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Examination of the Characteristics and Relevant Physical Factors Associated with Persistent Falls in Community-Dwelling Older Adults: An Exploratory Prospective Cohort Study

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Abstract

Objectives: This exploratory cohort study aimed to identify the physical factors associated with persistent falls, defined as falls occurring over two consecutive years, in the older population. **Methods**: We conducted a 1-year prospective cohort of community-dwelling adults aged ≥65 years who were living independently at enrolment. Baseline assessments included gait speed, handgrip strength, and muscle-specific strength (MSS). The participants were classified as persistent falls if they reported ≥1 fall in both periods. **Results**: Persistent fallers exhibited significantly decreased gait speed (0.88 [0.59–1.10] m/s vs. 1.15 [1.00–1.27]; p = 0.006, r = 0.337), handgrip strength (19.9 [17.0–27.8] kg vs. 25.0 [21.5–30.0] kg; p = 0.041, r = 0.253), and MSS (64.6 [58.2–69.2] % vs. 73.0 [66.6–79.2] %; p = 0.008, r = 0.327) compared to non-persistent fallers. Slower gait speed was most strongly associated with persistent falls (OR = 0.01, p=0.035), while handgrip strength (OR = 0.84, p = 0.096) and MSS (OR = 0.91, p = 0.066) were only mildly associated. **Conclusions**: These exploratory findings suggest slow gait speed exhibited a significant association and MSS and handgrip strength exhibited potential associations with persistent falls in community-dwelling older adults.

Keywords: Persistent Falls, Gait Speed, Muscle-Specific Strength, Handgrip Strength, Older Adults

Introduction

Falls are a concern among community-dwelling older adults because they often lead to severe injuries, reduced independence, and increased mortality rates. The Centers for Disease Control and Prevention (CDC)[1] has reported that more than one in four individuals aged ≥65 years experience a fall each year, and a fall once doubles the chances of falls again. Among various risk factors, sarcopenia—a progressive loss of muscle mass and strength—is notably associated with an increased risk of falls[2,3].

Recurrent falls, which are typically defined as two or more falls within a year, are particularly concerning due to their association with functional decline and higher mortality rates[4]. Identifying and understanding the risk factors for recurrent falls are crucial for developing effective prevention strategies. Recurrent falls have been

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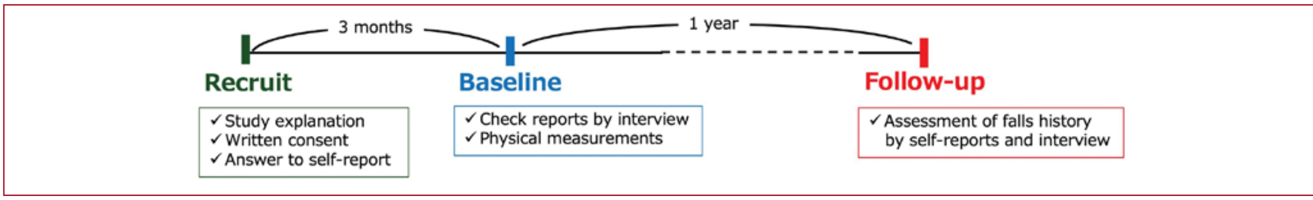

Figure 1. Study protocol.

extensively studied as markers of risk of falls, but it is known that such fallers have poor physical performance and that those with an SPPB score of 10 or higher have a low fall risk[5,6], so there are many unknowns about the risk prior to the traditional recurrent falls. Therefore, fall risk needs to be identified earlier in groups with high-functioning. We focused on individuals who consistently fall once per year over multiple years (i.e., persistent falls), by clarifying the physical functions associated with this, it may be possible to predict the risk of falls in older adults with high-functioning earlier, and also to identify the physical functions that should be treated with intervention. This lack of knowledge might be partly attributed to the lack of longitudinal data that capture chronic or persistent falls over time. The systematic review[7] has reported that the studies investigating falls have follow-up periods of 1 year or less, which limits their ability to identify persistent falls or long-term risk of fall trajectories. Consequently, persistent falls remain a clinically important but under-recognized topic in falls prevention research. Tchalla et al.[8] reported that even if there were no differences in physical performance and activity between the no fall and falls every year groups, the rate of incidence, such as hospital visits and fractures, was higher in falls every year group. However, the factors associated with persistent falls remain under-investigated. Muscle-specific strength (MSS), an index reflecting the muscle quality (e.g., grip strength relative to muscle mass), has recently emerged as a potential marker of functional decline[9]; however, its association with persistent falls has not yet been elucidated.

This exploratory cohort study aimed to identify the physical factors associated with persistent falls in community-dwelling older adults.

