by decreases in both visceral and subcutaneous fat. In the yE group, the muscle mass was comparable to that in young women; however, there was a remarkable reduction in the lower-limb muscle mass (9% - 10%). In the oE group, muscle mass was reduced in all body parts, including upper and lower limbs and trunk. In young women, significant positive correlations between muscle mass and muscle strength in the upper and lower limbs were observed. No such correlations in the lower limbs were found in elderly women, indicating that muscle mass is not proportionally reflected in muscle strength. In conclusion, for improving and maintaining the health of elderly women, especially those above the age of 75 years, it is important to maintain muscle mass, including muscle strength, and prevent the loss of muscle quality.

Keywords

Elderly Women, Body Composition, Muscle Mass, Muscle Strength

1. Introduction

Japan is a country where the percentage of the elderly is most rapidly increasing, with the aged population accounting for 28.8% in 2020, and the number of people in need of nursing care is also increasing [1]. Among recipients of the long-term nursing care aged ≥ 65 years, locomotive organ disorders, such as fractures/falls and articular diseases, are the major reasons that lead patients to opt for nursing care, accounting for approximately 10% and 30% in men and women, respectively [1]. A condition with mobility impairment caused by locomotive organ disorders is referred to as "locomotive syndrome (LS)" [2]. Engaging in regular exercise, appropriate nutrition, and being active are important to avoid LS [3]. Cunningham *et al.* have shown that active elderly people have reduced risks including those for fractures, falls, and impairment in activities of daily living (ADL) [4]. The Japanese Ministry of Health, Labour and Welfare established numerical targets for health promotion in individuals aged ≥ 65 years, including that the daily number of steps and percentage of individuals who regularly exercise for men and women should be 7000 steps and 58% and 6000 steps and 48%, respectively [5]. However, according to the current data from the National Health and Nutrition Survey regarding the number of steps and percentage of individuals who regularly exercise among men and women (5396 steps and 41.9% and 4656 steps and 33.9%, respectively, in 2019), the targets have not been reached [6]. In 2020, people all over the world had restrictions imposed upon them to go out due to the spread of the coronavirus disease 2019 (COVID-19). Ammar *et al.* have reported decreases in the number of days of walking and physical activity per week and an increase in daily sedentary time in adults aged ≥ 18 years, which included older adults [7]. Similarly, a survey of healthy Japanese people aged ≥ 65 years reported that the time of physical activities was reduced by approximately 35%, compared with that before the spread of the infection [8]. A survey of Irish people who received ambulatory medical services and cocooning (age, ≥70 years) has shown that their physical and mental health conditions were aggravated by restrictions to going out [9]. Decreased physical activities because of the ongoing COVID-19 pandemic may have negative effects on health and quality of life in older adults in the future and warrant efforts to prevent nursing-care dependency.

LS is associated with decreases in motor functions, such as reduced muscular strength, balance function, and joint mobility [2] [3]. Makizako *et al.* have reported that age-related changes in physical abilities differed between men and women, especially in the walking speed of women [10]. LS and frailty are more frequent in women than in men [11] [12]. Janssen *et al.* have documented that among people aged ≥ 60 years, the prevalence of sarcopenia in women was higher than that in men [13]; thus, it is important to consider health maintenance and promotion in elderly women.

Muscle mass also decreases in an age-related manner [14] [15]. Janssen *et al.* have reported that the regression curve of age-related muscle mass loss in the lower limbs had a significantly larger slope than that in the upper limbs [14]. Fried *et al.* have included decreased muscle strength (handgrip strength) and walking ability as part of the diagnostic criteria for frailty [12]. Additionally, it has been reported that elderly people with frailty had decreased muscle mass [16] [17]. Reduced skeletal muscle mass is reportedly associated with impaired functioning and ADL disorders [13]. Therefore, thoroughly examining body composition and muscle strength in addition to maintaining and improving them is necessary to prevent older adults from requiring nursing care. Genton *et al.* performed longitudinal measurements and reported that subjects aged ≥ 75 years at baseline lost more body weight and fat-free mass (FFM) than those aged 65 - 74 years [18]. Therefore, it is necessary to separately ascertain the body size and compositions in young (yE group) and old elderly people (oE group).

