Associations of sit-up ability with sarcopenia classification measures in Japanese older women

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Abstract: To test the hypothesis that sit-up performance is associated with sarcopenia classification measures, 93 older women aged 53–78 years were divided into three groups based on achieved repetitions (30 s) for the sit-up performance test: Group 0 (G 0, $n = 33$) performed 0 repetitions, Group 1–9 (G 1–9, $n = 30$) performed between 1 and 9 repetitions, and Group 10+ (G 10+, $n = 30$) performed over 10 repetitions. Dual-energy X-ray absorptiometry-derived appendicular lean soft tissue mass (aLM), handgrip strength (HGS), usual walking speed, and chair stand were measured, and low muscle mass (aLM index) and poor physical function were defined according to previous studies. Age and body mass index were similar among the three groups. HGS was higher in G 10+ compared with G 0. The prevalence rate of low muscle mass was 30% for G 0, 20% for G 1–9, and 3% for G 10+. Low HGS was observed in both G 0 (24%) and G 1–9 (20%), but not in G 10+. Only two persons in G 0 were classified as slow walking speed. Our results suggest that sit-up performance may be a useful indicator to determine the extent of sarcopenia because low muscle mass and poor function were almost non-existent in individuals who could perform over 10 sit-ups.

Keywords: aging, skeletal muscle mass, physical function, abdominal curl, elderly adult

Introduction

Sarcopenia refers to low muscle mass and poor physical function in older adults [1]. In many cases, sarcopenia is detrimental to the health of older adults such that it frequently leads to metabolic disorders [2, 3], future disability [4, 5], and mortality [6, 7]. In research settings, a widely used technique to evaluate muscle mass is a dual-energy X-ray absorptiometry (DXA). However, DXA measurements are not widely available for healthy older individuals because access to the equipment is very limited. Thus, it would be difficult to use this measurement for individuals who have an interest in evaluating the degree of sarcopenia.

Few studies are available that examine the extent to which physical performance tests can predict sarcopenia in older adults. For instance, Gray et al. [8] investigated the associations between DXA-derived appendicular lean soft tissue mass (aLM) and easily accessible functional measures in community-dwelling older adults (11 men and 32 women). They found that physical characteristics (age, sex, height, and body mass) and functional measures [handgrip strength (HGS), 10-m walking time, and chair stand power] can account for 96% of the variance in aLM. Martinez et al. [9] also investigated the relationship between timed up and go test and sarcopenia. They reported that timed up and go test times longer than or equal to 10.85 s predicted sarcopenia in older hospitalized patients, although this study used anthropometric prediction equations to estimate muscle mass.

Sit-ups are commonly incorporated in home-based exercise routines for improving muscular strength and mass of the abdominal and hip flexor muscles [10]. Interestingly, researchers from the Canadian Fitness

Survey (3,933 men and 4,183 women) reported that men and women in the lowest quartile for sit-up scores had a significantly higher risk for all-cause mortality compared with those in the highest quartile [11]. During normal aging, manifestations of sarcopenia appear first in the anterior thigh as well as abdomen before whole body sarcopenia can be diagnosed [12]. In addition, it is observed in some cases that older women cannot perform a bent-knee sit-up (0 repetition), which may be due to weak muscles in the anterior trunk and hip flexor. Therefore, we hypothesized that the ability to perform sit-ups could be used to estimate the extent of sarcopenia in older adults, especially in women. The aim of this study was to examine whether sit-up performance was associated with sarcopenia status and prevalence of sarcopenia diagnostic criteria.

Methods

Subjects

A total of 93 Japanese older women aged 53–78 years were recruited through printed advertisement and by word of mouth from the surrounding area of the university campus. 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 postmenopausal and free of overt chronic disease (e.g., myocardial infarction, cancer, stroke, and neuromuscular disorders). Participation in regular sports activity (at least twice a week and over the last 3 years) was assessed by a questionnaire. This study was conducted according to the World Medical Association Declaration of Helsinki and was approved by the University's Institutional Review Board, and written informed consent was obtained from participants.

