***Journal of Aging and Physical Activity*, (Ahead of Print)**
https://doi.org/10.1123/japa.2024-0415

Human Kinetics
ORIGINAL RESEARCH

Association Between Leg Skeletal Muscle Mass Asymmetry Index and the Timed Up-and-Go Test in Community-Dwelling Older Adults

Taishiro Kamasaki,[1] Mizuki Hachiya,[1] Hiroyuki Okawa,[1] Kazuhiko Fujiwara,[1] Kodai Hosaka,[2,3] Takuya Suenaga,[3,4] Yo Kichize,[5] Satoshi Fujimura,[6] Shotaro Ide,[7] Yasuhiro Mizokami,[8] Minoru Kamata,[9] and Hiroshi Otao[1]

[1]Faculty of Rehabilitation Sciences Department of Rehabilitation Sciences, Nishikyushu University, Kanzaki, Japan; [2]Rehabilitation Center, Medical Corporation Kabutoyama-kai Kurume Rehabilitation Hospital, Kurume, Japan; [3]Graduate School of Life Support Sciences, Nishikyushu University, Kanzaki, Japan; [4]Department of Rehabilitation Medicine, Keitendo Koga Hospital, Kishima, Japan; [5]Department of Rehabilitation, St. Mary's Hospital, Kurume, Japan; [6]Department of Rehabilitation Medicine, Medical Corporation Kouwakai Yokosuka Hospital, Saga, Japan; [7]Department of Rehabilitation Medicine, Medical Corporation Association Shunseikai Amagi Chuo Hospital, Asakura, Japan; [8]Miz Co., Ltd, Saga, Japan; [9]Suwa Central Hospital, Chino, Japan

Objectives: Given that body composition assessment is becoming more common, demonstrating the significance of assessing muscle mass asymmetry, which has not been a focus in the past, would be important. This study examined the association between the leg skeletal muscle mass asymmetry index (LSMAI) and the timed up-and-go (TUG) test to assesses dynamic postural control capabilities, in community-dwelling older adults. ***Methods:*** This study is a cross-sectional study. The study had 122 (75 ± 6 years, 74% female) participants who fulfilled the required sample size. A generalized linear model was used to examine the association between the TUG and the LSMAI. ***Results:*** An association was found between the TUG and LSMAI (standard regression coefficient, 0.21, $p = .022$). As with the crude model, a significant association was found between TUG and LSMAI in the adjusted model (standardized coefficient $= 0.31$, $p = .009$). ***Conclusions:*** Assessing LSMAI in older adults is crucial. Moreover, this finding indicates the need to consider LSMAI in maintaining the dynamic posture control capabilities of older adults. ***Implications:*** The new finding that LSMAI in older adults is associated with TUG emphasizes the need for assessment and intervention of LSMAI. This suggests that the approach to LSMAI may contribute to maintaining and improving dynamic posture control ability.

Keywords: TUG, dynamic posture control capabilities, SMI

Key Points

- This study provided new findings that the leg skeletal muscle mass asymmetry index (LSMAI) is associated with the timed up-and-go test.
- Older adults should have their body composition assessed, including LSMAI, in addition to muscle strength and muscle mass.
- Approaches to LSMAI may lead to the maintenance and improvement of dynamic posture control capabilities.

Research that contributes to care prevention and health promotion is urgently needed as the global aging rate increases. Muscle mass and muscle strength decline with age (Doherty, 2001). Specifically, they reach peak levels between the ages of 20 and 40 years, after which they gradually decline (Mitchell et al., 2012). Considering the results of studies that have revealed these age-related muscle changes, muscle mass, and muscle strength are one of the factors necessary for care prevention and health promotion in older adults.

Healthy older adults have lower limb muscle strength associated with gait parameters, such as walking speed and stride length (Stotz et al., 2023). Grip strength, a representative value of muscle strength assessment, is also associated with the risk of falls in older adults (Lee et al., 2022). Sarcopenia, characterized by reduced muscle strength and muscle mass can predict cognitive function 2 years later among community-dwelling older adults (Peng et al., 2023). Interestingly, low muscle mass affects the risk of mortality in older adults (Li et al., 2022). Thus, many studies have focused on muscle mass and strength in older adults, and undoubtedly, this is a noteworthy factor given the age-related changes in the organism.