Hayashida *et al.* have reported that the association between muscle mass and strength in the lower limbs differ depending on sex and age [15], and Reed *et al.* have reported that the correlation between muscle circumference and strength in the upper limbs is different from that in their lower limbs [19]. However, there are a few studies comparing muscle mass-strength correlation patterns in the upper and lower limbs between elderly people and young people.

In the present study, we aimed to clarify the characteristics of body compositions in the yE (age, 65 - 74 years) and oE (age, ≥75 years) groups of elderly Japanese women and to compare muscle mass-strength of the above correlation patterns in elderly with those in young people to provide valuable information for the prevention of motor function deterioration in old age.

2. Materials and Methods

2.1. Subjects

A total of 30 elderly women aged ≥ 65 years (mean age 76.2 ± 7.3 years, range: 65 - 92 years) who were residents of Kobe City, Hyogo Prefecture, were included in this study. The subjects were recruited using posters displayed on bulletin boards in residential areas in Kobe City and eligible persons who voluntarily decided the study participation after an explanation about the purpose and methods of the study were enrolled after they provided their consent. The elderly who lived independently and were capable of effective communication were included. The participants were divided into two groups: 65 - 74 years old (yE group) and ≥ 75 years old (oE group). A total of 45 young women aged 19 - 22 years (mean age, 20.6 ± 0.9 years) living in Hyogo Prefecture were recruited in the same manner as a control group and included in measurements.

This study was conducted with an approval from the Human Subject Research Ethics Committee of Kobe Women's University (approval number: H29-20, 2019-12-1).

2.2. Measurements

The participants underwent body composition and muscle strength measurements between August 2017 and September 2019. When a subject did not consent to any particular measurement items, those items were excluded from the data.

Body composition

The Inbody770 body composition analyzer (InBody Japan Inc., Tokyo, Japan) was used to measure body compositions. This device uses the eight-polar method that has been demonstrated to measure FFM and muscle mass values at different sites more accurately [20]; body compositions measured by this method using six different frequencies (1, 5, 50, 250, 500, and 1000 kHz) have been reported to correlate suitable with measurements by the dual-energy X-ray absorptiometry and the conventional under water weighing and deuterium oxide dilution methods [21] [22] [23]. This device has a high reliability, rapid measurement time, and ease of handling.

The measurement items were as follows: FFM, total body water, intracellular water (ICW), extracellular water (ECW), muscle mass, skeletal muscle mass, regional muscle mass (right arm, left arm, trunk, right leg, and left leg), body fat mass (FM), percent body fat, regional body FM (right arm, left arm, trunk, right leg, and left leg), waist-hip ratio (WHR), bone mineral content (BMC), and basal metabolism. On the day of the measurement, the participants were required to finish breakfast at least 3 hours before the measurement, avoid food and drink between breakfast and the measurement, defecate and urinate before the measurement, and wear no pacemakers. Young women underwent measurements during the post-menstruation low-temperature phase to avoid effects of the sexual cycle.

Muscle strength

In order to investigate the correlation between muscle mass and strength, measurements of muscle mass and strength were performed on the same day. The muscle strength measurements involved handgrip and leg muscle strength. The participants who consented to both the muscle mass and strength measurements were included (elderly subjects: n = 24; young subjects: n = 24).

GRIP-D (Takei Ltd. Niigata, Japan) was used to measure the handgrip strength. The measurement was recorded twice on the left and right hands, and the best value for each hand was used for analyses.

The Assist Frame for Locomo Scan (ALCARE Co., Ltd., Tokyo, Japan) was used to measure the leg muscle strength. This device measures the strength of quadriceps muscles involved in knee extension exercises. Omori *et al.* confirmed that measured values of this device highly correlate with those measured by a large isokinetic device (BIODEX), which is a gold-standard for quantitative assessment of leg muscle strength [24]. In addition, it is widely used in clinical practice because it can measure relatively easily and in a short time. Strength of the quadriceps muscle was defined as the leg muscle strength in this study. The leg muscle strength was measured according to load measuring method [25] and the measurement was recorded twice on the left and right legs, and the best value for each leg was used for analyses.