Physical performance test

Physical performance test consisted of three types of exercise: sit-ups, timed 4-m usual walk, and chair stand. The sit-up test required subjects to perform as many correct bent-knee sit-ups as possible. Subjects lay on a mat in a supine position with the knees bent at an angle of approximately 90° and the feet together. The arms crossed at the chest with the hands on opposite shoulders. A technician held subject's ankles. Subjects performed a full sit-up to the upright position with their elbows touching their thighs and then returned to the supine position where their shoulders (scapula) touched the mat surface. The number of repetitions in 30 s was counted. Usual walking time was measured using a 4-m straight course. Subjects started at one end of the course and were asked to walk to the end at their usual (normal) pace. The elapsed time from the subject passing the start and finish point was recorded using a digital stopwatch. The chair stand test required subjects to rise from a chair at a total of 5 times as quickly as they could, with arms across their chest. The elapsed time required to complete all 5 repetitions was recorded using a digital stopwatch. Test–retest reliability of physical performance (sit-ups and chair stand) measurements using the intraclass correlation coefficient ($ICC_{3,1}$), standard error of measurement (SEM), and minimal difference needed to be considered real [13] was previously determined for data from Japanese older adults (10 women and 4 men) tested twice within 2 days for sit-ups (0.947, 1.72 repetitions, and 4.75 repetitions, respectively) and chair stand (0.967, 0.10 s, and 0.28 s, respectively).

HGS measurements

HGS was measured for the dominant hand with a calibrated Smedley hand dynamometer (TKK 5401 Grip-D, Takei Scientific Instruments, Tokyo, Japan). All subjects were instructed to maintain an upright standing position, arms down by the side, holding the dynamometer in the hand without squeezing. The width of the dynamometer's handle was adjusted to the hand size of the subjects (the middle phalanx rested on the inner handle). Hand dominance was ascertained by asking each subject which hand they used to perform well-learned skills, such as writing, throwing a ball, and grasping a racket. Subjects were allowed to perform one test trial, followed by two maximum trials, and the highest value was used for analysis. Test–retest reliability of HGS measurements using $ICC_{3,1}$, SEM, and minimal difference was previously determined [14] for data from the 23 subjects tested twice 24 h apart: 0.975, 2.5 kg, and 7.0 kg, respectively.

DXA measurements

A whole body scan was performed using a DXA (Discovery A, Hologic Inc., Bedford, MA, USA). Quality assurance testing and calibration were performed the morning of data collection days to ensure that the DXA was operating properly. Subjects were asked to refrain from vigorous exercise for at least 24 h prior to the scans. aLM calculation was based on the sum of lean mass in all four limbs. Test–retest reliability of DXA measurements using $ICC_{3,1}$, SEM, and the minimal difference was previously determined [15] from two aLM scans (0.99, 0.21 kg, and 0.58 kg, respectively).

Abdominal muscle thickness (MT) measurements

MT was measured using B-mode ultrasound (Aloka ProSound-2, Tokyo, Japan) at the anterior trunk (at a distance of 2–3 cm to the umbilicus and the widest part of

the lower rectus abdominis) on the right side of the body as previously described [16]. Briefly, the measurements were taken while the subjects stood quietly. A 7.5-MHz scanning head was placed on the skin surface of the measurement site using the minimum pressure required, and cross-sections of the muscle were imaged. Abdominal MT was measured as the perpendicular distance between the subcutaneous adipose tissue–muscle interface and the deep muscle fascia interface. Test–retest reliability of abdominal MT measurements using $ICC_{3,1}$, SEM, and minimal difference was previously determined for data from Japanese adults (17 men and 4 women) scanned twice 24 h apart: 0.976, 0.36 cm, and 1.00 cm, respectively.

Diagnosis criteria

Low muscle mass was defined as an aLM index (aLM divided by height square, unit is kg/m^2) value of two standard deviation (SD) below the mean for young women. A previous study reported an aLM index of Japanese women aged 18–40 years [6.78 kg/m^2 (SD 0.66)], and thus, the reference value for low muscle mass of women was 5.46 kg/m^2 [17]. According to the previous study, low HGS was defined as a value of lower than 20 kg [18, 19]. Slower walking speed was defined as a value of less than 1.0 m/s in this study [20].

Statistical analysis

Results are expressed as mean and SD. The subjects were divided into three groups based on achieved repetitions for the sit-up performance test: Group 0 (G 0, $n = 31$) performed 0 repetition, Group 1–9 (G 1–9, $n = 27$) performed between 1 and 9 repetitions, and Group 10 + (G 10+, $n = 26$) performed over 10 repetitions. The differences among the three groups for age, height, body mass, body mass index (BMI), body composition, aLM, abdominal MT, HGS, and physical performance were tested for significance by one-way analysis of variance, 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 sit-up performance and muscularity or HGS. Significance was set at $p < 0.05$.