However, asymmetries in muscle strength and muscle mass are subject to debate. In recent years, a clear association emerged between asymmetry in toe grip strength and center-of-gravity sway (Koda et al., 2018). Furthermore, older adult men with both reduced grip strength and grip asymmetry are significantly at higher risk of hip fractures (Zhou et al., 2024). In other words, it is suggested that asymmetry in muscle strength has a negative impact on posture control in older adults. On the other hand, recent studies have focused not only on muscle strength but also on muscle asymmetry. However, fewer studies have reported muscle mass asymmetry than muscle strength asymmetry, and certain consensus have not been reached. Recently, body composition assessment is becoming more common, and the diagnostic criteria of the Asian Working Group for Sarcopenia also incorporates the muscle mass by body composition assessment (Chen et al., 2020). In view of these times, more studies reporting the association between muscle mass asymmetry, as assessed by body

---

Hachiya https://orcid.org/0009-0004-2521-8396
Otao https://orcid.org/0009-0008-5810-524X
Kamasaki (tai.pt.ft@gmail.com) is corresponding author, https://orcid.org/0000-0002-3226-4452

composition, and care prevention and health promotion in older adults are necessary. We have hypothesized that muscle mass asymmetry is also associated with posture control capability in older adults based on the aforementioned previous studies (Koda et al., 2018; Zhou et al., 2024). Posture control capability is one of the most important abilities for the care prevention and promotion health of older adults, as it can lead to falls and fractures.

Thus, this study aimed to (a) calculate the leg skeletal muscle mass asymmetry index (LSMAI) and test its association with the timed up-and-go test (TUG), which is a standard method for assessing dynamic posture control capability in a simple manner (Alonso et al., 2018). The study also aimed to (b) compare the degree of association of TUG with the conventionally important skeletal muscle mass index (SMI) and the LSMAI. The results of this study will clarify the significance of assessing not only muscle strength and SMI, but also LSMAI. Moreover, this study may suggestive new interventions for older adults to improve asymmetry and maintain and improve dynamic postural control.

Methods

Participants

This cross-sectional study included community-dwelling healthy older adults who were independent in their activities of daily living and had participated in physical fitness tests aimed at care prevention and health promotion. This physical fitness test is carried out every 6 months. This study included a total of five physical fitness tests conducted between March 2021 and March 2024. Participants were recruited by displaying posters, posting on website, and calling on staff. Individuals aged ≤64 years, were not walking independently, had mini-mental state examination scores below 23, and suspected of cognitive decline were excluded. Some participants attended a total of five measurement sessions more than once, in which case the measurement data from the first participation were used, and the remaining data were excluded. The participants of the physical fitness tests were fully informed of the study's content and objective. They provided consent and cooperated well. The Ethical Review Committee of the Nishikyushu University approved this study (24PBV09).

Methods

Basic Data

Basic data on participants were recorded on sex, age, living alone, and pain during exercise. Additionally, height and weight were measured and body mass index was calculated.

Body Compositions

Body composition was measured using a body composition analyzer (InBody 470, InBody Japan o., Ltd.) based on bioelectrical impedance analysis. The measurement position required the participants to stand barefoot, with the heel in contact with the electrode, and the upper limb grasped the hand electrode. SMI, trunk muscle mass index, and leg skeletal muscle mass were automatically calculated from the measurements. For the LSMAI, the leg SMI (LSMI) was first calculated for both the right and left sides (LSMI = leg muscle mass of Rt or Lt/height^2). The LSMI of each side was then used to calculate the LSMAI (LSMAI [%] = (high leg muscle mass SMI − low leg muscle mass SMI)/high leg muscle mass SMI × 100]; Sato et al., 2023). Body composition was assessed by bioelectrical impedance analysis using InBody, a useful assessment method with accuracy comparable to the dual-energy X-ray absorptiometry method (Fang et al., 2020).

Timed Up-and-Go Test

The TUG was measured with a digital stopwatch. The participants stood up from a chair with a 40-cm seat, walked around a landmark 3 m in front of them, return to the chair, and sit down. The time required for the series of actions was recorded. Measurements were taken twice, and the fastest time was used for the analysis. The TUG has been proven to be highly reliable and clinically useful (Rodrigues et al., 2023).

Other Measurements

Grip strength was measured with a Smedley grip strength tester (T.K.K. 3364, Takei Scientific Instruments Co., Ltd.). The measurement limb position was the standing position, with the elbow joint extended. The measurements were obtained twice, alternating between the left and right, and the maximum value was used. The Smedley grip strength meter was reported to be highly reliable (Mehmet et al., 2020).

Walking speed was measured with a digital stopwatch. Participants were instructed to walk 11 m on a level ground at their usual walking speed, and the time taken to walk the middle 5 m was recorded. The recommended length of the walking path when assessing walking speed should be measured on a long walking path of approximately 10 m rather than a short walking path (Peters et al., 2013). Therefore, in this study, measurements were carried out on an 11-m walking path. The measured walking speed was reported to be reliable (Bohannon, 1997).

