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Longitudinal association between body mass index-adjusted skeletal muscle mass and domain-specific progression of locomotive syndrome in community-dwelling adults aged 50 years and older

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ABSTRACT

Locomotive syndrome (LS) is characterized by mobility decline in older adults and is associated with future long-term care needs and reduced independence. Skeletal muscle mass plays a crucial role in maintaining mobility. However, the longitudinal association between appendicular skeletal muscle mass adjusted for body mass index (ASM/BMI) and LS progression remains insufficiently examined. This study examined the association between baseline ASM/BMI and LS progression by each LS assessment component. This prospective cohort study followed community-dwelling adults aged ≥50 years for 1 year. LS progression was evaluated using changes in the two-step test, stand-up test, and the 25-question geriatric locomotive function scale (GLFS-25). ASM was assessed using bioelectrical impedance analysis, and ASM/BMI was calculated as ASM divided by body mass index. Associations were examined using multivariable logistic regression models adjusting for age, sex, and baseline LS stage. Incidence of LS progression differed across components. Higher baseline ASM/BMI was significantly associated with a lower risk of LS progression assessed by the two-step test (adjusted odds ratio per 0.01-unit increase, 0.94; 95% confidence interval, 0.90–0.98). Baseline ASM/BMI was not significantly associated with LS progression based on the stand-up test or GLFS-25. Among community-dwelling adults aged ≥50 years, lower baseline ASM/BMI was associated with a higher likelihood of LS progression in dynamic mobility capacity assessed by the two-step test, but not with overall LS progression based on the stand-up test or GLFS-25. These results suggest that ASM/BMI is a domain-specific predictor for declines in walking-related mobility.

Keywords: locomotive syndrome, appendicular skeletal muscle mass, community-dwelling adults, cohort study

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INTRODUCTION

Locomotive syndrome (LS) is a concept that captures mobility decline in older adults[1] and is associated with higher risks of falls and fractures.[2] LS involves declines in musculoskeletal function, including bone, joint, and skeletal muscle, and represents an important public health issue in super-aged societies such as Japan, particularly for extending healthy life expectancy.[1] Accordingly, objective and practical assessment indicators are needed to detect LS onset and progression at an early stage and to guide prevention and intervention efforts.[3]

Skeletal muscle mass is a key component of body composition associated with mobility and physical function in older adults.[4,5] The height-adjusted skeletal muscle mass index (SMI) has been widely used to assess skeletal muscle mass in studies of Asian older adults.[6] In recent years, appendicular skeletal muscle mass adjusted for body mass index (ASM/BMI) has gained attention as an index reflecting relative muscle mass in relation to body size,[7-9] and has been suggested to be associated with weight-bearing physical function and metabolic abnormalities. These findings suggest that ASM/BMI may have clinical utility for functional assessment in older adults.

A previous cross-sectional study has investigated the association between lower muscle mass with LS.[10] However, this study utilized height-adjusted SMI and focused primarily on questionnaire-based assessments, leaving the temporal association with performance-based tests, such as the two-step and stand-up tests, less clear. Furthermore, it remains unexplored whether ASM/BMI—an index reflecting relative muscle mass for body size—serves as a precursor to decline in specific physical domains of LS.

Therefore, the aim of this study was to examine the association between baseline ASM/BMI and LS progression by each LS assessment component over 1 year among community-dwelling middle-aged and older adults. By longitudinally evaluating how ASM/BMI relates to subsequent mobility decline across the three individual components—two-step test, the stand-up test, and the 25-question geriatric locomotive function scale (GLFS-25), this study aims to clarify the domain-specific predictive value of relative muscle mass and address the existing gaps in the literature. It was hypothesized that ASM/BMI, as an indicator reflecting dynamic mobility function under weight-bearing conditions, would be associated with LS progression.