Results

Comparison among the three groups (G 0, G 1–9, and G 10+)

Approximately half of the subjects (14 women in G 0, 17 women in G 1–9, and 18 women in G 10+) reported participation in regular sports activity including walking, swimming, and ground golf (a popular sport for older populations in Japan). The prevalence rate of regular sports activity was 42% in G 0, 57% in G 1–9, and 60% in G 10+. Age was similar among the three groups. G 10+ was taller than G 1–9. Body mass and BMI were similar among the three groups. Percentage of body fat was lower in G 10+ compared with other two groups. aLM as well as aLM index were lower in G 0 than that of G 10+. Abdominal MT tended ($p = 0.056$) to be lower in G 0 than that of G 10+. There were no significant differences in usual walking speed and chair stand among the three groups. HGS was higher in G 10+ compared with G 0. Average number of sit-up performance was 0 time for G 0, 4.6 times for G 1–9, and 14.4 times for G 10+ (Table I).

Relationships between sit-up performance and muscularity or HGS

There were no significant correlations between sit-up performance and body mass ($r = 0.008$, $p = 0.937$) or BMI ($r = 0.143$, $p = 0.172$). The sit-up performance was positively correlated to abdominal MT ($r = 0.251$, $p = 0.015$), aLM ($r = 0.371$, $p < 0.001$), and HGS ($r = 0.358$, $p < 0.001$).

Prevalence rates of low muscle mass and poor physical function in each group

The prevalence rate of low muscle mass was 30% for G 0 (10 were classified), 20% for G 1–9 (6 were classified), and 3% for G 10+ (only 1 was classified). Low HGS was observed in both G 0 (24%, 8 were classified) and G 1–9 (20%, 6 were classified), but not in G 10+. Only two persons in G 0 were classified with slow walking speed (Table I). Regular sports activity was reported in 10 of 17 women who were classified with low muscle mass (6 of 10 in G 0, 4 of 6 in G 1–9, and 0 of 1 in G 10+). Similarly, approximately half of the women who were classified with low HGS performed regular sports activity (4 of 8 in G 0 and 3 of 6 in G 1–9).

Discussion

The main findings of this study were that (1) low muscle mass and poor physical function were almost non-existent in individuals who can perform over 10 sit-ups (G 10+), (2) similar prevalence for low muscle mass and poor physical function was observed in two groups (G 0 and G 1–9) with lower than 10 sit-ups, and (3) sit-up performance was associated with muscularity and HGS.

In this study, the average number of repetitions performed during 30 s sit-up test was approximately 5 times

Table I ▌ Body composition, physical function, and prevalence rate of weakness and low lean mass

| Variables | Overall | Sit-up performance (repetitions/30 s) | | | p value |
		G 0	G 1–9	G 10+	
N	93	33	30	30	–
Age (years)	67 (8)	69 (7)	66 (8)	65 (8)	0.182
Height (m)	1.51 (0.05)	1.51 (0.06)	1.50 (0.05)[c]	1.53 (0.04)[b]	0.032
Body mass (kg)	53.8 (8.2)	53.5 (8.2)	53.8 (8.6)	54.0 (8.1)	0.965
BMI (kg/m^2)	23.5 (3.4)	23.6 (3.6)	23.9 (3.8)	22.9 (3.0)	0.534
Body fat (%)	34.7 (6.4)	37.0 (5.8)[c]	35.5 (5.1)[c]	31.5 (6.8)[a,b]	0.001
tLM (kg)	34.4 (4.1)	33.1 (3.5)[c]	34.2 (4.3)	36.2 (3.9)[a]	0.007
aLM (kg)	14.1 (2.0)	13.4 (1.6)[c]	14.0 (2.1)	15.0 (1.8)[a]	0.004
aLM index (kg/m^2)	6.14 (0.69)	5.90 (0.64)[c]	6.19 (0.79)	6.34 (0.58)[a]	0.036
Abdominal MT (cm)	0.77 (0.17)	0.72 (0.18)	0.76 (0.17)	0.82 (0.16)	0.056
Sit-up (repetition)	6.2 (6.6)	0.0 (0.0)[b,c]	4.6 (2.7)[a,c]	14.4 (3.9)[a,b]	<0.001
U-walk speed (m/s)	1.37 (0.24)	1.31 (0.26)	1.35 (0.26)	1.47 (0.21)	0.249
Chair stand (s)	6.5 (1.6)	6.8 (1.8)	6.7 (1.6)	6.0 (1.3)	0.099
HGS (kg)	24.0 (4.1)	22.4 (4.2)[c]	23.7 (4.0)	26.0 (3.3)[a]	0.002
aLM index < 5.46 kg/m^2 (n)	17/93	10/33	6/30	1/30	–
HGS < 20 kg (n)	12/93	8/33	6/30	0/30	–
U-walk speed < 1.0 m/s (n)	2/93	2/33	0/30	0/30	–