The 30-s chair stand test (CS-30) was measured using a 40-cm chair and a digital stopwatch. The upper limbs were crossed in front of the chest, and the participants repeatedly stood and sit as fast as possible, and the number of repetitions was recorded. The measurement was made only once. The CS-30 is useful for assessing lower limb muscle strength (Jones et al., 1999), and many studies have reported its validity (Ikeda et al., 2023; Sawada et al., 2021).

The Mini-Mental State Examination was measured using a questionnaire in a face-to-face session. Mini-Mental State Examination is a common method for assessing cognitive function (Folstein et al., 1975), consists of 11 items, and is scored on a 30-point scale. Higher points indicate better cognitive function, and a point of ≤23 indicates suspected cognitive impairment (Holsinger et al., 2007).

Trail making test-A (TMT-A) was performed using a questionnaire in a face-to-face session. The TMT is the most widely used neuropsychological test (Espenes et al., 2020). Generally, if the test is not completed after 300 s, it is terminated (Thompson et al., 1999). The study recorded the time taken to complete the TMT-A test. TMT is a highly reliable assessment method (Bowie & Harvey, 2006).

The Geriatric Depression Scale-5 was measured using a face-to-face session. The Geriatric Depression Scale-5 is a test used as a screening test for depression (Brañez-Condorena et al., 2021). The test was reported to be reliable (Albiński et al., 2011) and can be used in older adults with cognitive decline (Lach et al., 2010).

Statistics Analysis

Statistical analysis was first conducted to identify the characteristics of the analyzed participants. Continuous variables are presented as means and *SD*s and categorical variables as the number of participants and percentage, followed by comparisons by sex. To confirm the extent of differences, the *t* test was used for continuous variables and the χ-square test for categorical variables, and effect sizes were calculated using Cohen's *d* and ϕ coefficient, respectively. The

Table 1 Characteristics of the Analyzed Participants

	Over all	Male	Female			95% CI	
	($N = 122$)	($n = 32$)	($n = 90$)	p	ES	Lower	Upper
Age (years)	75 ± 6	77 ± 6	75 ± 6	.059*	0.39[a]	–0.02	0.80
Height (cm)	153.7 ± 6.7	161.8 ± 4.5	150.8 ± 4.7	<.001*	2.38[a]	1.87	2.88
Weight (kg)	53.1 ± 8.6	60.3 ± 5.1	50.5 ± 8.1	<.001*	1.31[a]	0.88	1.75
BMI (kg/m^2)	22.4 ± 3.0	23.1 ± 2.0	22.2 ± 3.3	.093*	0.28[a]	–0.13	0.68
Living alone (yes) n (%)	28 (23%)	3 (9%)	25 (28%)	.047†	0.19[b]	0.04	0.32
Pain (yes) n (%)	70 (57%)	16 (50%)	54 (60%)	.406†	0.09[b]	–0.10	0.27
Body compositions							
SMI (kg/m^2)	6.4 ± 1.3	7.6 ± 1.8	5.9 ± 0.6	<.001*	1.51[a]	1.05	1.96
TMI (kg/m^2)	7.0 ± 0.8	7.7 ± 0.7	6.7 ± 0.6	<.001*	1.66[a]	1.19	2.12
LSMI (kg/m^2)	2.4 ± 0.3	2.7 ± 0.2	2.3 ± 0.2	<.001*	1.91[a]	1.42	2.39
LSMAI (%)	2.0 ± 2.1	1.5 ± 1.3	2.2 ± 2.3	.120*	–0.33[a]	–0.74	0.09
TUG (s)	5.6 ± 1.1	5.4 ± 1.1	5.6 ± 1.0	.349*	–0.19[a]	–0.60	0.21
Handgrip strength (kg)	26.2 ± 7.1	35.7 ± 4.7	22.8 ± 4.3	<.001*	2.94[a]	2.38	3.49
Gait speed (m/s)	1.3 ± 0.2	1.3 ± 0.3	1.4 ± 0.2	.052*	–0.41[a]	–0.82	0.00
CS-30 (times)	24 ± 7	23 ± 8	24 ± 7	.753*	–0.07[a]	–0.47	0.34
MMSE (points)	29 ± 1	29 ± 1	29 ± 1	.394*	–0.18[a]	–0.58	0.23
TMT-A (s)	83 ± 23	92 ± 25	79 ± 22	.015*	0.57[a]	0.11	1.02
GDS-5 (points)	0 ± 1	0 ± 1	0 ± 1	.177*	–0.24[a]	–0.66	0.18

Note. Values are represented as mean ± SD and number (%). BMI = body mass index; SMI = skeletal muscle mass index; TMI = trunk skeletal muscle mass index; LSMI = leg skeletal muscle mass index; LSMAI = leg skeletal muscle mass asymmetry index; TUG = timed up-and-go test; CS-30 = 30-s chair stand test; MMSE = Mini-Mental State Examination; TMT-A = trail making test-A; GDS-5 = geriatric depression scale-5; ES = effect size; CI = confidence interval.