Materials and Methods

The design of this study was a prospective cohort study. Figure 1 presents the study protocol. Participants were recruited from adults who used the measurement center by displaying flyers at the center and by center staff calling on them. In addition, center users also called on their family and friends to participate. Those who wished to participate in the study were given a study explanation document, and if they agreed to the written explanation, they signed their consent. In addition, those who requested additional explanation were given in person by the research director (D.T). All of this was done before the start of measurements, and written informed consent was obtained from all participants before inclusion in the study. Eligible participants were community-dwelling adults aged ≥65 years who lived independently at baseline which was our previous study[9], and were able to attend the 1-year follow-up. The investigation at baseline was conducted between August and September 2023 at the Senior Citizen Community Center in Japan. The eligibility criteria included walking independence without aids, and the exclusion criteria included the missing baseline or follow-up measurements and cognitive impairment that was suspected by a qualified physical or occupational therapist—during the self-report check interview—to preclude capacity to provide informed consent.

The participant information at baseline, including age, sex, anthropometrics, and history of falls in the past year, was assessed via questionnaire surveys, interviews, and clinical assessments. The body mass index (BMI) was calculated by dividing the body weight (kg) by the height squared (m^2). Comorbidities were defined as chronic, impactful diseases (including hypertension, diabetes mellitus, stroke, heart disease, pulmonary disease, cancer, kidney disease, and musculoskeletal disorders), whereas the transient or minor conditions that do not significantly affect long-term health outcomes were not classified as comorbidities. Frailty was assessed based on the Japanese version of the Cardiovascular Health Study (J-CHS) criteria[10], which is a modified version of the original CHS frailty phenotype.

The five criteria of frailty assessment include: unintentional weight loss, self-reported exhaustion, low physical activity, slowness (measured by gait speed), and weakness (measured by handgrip strength). Participants meeting ≥3, 1–2, and zero criteria were classified as frail, prefrail, and robust, respectively.

Components of sarcopenia

As a physical function, handgrip strength was assessed on the dominant hand using a dynamometer (T.K.K.5401, Takei-Kiki-Kogyou Corporation, Japan) in a standing position, with the elbow extended and the arms fixed to the body. This assessment was conducted three times, and the highest value (kg) of the three attempts was recorded. Handgrip strength shows excellent test–retest reliability and predictive validity for functional decline[11,12].

The total muscle mass was measured using a bioelectrical impedance analysis (BIA) device (MC-780A-N, TANITA, Japan) in an upright position[13]. MC-780A-N is a multifrequency BIA device with eight electrodes (two electrodes for each hand and foot) that independently measure the impedance of each segment and the whole body. The device estimates the segmental muscle mass by measuring the electrical resistance of each segment separately. For the BIA measurement, the participants were made to stand on their bare feet and wait till the results were printed from the device. The muscle mass of all four extremities was calculated to obtain the appendicular skeletal mass. The skeletal muscle mass index (SMI), calculated by dividing the appendicular skeletal muscle mass by height squared (m^2), was employed. All of these measurements were performed by qualified physical therapists, with students from a physical therapy school assisting when necessary.

The MSS, defined on the basis of a previous study[9], was calculated as follows: MSS (%) = handgrip strength (kg) / total muscle mass (kg) × 100. Although the MSS is a new concept and there is no common consensus, it has been shown that a decrease in the MSS is associated with poor performance on the five repetitions of the sit-to-stand (5STS) and timed up and go[10,14].

Outcomes of sarcopenia

The short physical performance battery (SPPB)[15] is a simple, accessible, and high reliability screening tool for physical performance in community-dwelling older adults. Lower SPPB score was independently associated with prior falls[16], and adults with SPPB ≤6 were higher risk of recurrent falls[17]. It comprises three tests: a balance test, a 4-m walking test, and five repetitions of the sit-to-stand (5STS) test. Each measured performance was assigned a categorical score ranging from 0 (inability to complete) to 4 (best performance possible). The balance test assessed the ability to maintain balance in three positions, namely, side-by-side, semi-tandem, and tandem stance. Each position was held for 10 s. A score of 0 was given when the participant could not hold the side-by-side position for 10 s, whereas higher scores were assigned based on the ability to hold more challenging positions. The 4-m gait test measured the walking time (in seconds) over a 4 m distance. The time taken to walk the distance was recorded and scored. Faster times gained higher scores, with 4 points awarded for the fastest performance (0 points: unable to complete the test; 1, 2, 3, and 4 points for ≥8.70, 6.21–8.70, 4.82–6.20, and ≤4.82 s, respectively). From this test, the walking distance per second was calculated to obtain the walking speed (m/s). The 5STS test measured how quickly a participant could complete five consecutive chair stands (0 points, unable to complete even one chair stand; 1, 2, 3, and 4 points for ≥16.7, 13.7–16.69, 11.2–13.69, and ≤11.19 s, respectively). The sum of the scores in the SPPB ranged from 0 to 12 points. All of these measurements were performed by qualified physical therapists, with students from a physical therapy school assisting when necessary.

Falls

A fall is defined as “an unexpected event in which the person comes to rest on the ground, floor, or lower level”[18]. The fall history at baseline was assessed through a self-report answering “Have you had a fall in the past year?”, based on Item No. 9 on the Kihon checklist[19]. We checked through interviews to see if the responses were consistent with our definition of a fall, so that we could obtain more accurate evaluation results. After 1-year, falls within 1-year were investigated again by self-report and interview during follow-up. From these assessments, we defined four groups: the no fall group, if there were no reported falls at either baseline or follow-up; the falls history group, if the falls were reported only at baseline; the new falls group, if the falls were reported only at follow-up; and the persistent falls group if the falls were reported at both baseline and follow-up.