2.3. Statistical Analysis

The measurement results are presented as means ± standard deviation. IBM SPSS Statistics for Windows (version 21.0, SPSS Inc., Chicago, IL) was used for all analyses. One-way analysis of variance was used for comparison among the three groups in age groups and Student's *t*-test was used for comparison between the two groups. The Pearson correlation coefficient was used to detect a correlation between muscle mass and muscle strength. The significance level used was less than 5%.

3. Results

3.1. Characteristics of Subjects' Physique

The height, weight, and body mass index (BMI) of the subjects are shown in Table 1. The physiques of the elderly and young groups in this study were within the ranges of corresponding general Japanese populations [26].

3.2. Physique and Body Compositions of Elderly and Young Subjects

Table 2 shows physique of the elderly and young groups. The height of the elderly group was significantly shorter than that of the young group. However, the body weight did not differ significantly between the two groups, and the BMI of the elderly group was significantly higher than that of the young group. When the elderly group was divided into the yE and oE groups, the height values of the

Table 1. Characteristics of subject's physique.

	Elderly n = 30	Young n = 45	Reference A n = 872 - 874	Reference B n = 157 - 163
Age (years)	76.2 ± 7.3	20.6 ± 0.9	≥70	20 - 29
Height (cm)	150.4 ± 5.2	159.2 ± 5.4	148.9 ± 6.2	157.5 ± 5.4
Body weight (kg)	50.4 ± 8.2	50.9 ± 6.5	51.0 ± 8.7	51.3 ± 9.0
BMI (kg/m^2)	22.3 ± 3.4	20.1 ± 2.4	23.0 ± 3.7	20.6 ± 3.3

Values are means ± standard deviation. A, B: Reference values from National Health and Nutrition Survey in 2017 [26].

Table 2. The body composition in elderly and young women.