[a] Cohen's d. [b] ϕ coefficient.

*T test. †chi-square test.

correlation between the TUG and SMI, LSMI, and LSMAI was then examined using Pearson's correlation analysis. Subsequently, a partial correlation analysis with age as a covariate was performed. Furthermore, the association between the TUG and LSMAI was examined using a generalized linear model with the TUG and LSMAI the dependent and independent variables, respectively (crude model). In addition, a model was created with the SMI, LSMI, handgrip strength, walking speed, CS-30, living alone (ref: no), pain (ref: no), sex (ref: female), and age as covariates to adjust for confounding (adjustment model). In the generalized linear model, the analysis of variance confirmed the significance of the model. The goodness of fit of the regression equation was confirmed by R2, residuals by the Durbin–Watson ratio and multicollinearity by the variance inflation factor. The normality of residuals was confirmed by the Shapiro–Wilk test. The significance level was set at 5% ($p < .05$) and SPSS (version 28.0, IBM Corp.) was used for analysis.

Sample Size

Sample sizes required for the generalized linear model were calculated a priori with effect size (f^2) = 0.15, α error = .05, power = 0.8, and 10 independent variables. Thus, 118 participants were required. G*Power (version 3.1.9.7) was used to calculate the power.

Results

Participant Characteristics

The characteristics of the analyzed participants are presented in Table 1. The participants were 122 community-dwelling older adults (75 ± 6 years, 74% female). Moreover, 243 participants who met the exclusion criteria of having participated in more than one physical fitness tests ($n = 232$), and middle-aged participants aged ≤ 64 years ($n = 11$) were excluded (Figure 1). The study participants met the a priori calculated required sample size. The LSMAI was not significantly different between men and women ($p = .120$, effect size = –0.33).

Correlation Between the TUG and Body Composition

The results of the correlation analysis between body composition and the TUG are presented in Table 2. Correlation analysis showed that the SMI ($r = -.12$, $p = .196$) and LSMI ($r = -.04$, $p = .684$) did not significantly correlate with the TUG. On the contrary, only the LSMAI showed a significant correlation ($r = .21$, $p = .022$) with the TUG. Partial correlation analysis was also conducted with age as a covariate. The results showed that the SMI ($r = -.11$, $p = .234$) and LSMI ($r = -.03$, $p = .726$) were not significantly correlated with the TUG. On the contrary, the LSMAI showed a significant correlation ($r = .22$, $p = .018$) with the TUG.

Association Between the TUG and LSMAI

The association between the TUG and LSMAI is shown in Table 3. The association was examined using a generalized linear model, with the TUG and LSMAI as the dependent and independent variables, respectively. A significant association (standardized coefficient = 0.21, $p = .022$) was found between the TUG and LSMAI in the crude model. In the adjusted model, the SMI, LSMI, handgrip strength, walking speed, CS-30, living alone, pain, sex, and age were entered as covariates to adjust for confounding. A significant association was found between the TUG and LSMAI in