MATERIALS AND METHODS

Design and setting

This prospective cohort study used data from Study for Diagnosis, Early Detection, and Treatment of Locomotive Syndrome Using an Epidemiological Cohort (DETECt-L). The DETECt-L Study is a cohort study of residents aged ≥18 years in Hiroshima City, Higashi-Hiroshima City, Hatsukaichi City, and Kure City. Data were collected between April 2021 and November 2025. Follow-up was conducted 365 ± 60 days after baseline; participants outside this window were excluded. For the follow-up survey, eligible participants were contacted via mail (postcards) to invite them to a second assessment. The follow-up assessment followed the exact same protocol as the baseline survey, including the LS risk tests (stand-up test, two-step test, and GLFS-25), body composition measurements via bioelectrical impedance analysis (BIA), usual gait speed, and grip strength. Participants were recruited via staff at community comprehensive support centers, public halls, and gymnasiums; community exercise instructors in Hiroshima Prefecture; and study flyers.

Participants

Community-dwelling individuals able to walk independently were eligible for participation.

Exclusion criteria included severe diseases, including stroke, unstable cardiovascular disease, severe respiratory disease, diabetic peripheral neuropathy, Parkinson's disease, and rheumatoid arthritis, and suspected cognitive impairment. These criteria were assessed through oral self-reporting during the informed consent process. Trained staff provided a detailed explanation of the exclusion criteria to participants, who then disclosed any relevant medical history or cognitive issues. Suspected cognitive impairment was further identified based on the participants' ability to comprehend instructions and provide reliable responses during the interview and physical assessments. Individuals with suspected cognitive impairment were excluded to ensure accurate questionnaire responses, and those with severe diseases were excluded to reduce the risk of falls during measurements and exacerbation of pre-existing conditions.

The study protocol was approved by Ethical Committee for Epidemiology of Hiroshima University (approval number, E2022-0086), and all participants provided written informed consent prior to participation. The study was conducted in accordance with principles of Declaration of Helsinki.

Based on the recommendations[9] of Asian Working Group for Sarcopenia (AWGS) 2025, the analysis was restricted to participants aged ≥50 years to focus on middle-aged and older populations in whom the clinical significance of skeletal muscle mass indices becomes clearer. In AWGS, the target population for evaluating sarcopenia and low muscle mass is primarily middle-aged and older adults, and the pathological significance of muscle mass indices and their association with mobility decline in individuals aged <50 years are considered limited. Because LS progression increases with age,[11] restricting the analysis to participants aged ≥50 years was intended to increase the internal validity of the longitudinal association.

Participants classified as LS stage 3 at baseline were included in the cohort; however, they were excluded from longitudinal analyses examining progression because further worsening cannot be defined within the LS staging classification. This approach was used to avoid ceiling effects and to support the validity of the progression outcome. In contrast, participants who transitioned from a lower LS stage at baseline to stage 3 during the 1-year follow-up were correctly identified and included in the progression group. Participants with missing data were excluded from the analyses.

Variables

The outcome was LS progression during 1-year follow-up,[3,11] evaluated separately using the two-step test, stand-up test, and GLFS-25. Participants were classified into two groups based on changes in LS stage over 1 year. Specifically, participants who developed LS from non-LS status at baseline or whose LS stage worsened were classified as the progression group. All other participants were classified as the non-progression group.

LS risk test. The LS risk test consists of two performance-based mobility tests (two-step test and stand-up test) and GLFS-25. Its associations with mobility decline and utility as a screening tool have been reported in general-population studies.[12-14] Details of each assessment component are shown below.

Two-step test was performed from a standing position, with participants taking two steps forward using the maximum possible stride length while taking care not to lose balance. The trial was considered complete if no additional steps were taken after landing. The distance from the starting line to the tip of the landing foot was measured. The test was performed twice, and the better value was adopted. The measured distance divided by height was defined as the two-step test score. LS stage based on this test was classified as follows: non-LS, two-step test score ≥1.3; stage 1, two-step test score ≥1.1 and <1.3; stage 2, two-step test score ≥0.9 and <1.1; stage 3, two-step test score <0.9.