	Elderly			Young (n = 45)
	Total (n = 30)	yE (n = 14)	oE (n = 16)	
Age (years)	76.2 ± 7.3*	69.8 ± 2.5[a,c]	81.9 ± 4.8[b,c]	20.6 ± 0.9[a,b]
Height (cm)	150.4 ± 5.2*	152.5 ± 5.5[a]	148.6 ± 4.4[b]	159.2 ± 5.4[a,b]
Body weight (kg)	50.4 ± 8.2	55.5 ± 7.2[c]	46.0 ± 6.4[b,c]	50.9 ± 6.5[b]
BMI (kg/m^2)	22.3 ± 3.4*	23.9 ± 3.0[a,c]	20.8 ± 3.0[c]	20.1 ± 2.4[a]
FFM (kg)	33.6 ± 3.6*	35.7 ± 3.2[c]	31.8 ± 2.9[b,c]	37.7 ± 3.4[b]
Total body water (L)	24.7 ± 2.6*	26.3 ± 2.4[c]	23.4 ± 2.1[b,c]	27.6 ± 2.5[b]
ICW (L)	15.0 ± 1.7*	16.1 ± 1.4[c]	14.1 ± 1.3[b,c]	17.1 ± 1.6[b]
ECW (L)	9.7 ± 1.0*	10.2 ± 1.0[c]	9.2 ± 0.8[b,c]	10.5 ± 1.0[b]
Muscle mass (kg)	31.6 ± 3.4*	33.7 ± 3.0[c]	29.8 ± 2.7[b,c]	35.4 ± 3.2[b]
Skeletal muscle mass (kg)	17.6 ± 2.2*	18.9 ± 1.9[c]	16.4 ± 1.8[b,c]	20.3 ± 2.0[b]
R Arm muscle mass (kg)	1.5 ± 0.3*	1.7 ± 0.3[c]	1.3 ± 0.3[b,c]	1.7 ± 0.2[b]
L Arm muscle mass (kg)	1.5 ± 0.3*	1.7 ± 0.3[c]	1.3 ± 0.3[b,c]	1.6 ± 0.2[b]
Trunk muscle mass (kg)	14.6 ± 2.0*	15.9 ± 1.7[c]	13.4 ± 1.6[b,c]	16.1 ± 1.5[b]
R Leg muscle mass (kg)	4.9 ± 0.7*	5.4 ± 0.6[a,c]	4.6 ± 0.5[b,c]	5.9 ± 0.7[a,b]
L Leg muscle mass (kg)	4.9 ± 0.7*	5.3 ± 0.7[a,c]	4.5 ± 0.5[b,c]	5.9 ± 0.7[a,b]
FM (kg)	16.8 ± 5.8*	19.7 ± 5.4[a,c]	14.2 ± 5.1[c]	13.2 ± 4.5[a]
Percent body fat (%)	32.4 ± 7.3*	35.1 ± 5.9[a]	31.6 ± 8.0[b]	25.4 ± 5.8[a,b]
R Arm fat mass (kg)	1.2 ± 0.5*	1.4 ± 0.5[a,c]	1.0 ± 0.4[c]	0.9 ± 0.3[a]
L Arm fat mass (kg)	1.2 ± 0.5*	1.4 ± 0.5[a,c]	1.0 ± 0.4[c]	0.9 ± 0.3[a]
Trunk fat mass (kg)	8.0 ± 3.2*	9.6 ± 2.8[a,c]	6.6 ± 2.9[c]	6.0 ± 2.4[a]
R Leg fat mass (kg)	2.7 ± 0.8*	3.1 ± 0.8[a,c]	2.3 ± 0.7[c]	2.3 ± 0.7[a]
L Leg fat mass (kg)	2.7 ± 0.8*	3.1 ± 0.8[a,c]	2.3 ± 0.7[c]	2.3 ± 0.7[a]
WHR	0.83 ± 0.05*	0.85 ± 0.04[a,c]	0.81 ± 0.05[c]	0.81 ± 0.03[a]
BMC (kg)	2.0 ± 0.2*	2.1 ± 0.2[a]	2.0 ± 0.2[b]	2.3 ± 0.2[a,b]
BM (kcal)	1096 ± 77*	1142 ± 68[c]	1057 ± 62[b,c]	1185 ± 74[b]

Values are means ± standard deviation. Young (range: 19 - 22 years), yE: young Elderly (65 - 74 years), oE: old Elderly (≥75 years); BMI: Body Mass Index; FFM: Fat-Free Mass; ICW: Intracellular Water; ECW: Extracellular Water; FM: Fat Mass WHR: Waist-Hip Ratio; BMC: Bone Mineral Content; BM: Basal Metabolism; R: Right; L: Left; *Significantly different between elderly (total) and young by Student's *t*-test. [a,b,c]Same superscript letters indicate significant difference ($p < 0.05$) by Tukey's test.

yE and oE groups were both significantly shorter than the height of the young group. The body weight of the yE group was slightly heavier than that of the young group, albeit insignificant; and the weight of the oE group was significantly lighter than that of the yE group or the young group. Therefore, the oE group had the lightest weight among the three groups. The BMI of the yE group was significantly larger than that of the young group; however, the BMI of the oE group was significantly smaller than that of the yE group and was comparable to that of the young group.

The FFM of the elderly group was significantly lower than that of the young group (Table 2). The FFM of the yE group was lower by approximately 5% than that of the young group, albeit insignificant. Meanwhile, the FFM of the oE group was significantly lower by approximately 11% than that of the yE group. Therefore, the FFM of the yE group tended to be comparable to that of young group and to be maintained; however, the FFM of the oE group was noticeably lower than those of the young group and yE group (Figure 1).