BMI, body mass index; tLM, total lean soft tissue mass; aLM, appendicular lean soft tissue mass; MT, muscle thickness; U-walk, usual walking; HGS, handgrip strength
[a]Difference from G 0. [b]Difference from G 1–9. [c]Difference from G 10+

in G 1–9 and 15 times in G 10+ *(Table I)*, which means that the time spent doing one sit-up repetition was an average of 6 s for G 1–9 and 2 s for G 10+. The reasons for the difference in sit-up performance among the three groups are unclear, but it may be associated with the magnitude of muscularity of the abdominal and hip flexor muscles. It has been reported that performing a bent-knee sit-up produced high levels of activation of the upper and lower rectus abdominis as well as the external oblique [21]. In older adults, manifestations of muscle loss appear first in the anterior thigh, which includes rectus femoris as well as the rectus abdominis before whole body muscle loss can be diagnosed [12]. In this study, we measured abdominal MT at the level of the umbilicus (the widest part of the lower rectus abdominis) and observed that abdominal MT was positively associated with sit-up performance, although the correlation coefficient was relatively low. Those results suggest that age-related site-specific and whole body muscle mass loss observed in this study (abdominal MT and aLM) may be mainly associated with sit-up performance in older women, which may also be related to higher prevalence of low aLM. In addition, the prevalence rate of regular sports activity was relatively low in G 0 (42%) compared with the other two groups (approximately 60%), although the

exercise intensity of those sports may be low. Interestingly, two-thirds of the women who were classified with low aLM and HGS performed regular sports activity. Therefore, it is unclear whether the low muscle mass and muscle strength were directly affected by regular sports activity in our subjects.

Our findings showed that older women who were classified with both low aLM and low HGS were observed not only in G 0 but also in G 1–9. Although sit-up performance was weakly associated with aLM and HGS, the mean values of absolute and relative aLM and HGS in G 1–9 were ranked between those of the G 0 and G 10+ groups. Therefore, it is expected that the G 1–9 may be located in a transitional phase from the normal state to the sarcopenic state.

In general, the sit-up test has been widely described as a test of abdominal muscle strength and endurance [22, 23]. A study investigating the relationship between sit-up performance and isokinetic abdominal muscle strength reported that there were weak correlations between sit-up performance and absolute and relative (divided by body mass) abdominal peak torques in young adults [24]. In this study, we did not measure abdominal strength, because HGS is a criterion for classification of sarcopenia. However, a strong association between HGS

and other strength measures, such as lower extremity muscular strength, has been previously reported [25, 26]. Our results support the results from the previous study that there was a significant and low correlation between sit-up performance and HGS. In line with the association between sit-up performance and muscle mass loss, low sit-up performance may be related to higher prevalence of low HGS.

In home-based exercise routines, sit-ups are commonly incorporated for improving muscular strength and mass of the abdominal and hip joint flexor muscles. The previous studies [10, 27] have reported the effect of exercise training on sit-up performance. For instance, Childs et al. [10] investigated the effect of sit-up training program (about 5 min/day, 4 days/week) on sit-up ability in young adults. The authors found that sit-up scores increased approximately 6% following a 12-week intervention. In this study, however, it is unknown whether the prevalence rate in low muscle mass and poor physical function ameliorates when sit-up performance improves following sit-up training. In addition, average sit-up test scores are higher in men than in women [11]. In many cases, men who cannot perform sit-ups are rarely observed. Thus, it is uncertain if the results pertain to older men because our subjects were only women. Additional research is needed to further clarify the clinical relevance of sit-up performance.

In conclusion, the present data support the hypothesis that the ability to perform sit-ups may be an indicator to determine the extent of sarcopenia in older women, although more research is required.

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