Statistical analysis

All analyses were conducted using JMP® Pro 18.0.2 (SAS Institute Inc., Cary, NC, USA). The data were expressed as median (25^{th}–75^{th} percentiles) or percentage, as appropriate. In two-group comparisons, the continuous variables were compared using the Wilcoxon rank-sum test, and the categorical variables were analyzed using the chi-square test, as appropriate. In addition to *p*-values, the effect sizes (r) were calculated for Wilcoxon rank-sum tests to evaluate the magnitude of between-group differences. The effect size was computed using the formula $r = Z / \sqrt{N}$, where Z is the standard normal deviate, and N is the total number of observations. The effect sizes were interpreted based on conventional thresholds: small ($r \approx 0.1$), medium ($r \approx 0.3$), and large ($r \geq 0.5$). Four-group differences were initially evaluated using the Kruskal–Wallis test. Subsequently, pairwise comparisons were conducted using the Wilcoxon rank-sum test with Bonferroni correction for multiple testing. Logistic regression analyses were performed to examine the association between each variable and persistent falls, defined as experiencing at least one fall per year over two consecutive years. Each variable was entered into a separate model adjusted for age. The results were reported as odds ratios (ORs) with 95% confidence intervals (CIs) and corresponding p-values. Due to the small number of participants with persistent

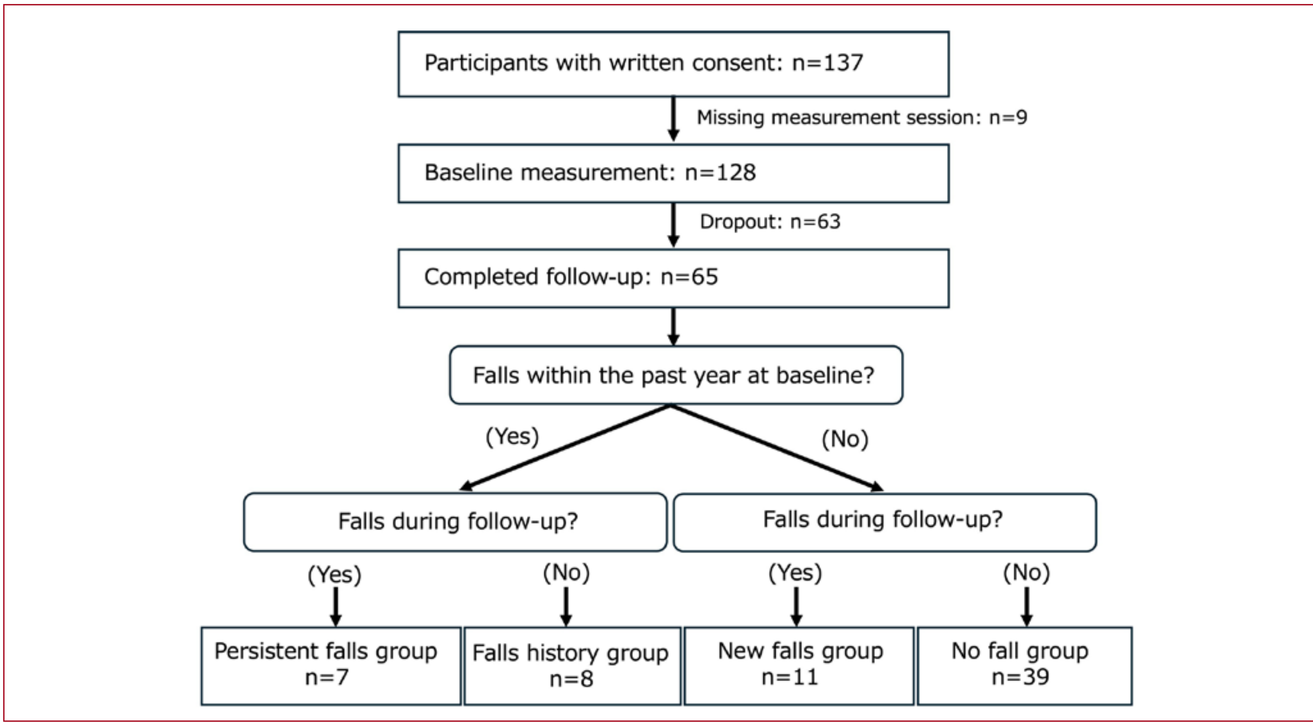

Figure 2. Flow diagram.

falls, Firth's penalized likelihood logistic regression was also applied to reduce the small-sample bias. The model included each explanatory variable and age as covariates. The JMP software does not provide ORs directly in Firth models; hence, the ORs were manually calculated as the exponentiated coefficients (OR = exp(β)). The results are presented as β coefficients, standard errors (SEs), 95% CIs, ORs, and p-values. CIs not available due to a quasi-complete separation were noted accordingly.