The FM of the elderly group was significantly higher than that of the young group (Table 2). The FM of the yE group was 1.5 times as high as that of the young group with statistical significance (Figure 1). The FM values of the yE group, in each body parts (upper and lower limbs and trunk), were significantly higher than those of the young group, and the differences in the upper limbs and the trunk were particularly large. However, the FM of the oE group was significantly lower by approximately 28% than that of the yE group and comparable to that of the young group. The regional FM values of the oE group were lower than those of yE group for all of the upper and lower limbs and the trunk. The WHR of the elderly group was significantly higher than that of the young group. The WHR of the yE group was significantly higher than that of the young group; however, the WHR of the oE group was significantly lower than that of the yE group and comparable to that of the young group (Table 2). To summarize the changes in the FFM, FM, and WHR with age, the FFM values of the yE and young groups were comparable to each other, and the FFM of the oE group was markedly lower than those; the FM and WHR of the yE group were significantly higher and those of the oE group were lower than those of the yE group.

Regarding the parameters of body water, the total body water, ICW, and ECW

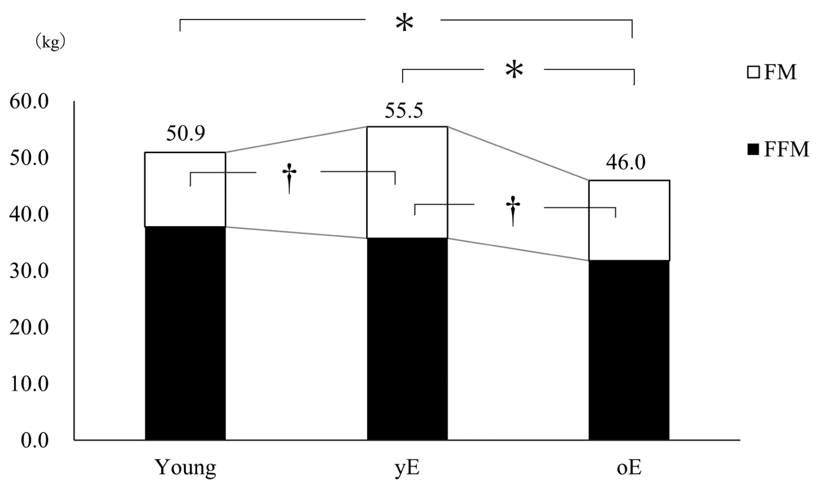

Figure 1. Body weight and distribution of FFM and FM among age groups. Young (n = 45, 19 - 22 years), yE (n = 14, 65 - 74 years), oE (n = 16, ≥75 years); FFM: Fat-free mass, FM: Fat mass; *indicates $p < 0.01$ by Tukey's test (oE vs Young, oE vs yE in FFM). †indicates $p < 0.01$ by Tukey's test (yE vs Young, oE vs yE in FM).

of the yE group were slightly lower than those of the young group, but not significantly. In contrast, the total body water, ICW, and ECW of the oE group were significantly lower than those of the young and yE groups. The BMC values of the yE and oE groups were significantly lower than the BMC of the young group (Table 2).

3.3. Muscle Mass in Elderly and Young Subjects

Table 2 shows that the muscle mass, skeletal muscle mass, and appendicular muscle mass of the elderly group were significantly lower than those of the young group. The skeletal muscle mass of the yE group was slightly lower than that of the young group, with insignificant difference. While the upper-limb and trunk muscle mass values of the yE group were comparable to those of the young group, the lower-limb muscle mass of the yE group was significantly lower by 9% - 10% than that of the young group. The skeletal muscle mass of the oE group was significantly lower than that of the yE group, and so were the lower- and upper-limb muscle mass as well as the trunk muscle mass.

3.4. Association between the Muscle Mass and Muscle Strength

The left and right handgrip strength values of the elderly group tended to be lower by 8% - 10% than those of the young group, with insignificant difference. The left and right leg muscle strength values were significantly lower by approximately 46% than those of the young group. (Figures 2(A)-(D))

In the upper limbs (Figure 2(A), Figure 2(B)), significant positive correlations between the muscle mass and the handgrip strength were observed in both the elderly (Right (R)/Left (L) $p < 0.001$) and young groups ((R) $p = 0.015$ (L) $p = 0.029$), indicating that the handgrip strength increases with the muscle mass in both groups. In addition, distribution patterns of muscle mass and handgrip strength were the same.