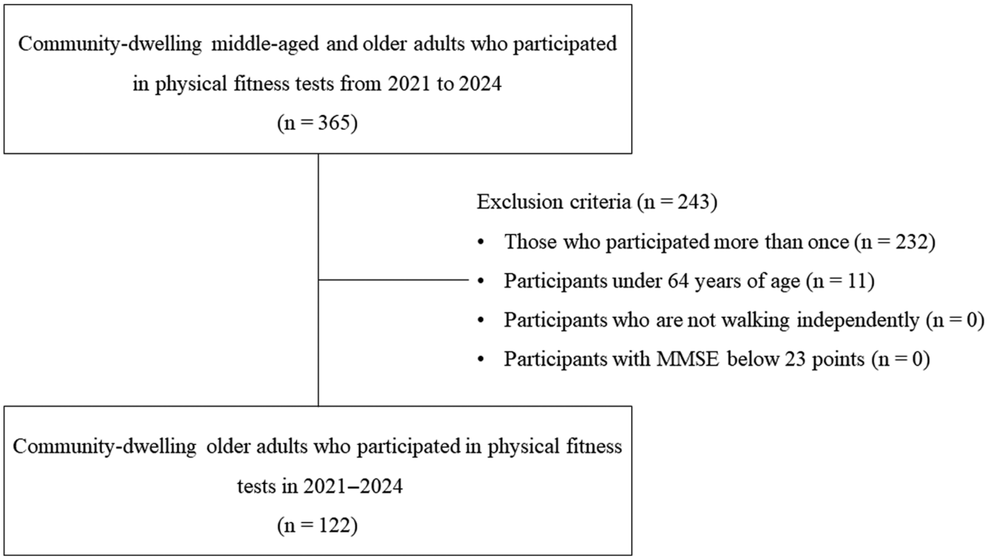

Figure 1 — Analysis participants selection flowchart.

Table 2 Correlation Between the TUG and Body Composition

	TUG			
	R	***p***	***r****	***p***
SMI	−.12	.196	−.11	.234
LSMI	−.04	.684	−.03	.726
LSMAI	.21	.022	.22	.018

Note. Pearson's correlation analysis. SMI = skeletal muscle mass index; LSMI = leg skeletal muscle mass index; LSMAI = leg skeletal muscle mass asymmetry index; TUG = timed up-and-go test.
*Partial correlation analysis (Covariate: Age).

the adjusted model (standardized coefficient = 0.31, $p = .009$). The regression equation for the adjusted model was significant ($p < .001$), the R^2 for goodness of fit of the equation was .45, the Durbin–Watson ratio for residuals was 1.95, and residuals were normally distributed. Multicollinearity was confirmed by variance inflation factor; however, no variable exceeded 5.

Discussion

This study examined the association between the LSMAI and the TUG. It also compared the degree of association of the TUG with the LSMAI and SMI, a representative value of muscle mass. The analysis showed that the LSMAI was associated with the TUG but not with the SMI.

The LSMAI of the study participants was 2.0% ± 2.1%. In the only study that investigated the LSMAI in community-dwelling older adults, the LSMAI was 2.0% (Iwasaka et al., 2020). Therefore, the LSMAI values in this study are considered valid. However, as only two studies, including the present study, have investigated the LSMAI in community-dwelling older adults, further studies are needed and the outcomes should be carefully considered.

Correlation analysis of the TUG with the SMI, LSMI, and LSMAI was conducted. The SMI and LSMI did not show a correlation. On the contrary, a significant positive correlation was found between the TUG and LSMAI. That is, the larger the LSMAI, the longer the TUG time. The participants were healthy older adults who were health conscious and lead independent lives. Nevertheless, asymmetry exists in leg skeletal muscle mass, and this value correlated with the TUG. However, the degree of correlation was not high. This reflects the characteristics of the participants because they were healthy older adults, and TUG values were biased, showing a ceiling effect.

The association between the TUG and LSMAI was examined in a generalized linear model, and a significant association was found after adjusting for confounding by covariates. Conversely, no association was found for the SMI and LSMI. The results emphasize that not only the SMI and LSMI, but, also the LSMAI should be assessed in community-dwelling older adults. Compared with the only study that investigated the LSMAI in long-term care older adults (Sato et al., 2023), the LSMAI was 3.2%, which is greater than that in the present study of community-dwelling older adults. This means that aging and physical frailty can lead to not only reduced muscle strength and muscle mass but also to greater LSMAI. In view of these considerations, the LSMAI may be an important new function that should be assessed and intervened with at an early stage of healthy, independent living in the community. Generally, muscle strength reduction precedes muscle mass reduction (Clark & Manini, 2010; Goodpaster et al., 2006). Therefore, muscle strength asymmetries may have occurred even earlier than muscle mass asymmetries. Future studies must fully investigate not only muscle strength and muscle mass but also age-related asymmetries in muscle strength and muscle mass will need to be further

Table 3 Association Between the TUG and LSMAI

	Nonstandardization factor	95% CI		Standardization factor	*p*	VIF
		Lower	Upper			
Crude model						
LSMAI	0.10	0.02	0.19	0.21	.022	
Adjustment model						
LSMAI	1.06	0.28	1.84	0.31	.009	2.74
SMI	−0.07	−0.22	0.09	−0.09	.396	2.05
LSMI	0.03	−0.04	0.10	0.07	.357	1.15
Handgrip strength	−0.05	−0.08	−0.01	−0.33	.022	4.02
Gait speed	−1.59	−2.28	−0.90	−0.37	<.001	1.30
CS-30	−0.04	−0.06	−0.02	−0.28	.002	1.43
Living alone (ref: no)	−0.01	−0.36	0.35	0.00	.958	1.15
Pain (ref: no)	−0.08	−0.08	0.21	−0.04	.582	1.09
Sex (ref: male)	0.17	−0.49	0.82	0.07	.616	4.28
Age	0.03	0.00	0.06	0.18	.040	1.50