The significance level for all tests was 0.05; however, no prespecified approach was used for multiplicity correction. Therefore, the results of the statistical analysis were not adjusted for multiplicity and must be interpreted with caution.

Results

A total of 137 participants who met the eligibility criteria consented to the study. Among them, nine participants were absent from the measurement, and the remaining 128 participants were measured. Of them, 65 participants (50.8%) in the 1-year follow-up were included in the analysis (Figure 2). A comparison of the characteristics at baseline during the follow-up and dropout revealed no differences, except that the 5STS time was longer in the follow-up than in the dropout (Supplementary Table S1).

Table 1 lists the characteristics of the persistent falls and non-persistent falls groups. Age in the persistent falls group was higher than that in the non-persistent falls group (median [interquartile range], 81 [80–81] years vs. 77 [74–80] years, respectively; p = 0.003). In contrast, the two groups did not differ significantly in sex, height, and comorbidity. Weight tended to be lower in the persistent group than in the non-persistent falls group (48.8 [41.6–52.6] kg vs. 54.3 [48.5–60.6] kg, respectively; p = 0.058); however, the BMI of the two groups did not differ significantly (21.59 [19.80–22.76] kg/m^2 vs. 22.15 [19.95–24.69] kg/m^2, respectively; p = 0.561). The frailty assessment by J-CHS revealed fewer robust (14.3% vs 55.2%) and more frail (42.9% vs 0%) individuals in the persistent falls group than in the non-persistent falls group. Note that no clear differences were found in each variable among the three groups (i.e., falls history, new falls, and no falls groups) comprising the non-persistent falls group (Supplementary Table S2).

Figure 3 presents the components and outcomes of sarcopenia associated with persistent falls and non-persistent falls groups. Among the components of sarcopenia, handgrip strength (19.9 [17.0–27.8] kg vs. 25.0 [21.5–30.0] kg, respectively; p = 0.041, r = 0.253) and MSS (64.6 [58.2–69.2] % vs. 73.0 [66.6–79.2] %, respectively; p = 0.008, r = 0.327) were lower in the persistent falls group than in the non-persistent falls group.