In the lower limbs (Figure 2(C), Figure 2(D)), the muscle mass and the muscle strength of the young group tended to have a positive correlation, and the correlation in the right leg was significant ($p = 0.040$). However, no significant correlations between the muscle mass and muscle strength were found in the elderly group. The muscle mass and muscle strength distribution patterns in the elderly group were different from those in the young group. Therefore, in the young group, there were associations between muscle mass and muscle strength in both the upper and lower limbs, and the muscle strength increased with the muscle mass. In the elderly group, an association between the muscle mass and muscle strength was found in the upper limbs, indicating that the muscle strength increased with the muscle mass; however, no association between the muscle mass and muscle strength was found in the lower limbs, indicating increases in the muscle mass were not reflected in the muscle strength.

4. Discussion

In this study, we characterized body compositions of elderly women after dividing

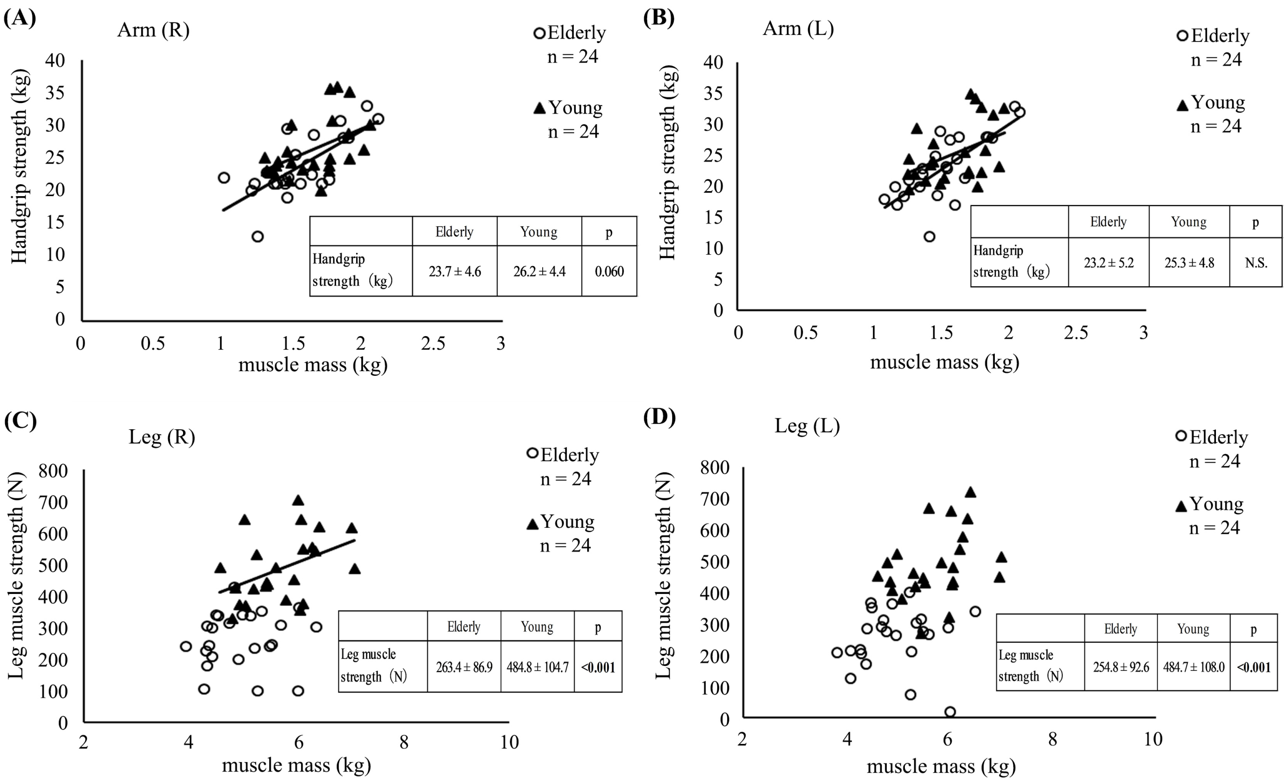

Figure 2. Correlation between appendicular muscle mass and muscle strength in elderly (n = 24) and young (n = 24) groups (Pearson). R: Right; L: Left; N: Newton. (A) Correlation between arm muscle mass and handgrip strength (R) ○ Elderly: r = 0.716, $p < 0.001$ ▲ Young: r = 0.488, p = 0.015; (B) Correlation between arm muscle mass and handgrip strength (L) ○ Elderly: r = 0.754, $p < 0.001$ ▲ Young: r = 0.445, p = 0.029; (C) Correlation between leg muscle mass and leg muscle strength (R) ○ Elderly: r = 0.082, p = 0.702 ▲ Young: r = 0.423, p = 0.040; (D) Correlation between leg muscle mass and leg muscle strength (L) ○ Elderly: r = 0.078, p = 0.718 ▲ Young: r = 0.340, p = 0.104.

the elderly participants into the yE group and the oE group and compared relationships between muscle mass and muscle strength between elderly and young women.

The physique data shown in Table 1 indicated that height, weight, and BMI of the elderly and young participants in this study did not differ significantly from those of Reference A and B values (National Health and Nutrition Survey, 2017) [26], confirming that both the elderly and young groups had physiques within ranges of respective general Japanese populations.

The elderly group had a shorter height, similar weight, lower FFM and total body water, and a higher FM than those of the young group (Table 2).

As shown in Figure 1, the weight of the yE group tended to be slightly higher and that of the oE group was significantly lower than that of the young group. Given the fact that the FFM of the yE group remained comparable, the higher weight tendency of the yE group seems to be attributable to the higher FM. In the oE group, the body weight was significantly lower than those of the young and yE groups; the FFM and FM were reduced by approximately 11% and 28% compared with those of the yE group, respectively. That is to say, the weight decrease of the oE group was attributable to decreases in both FFM and FM. In a 5