The stand-up test used stools with heights of 20, 30, and 40 cm. Participants were instructed to stand up from each stool using one leg or both legs, with arms crossed over the chest to prevent momentum. A trial was judged successful if the participant could maintain a standing position for ≥3 seconds. LS stage based on this test was classified as follows: non-LS, able to stand up using one leg from a 40-cm stool; stage 1, unable to stand up on one leg from a 40-cm stool but able to stand up using both legs from a 20-cm stool; stage 2, unable to stand up using both legs from a 20-cm stool but able to stand up from a 30-cm stool; stage 3, unable to stand up using both legs from a 30-cm stool.

GLFS-25 is a self-administered questionnaire consisting of 25 items, each scored from 0 (no impairment) to 4 (severe impairment). It assesses pain, activities of daily living, social activities, mobility difficulty, and mental health status. The total score ranges from 0 to 100 points, with a higher score indicating more severe impairment; specifically, a score of 100 represents the worst locomotive function. The total score (0–100 points) was used for analysis, and LS stage based on this test was classified as follows: non-LS, GLFS-25 score <7; stage 1, ≥7 and <16; stage 2, ≥16 and <24; stage 3, ≥24.

Body composition. Body weight, fat mass, and ASM were measured using a BIA device (InBody 270, InBody Japan, Tokyo, Japan). Although BIA may overestimate ASM compared with dual-energy X-ray absorptiometry, correlations and agreement have been examined, and BIA is widely used in epidemiological studies.[15,16] Body mass index (BMI) was calculated as weight (kg) divided by height squared (m^2), and percent body fat was calculated as fat mass (kg) divided by body weight (kg) multiplied by 100. ASM/BMI was calculated as ASM (kg) divided by BMI.

Gait speed. Participants walked 5 m at their usual pace. A 1-m lead-in and a 1-m lead-out walkway were provided before and after the measurement section. Time was measured using a stopwatch, and gait speed (m/s) was calculated. Usual gait speed is known to have high reliability and validity among community-dwelling older adults.[17]

Grip strength. Grip strength was measured using a digital dynamometer (TKK 5401 Grip-D, Niigata, Japan). Participants stood with feet shoulder-width apart, holding the dynamometer with the display facing outward. The shoulder was positioned in slight abduction so that the device did not touch the body. Grip width was adjusted so that the proximal interphalangeal joint of the index finger formed a right angle. Participants were then instructed to grip the dynamometer with maximal effort. Measurements were performed twice using the dominant hand, and the maximum value was used for analysis. Grip strength is a reliable measure reflecting overall muscle strength and physical function and is widely used in clinical and epidemiological research.[18]

Covariates. Covariates were selected a priori based on previous studies.[11,19,20] The multivariable models were adjusted for age, sex, and baseline LS stage; age and sex were included as key confounders,[11,19] and baseline LS stage was included to account for initial functional severity.[20] Grip strength and usual gait speed were considered as intermediate variables between skeletal muscle mass and LS progression. To avoid overadjustment bias, these variables were not included in the primary multivariable models.[21]

Bias

To minimize measurement bias, all physical function measurements were conducted by trained physical therapists or certified health fitness instructors using standardized procedures.

Statistical analysis

Normality of continuous variables was assessed before analysis. Continuous variables are presented as mean ± standard deviation when normally distributed and as median (interquartile range) when not normally distributed. Categorical variables are presented as counts (percentages).

Between-group comparisons used the independent-samples *t*-test or Mann–Whitney *U* test for continuous variables and the χ^2 test for categorical variables.