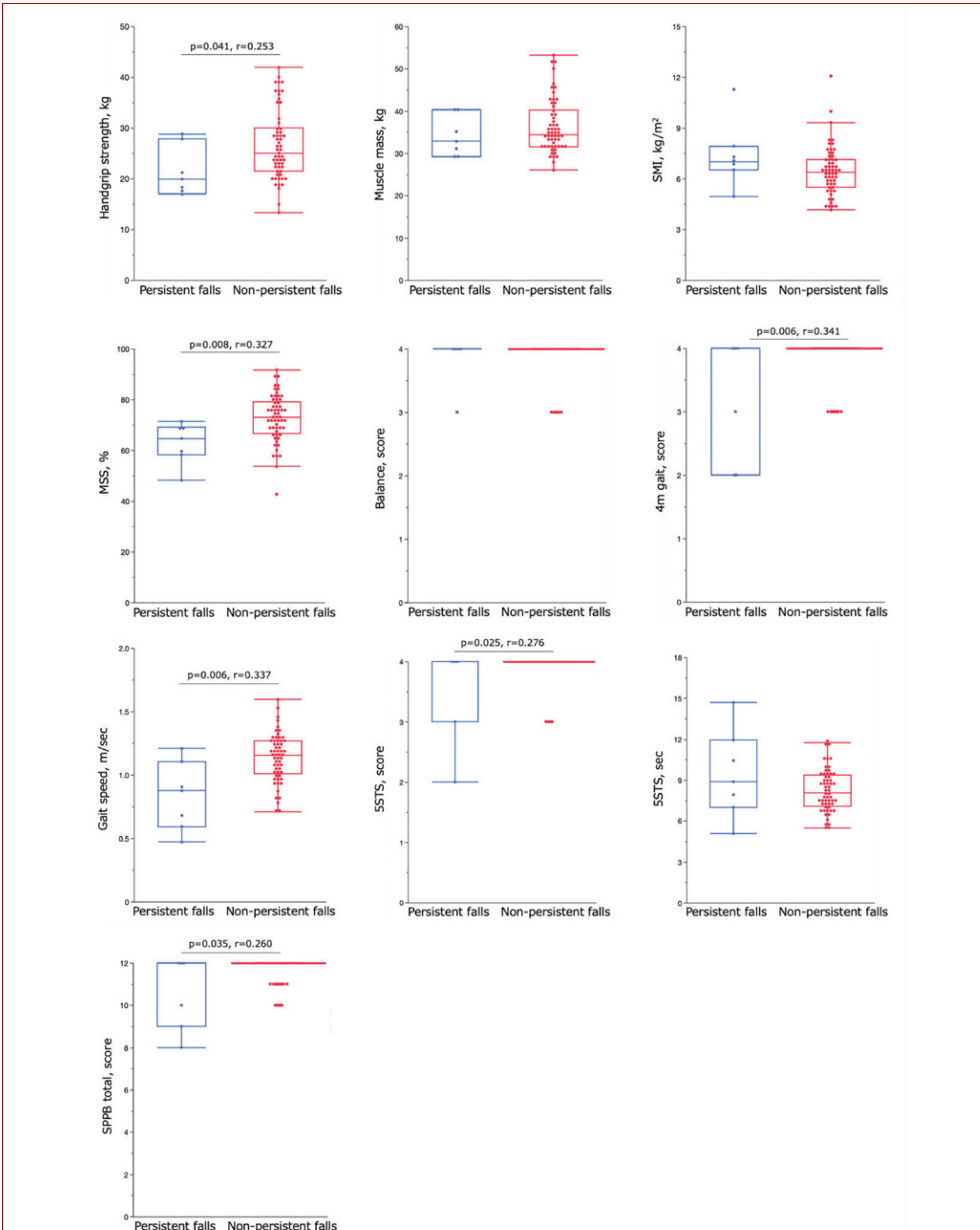

Figure 3. Physical status compared to persistent falls and non-persistent falls. SMI, skeletal muscle mass index; MSS, muscle-specific strength; 5STS, five repetitions of sit-to-stand test; SPPB, short physical performance battery.

	Persistent falls *n* = 7	Non-persistent falls *n* = 58	*p*-Value
Age, years	81 [80–86]	77 [74–80]	0.003
Sex, female	5 (71.4)	43 (74.1)	0.878
Height, cm	150.1 [138.4–156.1]	154.9 [149.2–159.5]	0.101
Weight, kg	48.8 [41.6–52.6]	54.3 [48.5–60.6]	0.058
BMI, kg/m²	21.59 [19.80–22.76]	22.15 [19.95–24.69]	0.561
Comorbidity			
Hypertension	3 (42.9)	13 (22.4)	0.236
Dyslipidemia	0	8 (13.8)	0.294
Diabetes	0	4 (6.9)	0.473
Cardiovascular	1 (14.3)	4 (6.9)	0.488
Cerebrovascular	0	1 (1.7)	0.726
Pulmonary	0	2 (3.5)	0.618
Cancer	0	1 (1.7)	0.726
Orthopedic	1 (14.3)	8 (13.8)	0.972
Overall amount	1 [0–1]	0 [0–1]	0.844
J-CHS			
Robust	1 (14.3)	32 (55.2)	<.001
Prefrailty	3 (42.9)	26 (44.8)	
Frailty	3 (42.9)	0	

Data are shown as median [interquartile range] or n (%). BMI, body mass index; J-CHS, Japanese version of the Cardiovascular Health Study criteria.

Table 1. Characteristics of the follow-up at baseline.

	OR	SE	95% CI	*p*-Value	LR x2	df	Omnibus p
Components of sarcopenia							
Handgrip strength, per 1 kg	0.84	0.10	0.65–1.00	0.096	14.53	2	<0.001
Muscle mass, per 1 kg	0.89	0.10	0.71–1.05	0.233	12.30	2	0.002
SMI, per 1 kg/m2	1.51	0.26	0.90–2.61	0.109	13.00	2	0.002
MSS, per 1 %	0.91	0.05	0.82–1.00	0.066	14.38	2	<0.001
Physical performance							
Balance, per 1 score	2.31	1.78	0.13–149.03	0.638	10.75	2	0.005
4-m gait, per 1 score	0.26	0.77	0.05–1.17	0.082	13.60	2	0.001
Gait speed, per 1 m/s	0.01	2.29	0.00–0.49	0.035	16.53	2	<0.001
5STS, per 1 score	0.32	0.86	0.05–2.16	0.192	12.03	2	0.002
5STS, per 1 s	1.13	0.23	0.71–1.77	0.584	10.79	2	0.005
SPPB total, per 1 score	0.52	0.43	0.21–1.25	0.126	12.73	2	0.002

Adjusted for age. OR, odds ratio; SE, standard error; CI, confidence interval; LR χ^2, likelihood-ratio chi-square; df, degrees of freedom; SMI, skeletal muscle mass index; MSS, muscle-specific strength; 5STS, five repetitions of sit-to-stand test; SPPB, short physical performance battery.

Table 2. Logistic regression model for persistent falls.

However, muscle mass and SMI did not differ significantly between the groups. Among, the outcomes of sarcopenia, the 4-m gait score (4 [2–4] vs. 4 [4–4], respectively; $p = 0.006$, $r = 0.341$), gait speed (0.88 [0.59–1.10] m/s vs. 1.15 [1.00–1.27], respectively; $p = 0.006$, $r = 0.337$), 5STS score (4 [3–4] vs. 4 [4–4], respectively; $p = 0.025$, $r = 0.276$), and total SPPB score (12 [9–12] vs. 12 [12–12], respectively; $p = 0.035$, $r = 0.260$) were lower in the persistent falls group than in the non-persistent falls group.

Group-wise comparisons by fall status (Supplementary Figure S1) showed a lower handgrip strength in the persistent falls group compared to the no falls group and a lower MSS in the persistent falls group compared to the no falls and new falls groups. The 4-m gait, 5STS, and total SPPB scores were lower in the persistent falls group compared to the no falls group. The gait speed in the persistent falls group was lower compared to the no falls, new falls, and falls history groups. However, no significant differences were found among the three groups.