- 12-year follow-up study in women aged 60 years on average, Hughes *et al.* have reported that the FFM did not change appreciably over time and decreased only 0.1 kg [27]. Genton *et al.* have shown that the FFM and body weight were maintained at 65 - 74 years of age but decreased significantly at ≥75 years [18]. These previously reported findings are consistent with ours.

As shown in **Table 2**, the percent body fat and FM of the elderly group were significantly higher than those of the young group, and the increase of the yE group was particularly noticeable. Regional FM values of the yE group accumulated markedly in the trunk, and the WHR of the yE group was also significantly larger than that of the young group. The WHR is considered to reflect the accumulation of abdominal fat (visceral fat) [28]. Buffa *et al.* have shown that the visceral fat accumulates with age [29]. Genton *et al.* have indicated significant age-associated increases in the waist circumference and WHR in elderly women aged 65 - 74 years [18]. Therefore, the FM increase in the yE group is presumably due to the age-associated accumulation of visceral fat.

Meanwhile, the FM of the oE group was significantly lower than that of the yE group. The FM has been shown to decrease rapidly after 80 years of age in cohort studies of Japanese women by Seino *et al.* [30] and in American people by Ding *et al.* [31]. The results of these previous studies suggest that the FM decline started in the oE group in the present study. Furthermore, the FM of the oE group was 5.5 kg lower than that of the yE group, and the body region of the decrease was as follows: 0.8 kg in the upper limbs; 1.6 kg in the lower limbs; and 3 kg in the trunk. Since the fat in the upper and lower limbs is considered to be mainly subcutaneous fat, the data suggest that the FM decrease of the oE group reflects not only the visceral fat decrease but also the subcutaneous fat decrease.

The comparisons of water in the body showed no significant differences in total body water, ICW, and ECW between the yE group and the young group; however, the total body water of the oE group was significantly lower than that of the young group or the yE group. The total body water difference between the oE group and the young or yE group was accounted for by not only the ICW decrease but also the ECW decrease. Therefore, while the total body water of the elderly group decreased with age, no major changes occur in the yE group, as was the case for FFM, and both ICW and ECW decreased in the oE group (**Table 2**). Lesser *et al.* have reported that the total body water and ICW in elderly people were lower than those in young people [32]. In contrast, Schoeller has reported that it was not clear whether the age-associated decrease in total body water was due to the ICW decreased and/or the ECW decrease [33]. The results of the present study showed that both ICW and ECW of the oE group were lower than those of the young or yE group, suggesting that the age-associated change in total body water of the elderly group includes ECW as well as ICW.