Note. Dependent variables: TUG. The normality of the residuals was confirmed to be normally distributed by performing the Shapiro–Wilk test. LSMAI = leg skeletal muscle mass asymmetry index; SMI = skeletal muscle mass index; LSMI = leg skeletal muscle mass index; CS-30 = 30-s chair stand test; TUG = timed up-and-go test; CI = confidence interval; VIF = variance inflation factor.

Crude model: Single regression analysis, ANOVA $p = .022$, $R^2 = .04$, Durbin–Watson ratio = 1.66. Adjustment model: Multiple regression analysis, ANOVA $p < .001$, $R^2 = .45$, Durbin–Watson ratio = 1.95.

investigated. In this study, we did not assess the movements during the TUG in detail, so there are limits to what we can say, but the muscle mass asymmetry may cause greater instability during the TUG. Although this is a study on muscle strength asymmetry, it has been reported that as asymmetry increases, the stride becomes unstable (Laroche et al., 2012), and the body sway increases (Koda et al., 2018), which supports our speculation.

This study's strong points are that it is the first study to identify an association between the TUG and the LSMAI among community-dwelling older adults. This new insight will contribute to maintain and improve the dynamic posture control capability of older adults, and will eventually contribute to the care prevention and health promotion. In addition, the sample sizes were calculated in advance, which guarantees the reliability of the results.

However, this study has some limitations. First, the participants were drawn from a single region and were a health-conscious population thus, sampling bias could occur. Second, it is not possible to mention to what extent the LSMAI needs to be increased to be considered a concern. In the future, cutoff values must be investigated to predict and discriminate clinical outcomes, for example, through longitudinal studies. Third, muscle strength asymmetries have not been winning. As discussed above, the muscle strength asymmetry index may be measured before muscle mass asymmetry index. Future research should investigate whether muscle strength or muscle mass asymmetries are more relevant to care prevention and health promotion, and which is more sensitive to age-related changes. Finally, as it is a cross-sectional study, causal relationships are not possible. However, this is the first study to clarify the association between the TUG and LSMAI, and be a significant contribution to the care prevention and health promotion of older adults.

Conclusions

The LSMAI was first found to be associated with TUG in community-dwelling older adults. In addition, the association was not made with the SMI and LSMI. The results of this study emphasize that the LSMAI in community-dwelling older adults is also be focused on and assessed. Although more studies are needed, the results indicate that interventions for the LSMAI may improve dynamic posture control capabilities, such as standing, sitting, and walking, which are included in the TUG.

Acknowledgments

The authors would like to thank Enago (www.enago.jp) for the English language review. The staff involved in assisting with the measurements, and the participants who agreed to participate in this study are also thanked profusely. **Funding**: This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors. **Data availability Statement**: As new analyses are being conducted for a potential publication, we do not yet have approval from our ethics committee to disclose the raw data; therefore, we are unable to provide the entire data set available to other researchers.

References

Albiński, R., Kleszczewska-Albińska, A., & Bedyńska, S. (2011). [Geriatric Depression Scale (GDS). Validity and reliability of different versions of the scale—Review]. *Psychiatria Polska, 45*(4), 555–562.

Alonso, A.C., Ribeiro, S.M., Luna, N.M.S., Peterson, M.D., Bocalini, D.S., Serra, M.M., Brech, G.C., Greve, J.M.D., & Garcez-Leme, L.E. (2018). Association between handgrip strength, balance, and knee flexion/extension strength in older adults. *PLoS One, 13*(6), Article e0198185. https://doi.org/10.1371/journal.pone.0198185

Bohannon, R.W. (1997). Comfortable and maximum walking speed of adults aged 20–79 years: Reference values and determinants. *Age and Ageing, 26*(1), 15–19. https://doi.org/10.1093/ageing/26.1.15

Bowie, C.R., & Harvey, P.D. (2006). Administration and interpretation of the trail making test. *Nature Protocols, 1*(5), 2277–2281. https://doi.org/10.1038/nprot.2006.390

Brañez-Condorena, A., Soriano-Moreno, D.R., Navarro-Flores, A., Solis-Chimoy, B., Diaz-Barrera, M.E., & Taype-Rondan, A. (2021). Accuracy of the Geriatric Depression Scale (GDS)-4 and GDS-5 for the screening of depression among older adults: A systematic review and meta-analysis. *PLoS One, 16*(7), Article e0253899. https://doi.org/10.1371/journal.pone.0253899

