



Article

Predictive Ability of Systems of Postural Control for 1-Year Risk of Falls and Frailty in Community-Dwelling Older Adults: A Preliminary Study

Tomoyuki Shinohara ^{1,*} , Ayumi Maruyama ², Yuta Yabana ³, Miyu Kamijo ^{1,3} and Shota Saito ⁴

¹ Department of Physical Therapy, Graduate School of Health Care, Takasaki University of Health and Welfare, 27 Naka Orui-machi, Takasaki-shi 370-0033, Gunma, Japan; 2530201@takasaki-u.ac.jp

² Department of Rehabilitation, Takase Memorial Hospital, 885-2 Minamiorui-machi, Takasaki-shi 370-0036, Gunma, Japan; 2330202@takasaki-u.ac.jp

³ Rehabilitation Center, Hidaka Rehabilitation Hospital, 2204 Maniwa, Yoshii-machi, Takasaki-shi 370-2104, Gunma, Japan; 2330203@takasaki-u.ac.jp

⁴ Department of Rehabilitation, Fujioka General Hospital, 813-1 Nakakurusu, Fujioka-shi 375-8503, Gunma, Japan; 0717sho@gmail.com

* Correspondence: shinohara-t@takasaki-u.ac.jp

Abstract

The specific postural control systems associated with falls and frailty in older adults remain poorly understood. This study aimed to examine whether postural control systems are associated with, and can predict, the presence of falls over a 1-year period and frailty after 1 year. We conducted a prospective cohort study involving 127 community-dwelling older adults. Balance was assessed using the Brief-Balance Evaluation Systems Test, and frailty was determined according to the Cardiovascular Health Study criteria. Data were collected at baseline and 1-year follow-up. The results suggested that lower baseline scores in anticipatory postural adjustments (APA) and gait stability were related to falls, and that a decrease of ≥ 2 points in gait stability assessed by the Timed Up and Go test may indicate the presence of falls. At baseline, several postural control systems—biomechanical constraints, stability limits/verticality, APA, postural responses, and gait stability—were significantly associated with frailty status after 1 year. Furthermore, 1-year declines in sensory orientation and gait stability were also significantly associated with frailty status and showed potential predictive ability for it. These preliminary findings suggest that specific systems of postural control may be differentially related to falls and frailty, supporting outcome-specific approaches to intervention.

Keywords: postural control; older adults; fall; frailty; Brief-BESTest



Academic Editor: Mark A. Tully

Received: 12 September 2025

Revised: 1 October 2025

Accepted: 14 October 2025

Published: 16 October 2025

Citation: Shinohara, T.; Maruyama, A.; Yabana, Y.; Kamijo, M.; Saito, S. Predictive Ability of Systems of Postural Control for 1-Year Risk of Falls and Frailty in Community-Dwelling Older Adults: A Preliminary Study. *J. Ageing Longev.* **2025**, *5*, 45. <https://doi.org/10.3390/jal5040045>

Copyright: © 2025 by the authors. Licensee MDPI, Basel, Switzerland. This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license (<https://creativecommons.org/licenses/by/4.0/>).

1. Introduction

Japan is becoming one of the world's fastest ageing societies, with nearly 30% of individuals aged ≥ 65 years [1]. This demographic shift has led to a significant increase in social security expenditures, including healthcare and long-term care costs, highlighting the importance of maintaining independent living among older adults. In this context, numerous public health initiatives and studies have focused on preventing frailty, which is a preclinical stage that precedes the need for long-term care. Among the various factors contributing to long-term care dependency, falls associated with a decline in physical function play a significant role [2]. Frailty, which is most often assessed within the physical frailty domain, is also recognised as a risk factor for falls [3,4]. Conversely, falls can

lead to restricted mobility and social participation, thereby accelerating the progression of frailty [5]. Additionally, concerns about falling have been reported to negatively affect physical activity and may further exacerbate frailty [6]. These findings suggested a bidirectional and potentially causal relationship between frailty and falls. Poor balance, an age-related deterioration in physical function, is not only a risk factor for falls but may also lead to reduced physical activity, thereby contributing to the development of frailty. In other words, impaired postural control can be a factor in falls and frailty; however, how it contributes to each of these outcomes remains unclear.