In the primary analyses, LS progression at 1 year was defined as a binary outcome based on worsening of LS stage according to the stand-up test, two-step test, and GLFS-25, respectively. Due to the limited number of events for each specific stage transition, all categories of worsening were combined to ensure sufficient statistical power and stability of the regression models, following the events per variable (EPV) concept. Associations between baseline ASM/BMI and LS progression at 1 year were examined using multivariable logistic regression models adjusted for age, sex, and baseline LS stage (categorical variable). By including the baseline LS stage as a covariate, we statistically accounted for the potential influence of initial functional severity on the likelihood of progression. Because LS stage 3 represents the most severe category at baseline and further deterioration cannot be captured within the staging system, participants classified as LS stage 3 at baseline were excluded from the analyses of LS progression to avoid ceiling effects. Results of regression analyses are presented as odds ratios (ORs) with 95% confidence intervals (CIs). ASM/BMI was treated as a continuous variable, and regression coefficients are presented as ORs per 0.01-unit increase in ASM/BMI. A two-tailed p-value <0.05 was considered statistically significant. All statistical analyses were performed using JMP Student Edition version 18.0 (SAS Institute Inc, Cary, NC, USA).

Sample size

Sample size was based on the EPV concept to ensure stable estimation in logistic regression analyses. Logistic regression models typically require at least 5 EPV and preferably ≥10 EPV.[22,23] In this study, the model included five parameters: age (continuous; 1 parameter), sex (female = 0; 1 parameter), baseline LS stage (categorical, non-LS, stage 1, and stage 2; entered as two indicator variables with non-LS as the reference category), and ASM/BMI (continuous; 1 parameter). Therefore, at least 25 events, and preferably ≥50 LS progression events, were targeted. In the analytical population, the number of events observed during the 1-year follow-up met these criteria; thus, the sample size was adequate for multivariable logistic regression.

RESULTS

Participant flow and baseline characteristics

Between April 2021 and November 2025, 1,028 individuals participated in the DETECt-L Study (Figure 1). Of these, 505 participants who attended only once were excluded. Among the 523 participants who attended the assessment on two or more occasions, 56 were excluded because they attended two or more times within the same fiscal year or because the second assessment was conducted outside the prespecified follow-up window (365 ± 60 days after the first assessment). As a result, 467 participants completed a second assessment at 1 year (365 days ± 60 days). After excluding 24 participants with missing data, 443 participants were included in the analysis. Finally, 60 participants aged <50 years were excluded, resulting in a final analytic sample of 383 participants. Baseline characteristics of the participants are shown in Table 1. Descriptive statistics stratified by LS stage for each test are presented in Table 2.

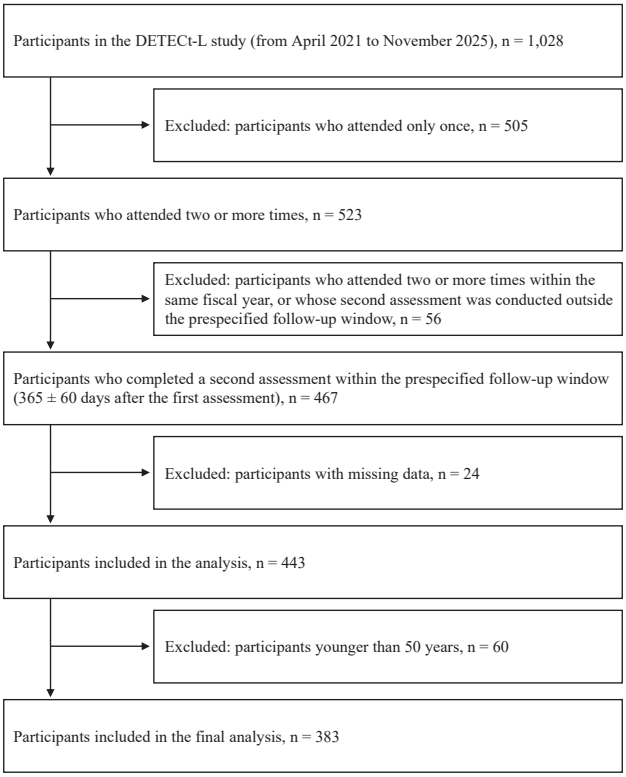

Fig. 1 Flow diagram of participant selection for the 1-year follow-up analysis
DETECt-L: Diagnosis, Early Detection, and Treatment of Locomotive Syndrome Using an Epidemiological Cohort