Chen, L.-K., Woo, J., Assantachai, P., Auyeung, T.-W., Chou, M.-Y., Iijima, K., Jang, H.C., Kang, L., Kim, M., Kim, S., Kojima, T., Kuzuya, M., Lee, J.S.W., Lee, S.Y., Lee, W.-J., Lee, Y., Liang, C.-K., Lim, J.-Y., Lim, W.S., . . . Arai, H. (2020). Asian working group for sarcopenia: 2019 consensus update on sarcopenia diagnosis and treatment. *Journal of the American Medical Directors Association, 21*(3), 300–307.e2. https://doi.org/10.1016/j.jamda.2019.12.012

Clark, B.C., & Manini, T.M. (2010). Functional consequences of sarcopenia and dynapenia in the elderly. *Current Opinion in Clinical Nutrition and Metabolic Care, 13*(3), 271–276. https://doi.org/10.1097/MCO.0b013e328337819e

Doherty, T.J. (2001). The influence of aging and sex on skeletal muscle mass and strength. *Current Opinion in Clinical Nutrition and Metabolic Care, 4*(6), 503–508. https://doi.org/10.1097/00075197-200111000-00007

Espenes, J., Hessen, E., Eliassen, I.V., Waterloo, K., Eckerström, M., Sando, S.B., Timón, S., Wallin, A., Fladby, T., & Kirsebom, B.-E. (2020). Demographically adjusted trail making test norms in a Scandinavian sample from 41 to 84 years. *The Clinical Neuropsychologist, 34*, 110–126. https://doi.org/10.1080/13854046.2020.1829068

Fang, W.-H., Yang, J.-R., Lin, C.-Y., Hsiao, P.-J., Tu, M.-Y., Chen, C.-F., Tsai, D.-J., Su, W., Huang, G.-S., Chang, H., & Su, S.-L. (2020). Accuracy augmentation of body composition measurement by bioelectrical impedance analyzer in elderly population. *Medicine, 99*(7), Article e19103. https://doi.org/10.1097/MD.0000000000019103

Folstein, M.F., Folstein, S.E., & McHugh, P.R. (1975). "Mini-mental state." A practical method for grading the cognitive state of patients for the clinician. *Journal of Psychiatric Research, 12*(3), 189–198. https://doi.org/10.1016/0022-3956(75)90026-6

Goodpaster, B.H., Park, S.W., Harris, T.B., Kritchevsky, S.B., Nevitt, M., Schwartz, A.V., Simonsick, E.M., Tylavsky, F.A., Visser, M., & Newman, A.B. (2006). The loss of skeletal muscle strength, mass, and quality in older adults: The health, aging and body composition study. *The Journals of Gerontology. Series A, Biological Sciences and Medical Sciences, 61*(10), 1059–1064. https://doi.org/10.1093/gerona/61.10.1059

Holsinger, T., Deveau, J., Boustani, M., & Williams, J.W. (2007). Does this patient have dementia? *JAMA, 297*(21), 2391–2404. https://doi.org/10.1001/jama.297.21.2391

Ikeda, T., Noma, K., Okura, K., Katayama, S., Takahashi, Y., Maeda, N., Tanabe, S., Wakita, A., Hamada, M., Fujiwara, T., & Senda, M. (2023). Validity of the 30-second chair-stand test to assess exercise tolerance and clinical outcomes in patients with esophageal Cancer: A retrospective study with reference to 6-minute walk test results. *Acta Medica Okayama, 77*(2), 193–197. https://doi.org/10.18926/AMO/65149

Iwasaka, C., Mitsutake, T., & Horikawa, E. (2020). The independent relationship between leg skeletal muscle mass asymmetry and gait speed in community-dwelling older adults. *Journal of Aging and Physical Activity, 28*(6), 943–951. https://doi.org/10.1123/japa.2019-0463

Jones, C.J., Rikli, R.E., & Beam, W.C. (1999). A 30-s chair-stand test as a measure of lower body strength in community-residing older adults. *Research Quarterly for Exercise and Sport, 70*(2), 113–119. https://doi.org/10.1080/02701367.1999.10608028

Koda, H., Kai, Y., Murata, S., Osugi, H., Anami, K., Fukumoto, T., & Imagita, H. (2018). Relationship between muscle strength asymmetry and body sway in older adults. *Journal of Aging and Physical Activity, 26*(3), 457–461. https://doi.org/10.1123/japa.2017-0096