Table 2 shows the multiple logistic analysis results. Gait speed was identified (OR = 0.01, $p = 0.035$) as a predictor associated with persistent falls. In addition, handgrip strength (OR = 0.84, $p = 0.096$), MSS (OR = 0.91, $p = 0.066$) and 4-m gait score (OR = 0.26, $p = 0.082$) were mildly associated with persistent falls. Similarly, in the regression analysis with bias correction using the Firth method (Supplementary Table S3), gait speed was identified (OR (exp(β)) = 0.02, $p = 0.023$) as a predictor associated with persistent falls and handgrip strength (OR (exp(β)) = 0.88, $p = 0.052$), MSS (OR (exp(β)) = 0.92, $p = 0.053$), and 4-m gait score (OR (exp(β)) = 0.30, $p = 0.083$) were mildly associated with persistent falls.

Discussion

This exploratory cohort study examined baseline characteristics associated with persistent falls—defined as ≥1 fall per year over two consecutive years—among community-dwelling adults aged ≥65 years who were living independently at enrolment. Participants were classified as persistent falls after the 1-year follow-up at baseline and at follow-up. The study participants had a physical function equivalent to that of Asian individuals with normative muscle health. Based on the SPPB score distribution, they constituted a high-functioning cohort (median SPPB [IQR 12 to 12]) in terms of physical function[20,21]. Persistent fallers were characterized by slow gait speed, and in unadjusted group comparisons also had lower handgrip strength and MSS. The relevant physical factor most closely related to persistent falls was gait speed, with MSS and handgrip strength showing a mild association.

Gait speed is a practical indicator and a predictive factor of fall risk in community-dwelling Asian older adults[22,23]. Even in international umbrella reviews, including in Asia, slow gait speed independently predicts falls and fractures and shows higher sensitivity and specificity than other functional parameters[24]. Furthermore, high handgrip strength decreases while low SMI increases the risk of falls[25,26]. Wang et al.[27] reported that handgrip strength was a crucial factor only in combined models for recurrent falls, with no significant impact when assessed alone. Furthermore, they reported a strong correlation between time up and go performance and handgrip strength. We hypothesized that a combination of handgrip strength and physical performance, which we did not assess in the current study, might be useful in predicting persistent falls. The varying associations of handgrip strength, SMI (including muscle mass), and gait speed with persistent falls might be attributed to the differences in age. Although these factors decline with age, muscle mass and handgrip strength begin declining relatively early in the 30s and 40s, respectively, while gait speed begins to decline in the 60s and later[28-30]. The study participants were at the stage when the gait speed begins to decline; hence, it might be a sensitive indicator of falls in our cohort.

A slow gait speed is a strong indicator of balance impairment[31]. While balance impairment might be associated with persistent falls, no such association was detected in the present study. However, the balance assessment herein was based solely on the sub-items of the SPPB, and due to the ceiling effect, it might not be appropriate as a balance assessment for relatively healthy elderly adults. Additionally, 5STS, combined with a balance assessment, was not associated with persistent falls in our cohort; however, a significant difference was observed between the dropout and follow-up groups in terms of 5STS, suggesting heterogeneity in the population. Therefore, we could not interpret the relationship between persistent falls and balance disorders based on our results.

Although MSS is still a new concept, and its relationship with falls remains unclear, our previous study[9] confirmed an association with MSS and 5STS performance. Additionally, Ayçiçek et al.[14] reported that MSS was significantly associated with the TUG performance. In the current study, MSS showed a mild association with persistent falls, with lower MSS scores in the persistent fall group and a moderate effect size similar to that of gait speed. However, this finding warrants further validation via large-scale studies in the future.

This study had some limitations. First, it was an observational cohort without randomization or an external control group. Therefore, causal inference is not possible. Second, we relied on a study-specific comorbidity checklist rather than a standardized index, this may limit comparability across studies. Third, falls were ascertained by self-report at baseline and again at 1-year, supplemented by interviews and a standard definition. Although these procedures aimed to improve accuracy, reliance on recall may have introduced misclassification and recall bias. Fourth, attrition was substantial: of 128 participants measured at baseline, 65 (50.8%) completed the 1-year follow-up. Although baseline characteristics were largely similar between completers and dropouts except for 5STS, selection/attrition bias cannot be ruled out. Finally, the sample size was small and multiplicity was not adjusted, which reduces statistical power and increases the risk of type I/II error; the small number of persistent fallers also limited the number of covariates that could be entered.

Conclusion

In this study, we investigated the association between persistent falls, defined as at least one fall per year for two consecutive years, and physical factors in comparatively healthy community-dwelling Japanese older adults. Persistent fallers were older and exhibited lower handgrip strength and MSS; however, only slow gait speed remained independently associated with persistent falls after age adjustment. These findings suggested that gait speed, which is an easily obtainable integrative performance marker, impacts the transition to persistent falling. Larger multicenter studies are warranted to elucidate optimal gait speed cut-offs, delineate the role of MSS, and determine whether modifying the gait speed can avert the onset of persistent falls and their downstream adverse outcomes.