Regarding muscle mass measurements (**Table 2**), the upper-limb and trunk muscle mass values of the yE group remained comparable to those of the young group, but the decrease in the lower-limb muscle mass was noticeable, and muscle mass values in the upper and lower limbs and the trunk of the oE group were lower. Muscle mass in older adults decreased in an age-dependent manner [14] [18] [30]. In a cross-sectional study, Janssen *et al.* have reported muscle mass in both the upper and lower limbs decreased with aging and in particular, in the lower part of the body [14]; these findings are consistent with ours. A previous study has shown that scores of all the handgrip strength, Five-Times-Sit-to-Stand test, and walking speed in elderly Japanese people decreased in an age-dependent manner, and the walking speed decrease in women was particularly noticeable [10]; these findings suggest the age-associated changes in the lower limbs are larger than those in other regions of the body. Physical activities have also been reported to decrease with aging and the decrease is particularly noticeable in women [34]. In addition to the age-associated muscle mass decrease, the reduced physical activities may also be accountable for the muscle mass decrease of the oE group.

The relationship between muscle mass and muscle strength differed between the elderly and young groups (**Figures 2(A)-(D)**). In the young group, positive correlations between muscle mass and muscle strength were noted for both the upper and lower limbs, indicating that the muscle strength increases with the muscle mass. In the elderly group, a significant positive correlation between muscle mass and muscle strength was found for the upper limbs, as in the young group; however, such a correlation was not found for the lower limbs. These data indicate that the muscle mass, particularly in the lower limbs, does not directly reflect the muscle strength in the elderly group. Goodpaster *et al.* conducted a three-year longitudinal study on lower-limb muscles in elderly people and have reported that both the muscle mass and muscle strength of the lower limbs decreased year by year but the latter decreased more rapidly than the former [35]. The rapid decrease in the lower-limb muscle strength may explain, at least in part, why no association between muscle mass and muscle strength of lower limbs was found in the elderly group in the present study. Reed *et al.* have reported that the correlation between muscle strength and muscle cross-sectional area in the lower limbs was weaker than that in the upper limbs [19]. Lexell *et al.* have shown that the lower-limb muscle fiber density in people in their 70s and 80s was lower than that in young people [36], and pennation angles of muscle fibers may have effects on the muscle fiber density decrease [37]. The muscle fiber pennation angle has been shown to decrease as age increases, and the pennation angle in elderly is significantly smaller than that in young people [38] [39]. Kubo *et al.* compared the muscle thickness and the pennation angle in upper and lower limbs between elderly and young people and have reported that the lower-limb muscle thickness and pennation angle of the elderly group were significantly smaller than those of the young group, but the upper-limb muscle thickness and pennation angle did not differ between the two groups [40]. Effects of these changes in muscle architecture on exertion of force may underlie the absence of association between muscle mass and muscle strength in the lower limbs.

These results revealed that age-related changes in body composition in the elderly differ depending on the age group; in the oE group, the changes were particularly large, and both FFM and FM decreased. The FM decrease of the oE group was presumably caused by the subcutaneous as well as the visceral fat decrease. In the yE group, there was a remarkable reduction in the lower-limb muscle mass, and upper-limb, trunk, and lower-limb muscles all decreased in the oE group. While positive correlations between muscle mass and muscle strength in the upper and lower limbs were found in the young group, no such a correlation in the lower limbs was found in the elderly group, indicating that the muscle mass changes are not directly reflected in muscle strength changes in elderly people. Therefore, to prevent motor function deterioration in old age, it is necessary to maintain muscle strength and mass to prevent the loss of muscle quality.

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Conflicts of Interest

The authors declare no conflicts of interest.

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