Table 1 Participant characteristics

Variable		All (n = 383)	Female (n = 320)	Male (n = 63)
Age (years)		71.5 ± 8.6	70.9 ± 8.7	74.3 ± 7.7
Height (cm)		155.7 ± 7.2	153.8 ± 5.9	165.5 ± 4.7
Weight (kg)		54.5 ± 9.4	52.7 ± 8.6	63.5 ± 7.8
BMI (kg/m^2)		22.4 ± 3.1	22.3 ± 3.2	23.2 ± 2.5
ASM/BMI		0.66 ± 0.14	0.62 ± 0.10	0.87 ± 0.11
Grip strength (kg)		25.9 ± 6.5	23.8 ± 4.2	36.8 ± 5.4
Gait speed (m/s)		1.44 ± 0.24	1.45 ± 0.24	1.41 ± 0.24
Two-step test	Non-LS	290 (75.7%)	239 (74.7%)	51 (81.0%)
	Stage 1	78 (20.4%)	68 (21.3%)	10 (15.9%)
	Stage 2	14 (3.7%)	13 (4.1%)	1 (1.6%)
	Stage 3	1 (0.3%)	0 (0%)	1 (1.6%)
Stand-up test	Non-LS	163 (42.6%)	140 (43.8%)	23 (36.5%)
	Stage 1	197 (51.4%)	159 (49.7%)	38 (60.3%)
	Stage 2	16 (4.2%)	14 (4.4%)	2 (3.2%)
	Stage 3	7 (1.8%)	7 (2.2%)	0 (0%)

GLFS-25	Non-LS	233 (60.8%)	186 (58.1%)	47 (74.6%)
	Stage 1	102 (26.7%)	91 (28.4%)	11 (17.5%)
	Stage 2	30 (7.8%)	28 (8.8%)	2 (3.2%)
	Stage 3	18 (4.7%)	15 (4.7%)	3 (4.8%)
Overall LS stage	Non-LS	116 (30.3%)	96 (30.0%)	20 (31.7%)
	Stage 1	203 (53.0%)	167 (52.2%)	36 (57.1%)
	Stage 2	42 (11.0%)	38 (11.9%)	4 (6.3%)
	Stage 3	22 (5.7%)	19 (5.9%)	3 (4.8%)

Data are presented as mean ± SD or n (%).
Overall LS stage was defined according to the original criteria as the most severe grade among the three LS risk tests; LS was considered present if at least one test met the corresponding cutoff value.
BMI: body mass index
ASM: appendicular skeletal muscle mass
GLFS-25: geriatric locomotive function scale-25
LS: locomotive syndrome

Table 2 Descriptive statistics for age, BMI, ASM/BMI, gait speed, and grip strength stratified by the presence or absence of LS as determined by each test

A. Two-step test

Variable	Non-LS (n = 290)	Stage 1 (n = 78)	Stage 2 (n = 14)	Stage 3 (n = 1)
Age (years)	70.0 ± 8.7	75.8 ± 6.6	77.7 ± 5.3	81
BMI (kg/m^2)	22.2 ± 2.9	23.0 ± 3.4	22.5 ± 5.3	20.6
ASM/BMI	0.68 ± 0.14	0.61 ± 0.13	0.61 ± 0.13	0.75
Grip strength (kg)	26.8 ± 6.7	23.4 ± 5.4	22.3 ± 4.9	28.7
Gait speed (m/s)	1.49 ± 0.22	1.33 ± 0.24	1.20 ± 0.28	0.68

B. Stand-up test

Variable	Non-LS (n = 163)	Stage 1 (n = 197)	Stage 2 (n = 16)	Stage 3 (n = 7)
Age (years)	67.7 ± 8.6	74.2 ± 7.7	74.6 ± 5.8	75.0 ± 8.3
BMI (kg/m^2)	21.6 ± 2.9	22.8 ± 2.9	25.4 ± 3.4	25.3 ± 3.8
ASM/BMI	0.68 ± 0.14	0.66 ± 0.14	0.60 ± 0.12	0.55 ± 0.09
Grip strength (kg)	26.6 ± 7.2	25.8 ± 6.0	22.3 ± 5.1	23.1 ± 2.6
Gait speed (m/s)	1.52 ± 0.24	1.40 ± 0.22	1.31 ± 0.21	1.15 ± 0.38