Lach, H.W., Chang, Y.-P., & Edwards, D. (2010). Can older adults with dementia accurately report depression using brief forms? Reliability and validity of the geriatric depression scale. *Journal of Gerontological Nursing, 36*(5), 30–37. https://doi.org/10.3928/00989134-20100303-01

Laroche, D.P., Cook, S.B., & Mackala, K. (2012). Strength asymmetry increases gait asymmetry and variability in older women. *Medicine and Science in Sports and Exercise, 44*(11), 2172–2181. https://doi.org/10.1249/MSS.0b013e31825e1d31

Lee, Y.-C., Chang, S.-F., Kao, C.-Y., & Tsai, H.C. (2022). Muscle strength, physical fitness, balance, and walking ability at risk of fall for prefrail older people. *BioMed Research International, 2022*(1), Article 4581126. https://doi.org/10.1155/2022/4581126

Li, C.-I., Liu, C.-S., Lin, C.-H., Yang, S.-Y., Li, T.-C., & Lin, C.-C. (2022). Independent and joint associations of skeletal muscle mass and physical performance with all-cause mortality among older adults: A 12-year prospective cohort study. *BMC Geriatrics, 22*(1), Article 597. https://doi.org/10.1186/s12877-022-03292-0

Mehmet, H., Yang, A.W.H., & Robinson, S.R. (2020). Measurement of hand grip strength in the elderly: A scoping review with recommendations. *Journal of Bodywork and Movement Therapies, 24*(1), 235–243. https://doi.org/10.1016/j.jbmt.2019.05.029

Mitchell, W.K., Williams, J., Atherton, P., Larvin, M., Lund, J., & Narici, M. (2012). Sarcopenia, dynapenia, and the impact of advancing age on human skeletal muscle size and strength; a quantitative review. *Frontiers in Physiology, 3*, Article 260. https://doi.org/10.3389/fphys.2012.00260

Peng, T.-C., Chiou, J.-M., Chen, T.-F., Chen, Y.-C., & Chen, J.-H. (2023). Grip strength and sarcopenia predict 2-year cognitive impairment in community-dwelling older adults. *Journal of the American Medical Directors Association, 24*(3), 292–298.e1. https://doi.org/10.1016/j.jamda.2022.10.015

Peters, D.M., Fritz, S.L., & Krotish, D.E. (2013). Assessing the reliability and validity of a shorter walk test compared with the 10-Meter Walk Test for measurements of gait speed in healthy, older adults. *Journal of Geriatric Physical Therapy, 36*(1), 24–30. https://doi.org/10.1519/JPT.0b013e318248e20d

Rodrigues, F., Teixeira, J.E., & Forte, P. (2023). The reliability of the timed up and go test among Portuguese elderly. *Healthcare, 11*(7), Article 928. https://doi.org/10.3390/healthcare11070928

Sato, R., Sawaya, Y., Ishizaka, M., Shiba, T., Hirose, T., & Urano, T. (2023). Leg skeletal muscle mass asymmetry is independently associated with gait speed in older adults requiring long-term care. *Geriatrics & Gerontology International, 23*(5), 371–375. https://doi.org/10.1111/ggi.14583

Sawada, S., Ozaki, H., Natsume, T., Deng, P., Yoshihara, T., Nakagata, T., Osawa, T., Ishihara, Y., Kitada, T., Kimura, K., Sato, N., Machida, S., & Naito, H. (2021). The 30-s chair stand test can be a useful tool for screening sarcopenia in elderly Japanese participants. *BMC Musculoskeletal Disorders, 22*(1), Article 639. https://doi.org/10.1186/s12891-021-04524-x

Stotz, A., Hamacher, D., & Zech, A. (2023). Relationship between muscle strength and gait parameters in healthy older women and men. *International Journal of Environmental Research and Public Health, 20*(7), Article 5362. https://doi.org/10.3390/ijerph20075362

Thompson, M.D., Scott, J.G., Dickson, S.W., Schoenfeld, J.D., Ruwe, W.D., & Adams, R.L. (1999). Clinical utility of the trail making test practice time. *The Clinical Neuropsychologist, 13*(4), 450–455. https://doi.org/10.1076/1385-4046(199911)13:04;1-Y;FT450

Zhou, S., Si, H., Wu, L., Liu, Y., Peng, L., Li, M., & Shen, B. (2024). Association between handgrip strength weakness and asymmetry with incident hip fracture among older Chinese adults. *Archives of Gerontology and Geriatrics, 122*, Article 105385. https://doi.org/10.1016/j.archger.2024.105385