Ethical Approval

Ethics approval was obtained from the Institutional Ethics Committee of Kobe Gakuin University (So-Rin 22–01). This study was conducted in compliance with the Declaration of Helsinki (1964) and its later amendments.

Consent to Participate

Written informed consent was obtained from participants prior to inclusion in the study.

Author's Contributions

YM is the corresponding author who constructed the research conceptualization, performed data collection, analysis, and interpretation, and was a major contributor to manuscript writing. DT, TO, RU, MK, and HK contributed to data collection and analysis, manuscript review, and feedback and edits to the manuscript. TY contributed to the data analysis, manuscript review, and feedback to the manuscript. All authors read and approved the final manuscript.

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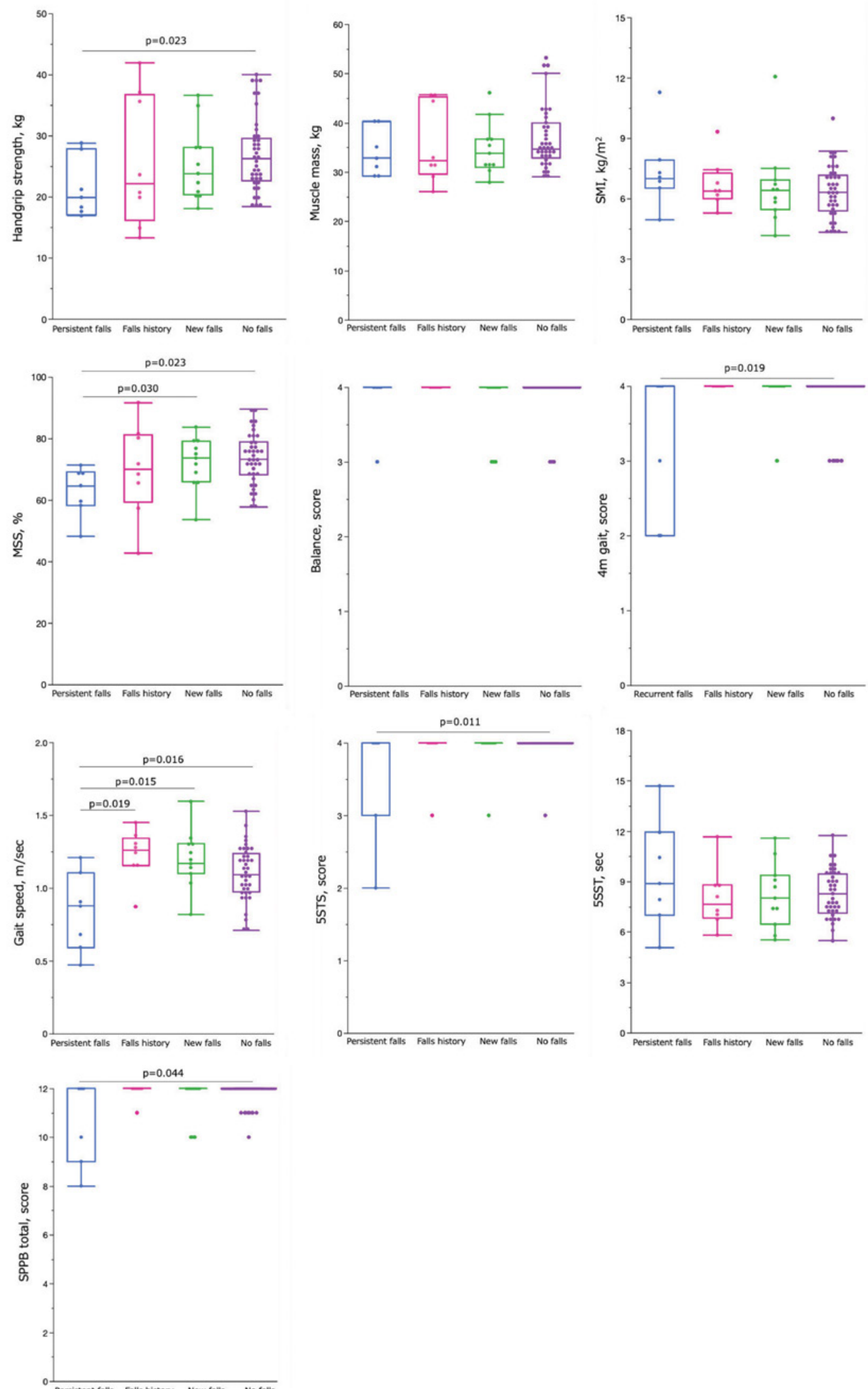

Figure S1. Comparison of the physical status among the four groups.