C. GLFS-25

Variable	Non-LS (n = 233)	Stage 1 (n = 102)	Stage 2 (n = 30)	Stage 3 (n = 18)
Age (years)	70.6 ± 8.7	72.0 ± 8.6	74.1 ± 8.6	75.8 ± 5.3
BMI (kg/m^2)	22.2 ± 3.1	22.6 ± 2.9	22.8 ± 4.0	24.3 ± 2.4
ASM/BMI	0.68 ± 0.15	0.63 ± 0.12	0.63 ± 0.09	0.60 ± 0.14
Grip strength (kg)	26.8 ± 6.8	25.4 ± 6.0	23.2 ± 4.7	22.9 ± 6.5
Gait speed (m/s)	1.48 ± 0.23	1.46 ± 0.24	1.31 ± 0.22	1.13 ± 0.26

D. Overall LS stage

Variable	Non-LS (n = 116)	Stage 1 (n = 203)	Stage 2 (n = 42)	Stage 3 (n = 22)
Age (years)	67.5 ± 8.5	72.6 ± 8.3	75.1 ± 7.8	75.1 ± 5.8
BMI (kg/m^2)	21.5 ± 2.9	22.7 ± 2.8	22.6 ± 4.2	24.5 ± 2.9
ASM/BMI	0.70 ± 0.15	0.65 ± 0.14	0.63 ± 0.11	0.60 ± 0.13
Grip strength (kg)	27.4 ± 7.5	26.0 ± 6.1	22.9 ± 4.7	23.2 ± 5.9
Gait speed (m/s)	1.54 ± 0.22	1.45 ± 0.23	1.31 ± 0.20	1.16 ± 0.28

Data are presented as mean ± SD.
Overall LS stage was defined according to the original criteria as the most severe grade among the three LS risk tests; LS was considered present if at least one test met the corresponding cutoff value.
BMI: body mass index
ASM: appendicular skeletal muscle mass
GLFS-25: geriatric locomotive function scale-25
LS: locomotive syndrome

Incidence of LS progression over 1 year

The incidence of LS progression over 1 year is shown in Table 3. During the 1-year follow-up, LS progression was observed in 32 participants (8.4%) based on the two-step test, 60 participants (16.0%) based on the stand-up test, and 47 participants (12.9%) based on the GLFS-25.

Table 3 Incidence of LS progression over 1 year (progression/non-progression)

Variable	All	Female	Male
Two-step test	32 (8.4%)/350 (91.6%)	28 (8.8%)/292 (91.3%)	4 (6.5%)/58 (93.5%)
Stand-up test	60 (16.0%)/316 (84.0%)	49 (15.7%)/264 (84.3%)	11 (17.5%)/52 (82.5%)
GLFS-25	47 (12.9%)/318 (87.1%)	36 (11.8%)/269 (88.2%)	11 (18.3%)/49 (81.7%)

Values are n (%). Participants with LS stage 3 at baseline were excluded from each test.
LS: locomotive syndrome
GLFS-25: geriatric locomotive function scale-25

Association between ASM/BMI and LS progression

Associations between baseline ASM/BMI and LS progression, as assessed by each LS component, are shown in Table 4. In multivariable analyses, higher baseline ASM/BMI was significantly associated with a lower risk of LS progression assessed by the two-step test (adjusted OR [aOR] per 0.01-unit increase, 0.94; 95% CI, 0.90–0.98). In contrast, baseline ASM/BMI was not significantly associated with LS progression based on the stand-up test or the GLFS-25.

Table 4 Association between ASM/BMI and LS progression

	Two-step test		Stand-up test		GLFS-25	
	Unadjusted OR (95% CI)	Adjusted OR (95% CI)	Unadjusted OR (95% CI)	Adjusted OR (95% CI)	Unadjusted OR (95% CI)	Adjusted OR (95% CI)
ASM/BMI (unit: 0.01)	0.96 (0.94, 0.98)	0.94 (0.90, 0.98)	1.00 (0.98, 1.02)	0.99 (0.96, 1.02)	1.01 (0.99, 1.03)	1.00 (0.97, 1.03)
C-statistic (AUC)	0.64	0.65	0.52	0.82	0.54	0.61
Hosmer–Lemeshow test (*p*)	1.00	1.00	0.95	1.00	1.00	1.00

ASM: appendicular skeletal muscle mass
BMI: body mass index
LS: locomotive syndrome
CI: confidence interval
GLFS-25: geriatric locomotive function scale-25
OR: odds ratio
AUC: area under the curve
Participants with LS stage 3 at baseline were excluded from each test. Adjusted variables: age, sex, LS stage at baseline.

DISCUSSION

This study showed that the association between ASM/BMI and LS progression during 1-year follow-up differed by each LS assessment component. The principal finding was that lower baseline ASM/BMI was significantly associated with a higher risk of LS progression assessed by the two-step test, whereas baseline ASM/BMI was not significantly associated with LS progression based on the stand-up test or GLFS-25. These findings suggest that ASM/BMI may not predict overall LS progression, whereas it may be associated with specific domains of mobility decline.

To our knowledge, this study is among the first to examine the longitudinal association between ASM/BMI and subsequent LS progression, with analyses conducted separately for each LS assessment component. To date, the relationship between skeletal muscle mass and LS has been examined mainly in cross-sectional studies, and SMI has often been used as the muscle mass index.[24,25] Although AWGS 2025 has highlighted the clinical relevance of ASM/BMI,[9] longitudinal evidence is lacking regarding the association between ASM/BMI and LS progression. This study is important in that it demonstrated that ASM/BMI was associated with worsening as assessed by the two-step test, but not by the other assessment components, thereby clarifying the role of ASM/BMI more specifically.

The observed association between ASM/BMI and progression assessed by the two-step test suggests that relative insufficiency of muscle mass may contribute to declines in dynamic mobility capacity. The two-step test is a continuous measure based on maximal stride length, and large-scale data have shown that its distribution declines with age.[11] Physiologically, ASM/BMI reflects a weight-normalized muscle mass index, which is closely related to the power-to-weight ratio required for dynamic weight-bearing tasks. The two-step test requires horizontal propulsion and dynamic balance. Both depend on muscle power relative to body weight. Although compensatory movements, including trunk forward lean or use of the upper limbs, are possible, there may be limits to maintaining maximal stride length through such strategies as it is constrained by the

force that muscle can generate relative to body weight. Relative insufficiency of muscle mass may therefore be more likely to manifest as measurable performance decline over a short period when dynamic mobility capacity is assessed using a continuous metric.

In contrast, the lack of association observed for the stand-up test and GLFS-25 may reflect differences in the measurement characteristics and constructs captured by these components. The stand-up test requires lower-limb strength but may allow greater compensatory strategies, including increased trunk forward lean to shift the center of mass and facilitate vertical rising.[26,27] While vertical rising tasks can be partially achieved through momentum and postural adjustments even with reduced muscle mass, maximal horizontal propulsion in the two-step test is less amenable to such compensations. Furthermore, because the stand-up test is stage-based and uses an ordinal scale, it may be less sensitive to short-term progression defined as an LS stage change, even when muscle mass decline is present. Meanwhile, GLFS-25 is a self-administered questionnaire that captures not only physical function but also pain, living environment, and psychological factors,[13] and may therefore be less well explained by muscle mass indices alone. Accordingly, the absence of a significant association between ASM/BMI and progression based on GLFS-25 may be consistent with the multidimensional nature of the assessment component.

While the relationship between LS and low muscle mass may be bidirectional—meaning individuals with LS are inherently more likely to exhibit muscle loss, our longitudinal findings suggest that ASM/BMI specifically precedes declines in dynamic mobility measured by the two-step test. Notably, the absence of an association with the stand-up test or GLFS-25 indicates that this relationship is not a simple, self-evident reflection of overall frailty but rather a domain-specific link.