	Follow-up *n* = 65	Dropout *n* = 63	*p*-Value
Age, years	78 [75–81]	77 [74–81]	0.720
Sex, female	48 (73.9)	48 (76.2)	0.759
Height, cm	154.9 [148.7–158.7]	153.8 [149.7–158.6]	0.958
Weight, kg	53.6 [47.5–59.4]	51.4 [46.7–57.7]	0.219
BMI, kg/m²	22.07 [19.91–24.59]	21.70 [20.26–23.51]	0.318
Comorbidity			
Hypertension	16 (24.6)	19 (14.8)	0.482
Dyslipidemia	8 (12.3)	7 (11.1)	0.833
Diabetes	4 (6.2)	6 (9.5)	0.476
Cardiovascular	5 (7.7)	6 (9.5)	0.712
Cerebrovascular	1 (1.5)	1 (1.6)	0.982
Pulmonary	2 (3.1)	2 (3.2)	0.975
Cancer	1 (1.5)	3 (4.8)	0.285
Orthopedic	9 (13.8)	5 (7.9)	0.281
Overall amount	0 [0–1]	1 [0–1]	0.534
J-CHS			
Robust	33 (50.8)	34 (50.1)	
Prefrailty	29 (44.6)	27 (42.9)	
Frailty	3 (4.6)	4 (6.4)	0.905
Fall history within the past year at baseline	15 (23.1)	17 (27.0)	0.610
Components of sarcopenia			
Handgrip strength, kg	24.3 [20.8–29.2]	24.6 [22.6–28.6]	0.518
Muscle mass, kg	34.3 [31.3–40.1]	33.5 [32.1–37.0]	0.622
SMI, kg/m²	6.45 [5.52–7.22]	6.43 [5.91–7.17]	0.408
MSS, %	72.0 [65.5–78.6]	73.9 [66.7–82.1]	0.149
Physical performance (SPPB)			
Balance, score	4 [4–4]	4 [4–4]	0.677
4-m gait, score	4 [4–4]	4 [4–4]	0.921
Gait speed, m/s	1.14 [0.97–1.26]	1.13 [0.96–1.27]	0.637
5STS, score	4 [4–4]	4 [4–4]	0.485
5STS, s	8.10 [7.07–9.41]	7.32 [6.15–8.54]	0.009
SPPB total, score	12 [12–12]	12 [12–12]	0.767

Data are shown as median [interquartile range] or n (%). BMI, body mass index; SMI, skeletal muscle mass index; MSS, muscle-specific strength; SPPB, short physical performance battery; 5STS, five repetitions of sit-to-stand test; J-CHS, Japanese version of the Cardiovascular Health Study criteria.

Table S1. Characteristics of follow-up and dropout at baseline.

	Fall history $n = 8$	New falls $n = 11$	No falls $n = 39$
Age, years	78 [75–81]	77 [73–80]	77 [74–80]
Sex, female	5 (62.5)	9 (81.8)	29 (74.4)
Height, cm	152.3 [147.3–161.2]	151.6 [148.2–161.6]	154.9 [150.9–158.8]
Weight, kg	50.3 [40.0–56.5]	51.1 [48.0–59.7]	54.8 [51.5–61.5]
BMI, kg/m^2	20.49 [17.80–22.99]	20.89 [19.77–24.25]	23.28 [20.62–25.21]
Comorbidity			
Hypertension	0	1 (9.1)	12 (30.8)
Dyslipidemia	1 (12.5)	0	7 (17.9)
Diabetes	1 (12.5)	1 (9.1)	2 (5.1)
Cardiovascular	0	0	4 (10.3)
Cerebrovascular	0	0	1 (2.6)
Pulmonary	0	0	2 (5.1)
Cancer	0	0	1 (2.6)
Orthopedic	3 (37.5)	1 (9.1)	4 (10.3)
Overall amount	1 [0–1]	0 [0–0]	1 [0–2]
J-CHS			
Robust	4 (50.0)	5 (45.5)	23 (59.0)
Prefrailty	4 (50.0)	6 (54.5)	16 (41.0)
Frailty	0	0	0

Data are shown as median [interquartile range] or n (%). BMI, body mass index; J-CHS, Japanese version of the Cardiovascular Health Study criteria.

Table S2. Characteristics of follow-up at baseline.

	β	SE	95% CI	OR (exp(β))	p-Value
Components of sarcopenia					
Handgrip strength, kg	-0.13	0.09	-0.36–0.01	0.88	0.052
Muscle mass, kg	-0.09	0.08	-0.30–0.06	0.91	0.208
SMI, kg/m^2	0.38	0.24	Not available*	1.46	0.119
MSS, %	-0.08	0.05	-0.18–0.00	0.92	0.053
Physical performance					
Balance score, points	0.36	1.52	-2.15–4.13	1.43	0.787
4-m gait, score	-1.20	0.74	-2.70–0.14	0.30	0.083
Gait speed, m/s	-4.20	2.10	-8.87–-0.46	0.02	0.023
5STS, score	-1.04	0.85	-2.63–0.55	0.35	0.223
5STS, s	0.13	0.22	-0.32–0.53	1.14	0.654
SPPB total, score	-0.59	0.42	-1.42–0.18	0.55	0.142

*Adjusted for age. SE, standard error; CI, confidence interval; OR, odds ratio; SMI, skeletal muscle mass index; MSS, muscle-specific strength; 5STS, five repetitions of sit-to-stand test; SPPB, short physical performance battery. * CI not available due to quasi-complete separation detected in the model.*

Table S3. Firth penalized generalized linear model for persistent falls.