From a practical perspective, the present results suggest that ASM/BMI may be useful as an indicator of future risk of decline in dynamic mobility capacity. Specifically, ASM/BMI can serve as an early-stage biomarker to identify individuals who have not yet exhibited functional LS progression but possess low physiological reserve. In community health screenings where body composition analyzers are available, identifying low ASM/BMI could facilitate targeted interventions—such as gait-focused exercise programs—before measurable declines in walking capacity occur. This approach allows for more precise and efficient resource allocation in community-based prevention efforts. Among community-dwelling middle-aged and older adults, early identification of individuals with low ASM/BMI may help inform more focused exercise interventions and lifestyle guidance aimed at preventing declines in walking and balance abilities. However, the findings do not support ASM/BMI as a comprehensive indicator that independently explains LS progression. ASM/BMI should be interpreted as an indicator associated with specific functional domains within multidimensional mobility decline, including gait-related domains such as step length. It may be most appropriately used in combination with multidimensional assessments, including muscle strength, neuromuscular function, pain, and psychosocial factors.

This study has several strengths. First, a longitudinal design with a 1-year follow-up was adopted, and analyses were conducted with attention to temporal order. Second, data were derived from an epidemiological cohort of community-dwelling individuals, and muscle mass and mobility were assessed using standardized procedures. Third, excluding individuals with baseline LS stage 3 from analyses avoided ceiling effects and supported the validity of the progression definition. Several limitations should also be acknowledged. First, the follow-up period was relatively short (1 year), precluding evaluation of long-term LS progression. Nevertheless, during this period, a worsening of stage was observed in between 8.4% and 16.0% of subjects. This suggests that a one-year period is clinically meaningful for detecting early functional decline in middle-aged and older adults living in the community. However, further long-term follow-up is necessary to clarify the long-term prognosis. Second, factors such as physical activity,[28] pain

severity,[29] nutritional status,[30] and comorbidities were not sufficiently assessed, and the influence of unmeasured confounding cannot be ruled out. As these factors are strongly associated with muscle mass and mobility, it is possible that the observed association between ASM/BMI and the two-step test is partly explained by these factors, leading to a potential overestimation of its effect. Future studies will therefore need to conduct analyses that comprehensively account for these multifaceted factors. Third, the study population was limited to community-dwelling middle-aged and older Japanese adults. Since body composition and the progression of LS are influenced by factors such as lifestyle and culture,[31,32] the association between ASM/BMI and LS may vary across different ethnic groups. Therefore, caution is required when generalizing these findings to non-Japanese populations. Additionally, our sample was predominantly female. Although we adjusted for sex in the multivariable models, we did not perform sex-stratified analyses or formal interaction tests. Given that age-related changes in body composition and mobility often exhibit sexual dimorphism,[19,33] sex-specific biological or social factors might have influenced the observed associations. Consequently, the generalizability of our results to male populations should be interpreted with caution. Fourth, this study treated all stage-level deteriorations as a single progression outcome. However, transitions between different stages (eg, from non-LS to stage 1 versus from stage 1 to stage 2) may carry different clinical implications for long-term prognosis. Future studies with larger sample sizes should consider stratified analyses to elucidate stage-specific associations between muscle mass and mobility decline.

In this longitudinal study of community-dwelling adults aged ≥50 years, lower baseline ASM/BMI was associated with a higher likelihood of LS progression in dynamic mobility capacity assessed by the two-step test at 1 year. In contrast, baseline ASM/BMI was not significantly associated with LS progression based on the stand-up test or the GLFS-25. Although this observational study does not directly establish causality, these findings are meaningful because the longitudinal analyses accounted for temporal order and showed an association between ASM/BMI and LS progression in specific domains of mobility function.

DISCLOSURE STATEMENT

All authors declare no conflict of interest to report in relation to this study.

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