Many studies have evaluated balance function impairment using composite scores of balance assessment scales without conducting a detailed assessment of balance function. In this context, the Balance Evaluation Systems Test (BESTest), which identifies the underlying postural control systems responsible for poor balance function [7], has recently been utilized in clinical practice. The BESTest is a comprehensive clinical tool that evaluates six systems of postural control: (1) Biomechanical constraints (e.g., ankle strength), (2) Stability limits/verticality (e.g., functional reach), (3) Anticipatory postural adjustments (APA, e.g., single-leg stance), (4) Postural responses (e.g., backward push-and-release), (5) Sensory orientation (e.g., standing with eyes closed), and (6) Gait stability (e.g., Timed Up and Go [TUG] test). Although the BESTest requires substantial time to administer due to its complexity, it enables clinicians to analyze distinct components of balance performance. Marques et al. [8] reported that both the BESTest and its abbreviated versions, the Mini-BESTest [9] and the Brief-BESTest [10], were significantly associated with fall history in the past year. These findings indicate that abbreviated tools such as the Brief-BESTest, which evaluates six systems of postural control, may also provide insight into specific aspects of balance function related to fall risk. Shinohara et al. [11] found that the postural response domain of the Brief-BESTest was particularly associated with fall history in older adults. However, these cross-sectional studies only evaluated falls over the past year. Magnani et al. [12] demonstrated that the BESTest and Mini-BESTest accurately predicted prospective falls over 6 months and proposed age-stratified cutoff values for fall risk prediction in community-dwelling older Brazilian adults. In their study, the predictive ability of the total score of a balance scale for 6-month fall risk was examined; however, no detailed analysis was conducted for each individual system of postural control. While these normative data from older Brazilian adults provide valuable reference values, complementary research using local data is important to confirm their applicability in different populations.

Regarding frailty, Marques et al. [13] reported that physically frail older adults showed significantly lower total and subscale scores on the BESTest in a cross-sectional study, indicating that this test can detect subtle deficits not captured by force plate analyses. However, all postural control systems evaluated using the BESTest were associated with frailty, and the specificity of each system in relation to frailty could not be demonstrated. Shinohara et al. [14] reported that frail older women, assessed using a multidimensional frailty assessment tool, exhibited notable impairments in specific subsystems (also reflected in the item components of the Brief-BESTest), such as stability limits, anticipatory postural adjustments, sensory orientation, and gait stability.

Despite these important findings, most previous studies have employed cross-sectional designs, and prospective cohort studies remain scarce. Moreover, although changes in balance function have been examined in populations with specific conditions such as stroke [15], Parkinson's disease [16], and hospitalised patients [17], there is a lack of longitudinal studies focusing on changes in the postural control system in community-dwelling older adults. If it becomes clear which postural control systems predict frailty or falls, addressing the decline in these specific systems could help prevent falls and frailty.

However, no cohort study has examined whether postural control systems are associated with, and can predict, the presence of falls over a 1-year period and frailty status after 1 year. Furthermore, investigating whether 1-year changes in each postural control system predict these outcomes could provide stronger evidence for a causal relationship between balance system decline and the development of falls or frailty. Such evidence would help to identify specific systems that should be prioritized as targets for interventions.

We hypothesized that certain postural control systems, assessed at baseline and through their 1-year changes, are associated with and predict the presence of falls over a 1-year period and frailty status after 1 year, and that the systems involved may differ between the two conditions. Regarding frailty, we focused on physical frailty, which is considered to be the factor most strongly associated with falls. Therefore, this study aimed to investigate whether the six systems of postural control, assessed using the Brief-BESTest, are associated with and predict the presence of falls over a 1-year period and frailty status after 1 year among community-dwelling older adults. Notably, this study was designed as a preliminary investigation to provide evidence supporting the validity of future large-scale cohort studies in this field.

2. Materials and Methods

2.1. Study Design

This two-wave cohort study was conducted between January 2022 and September 2025. Written informed consent to participate in the entire cohort study was obtained from all participants prior to their enrolment.

Ethical approval was obtained from the Research Ethics Committee of Takasaki University of Health and Welfare (approval nos. 2216, 2240, and 2358).

2.2. Participants

At baseline, 177 community-dwelling older adults aged ≥ 60 years were assessed. Of these, 127 completed the baseline and 1-year follow-up assessments and met the inclusion criteria. Data were collected from six public community centers in Takasaki City, Gunma Prefecture, Japan. Public community centers are community-based spaces established by local governments where activities, such as volunteer-led exercise classes for older adults, are held. The inclusion criteria were as follows: (1) independence in basic activities of daily living, (2) ability to leave home independently, including visiting community centers, (3) ability to ambulate indoors without assistive devices such as canes, and (4) absence of missing data in the variables included in the analysis. Individuals with severe cognitive impairment, progressive neurological diseases, or unstable medical conditions were excluded in the baseline and follow-up assessments. Table 1 describes the characteristics of the participants. At baseline, age, sex, and medical conditions were recorded, allowing participants to report more than one medical condition. Cognitive function was assessed using the Rapid Dementia Screening Test (RDST) [18,19]. The RDST consists of two subtests: (1) a verbal fluency task (“supermarket” category), in which participants are asked to name as many items as possible that can be purchased in a supermarket within one minute, and (2) a numeral conversion task, in which participants convert Arabic numerals into their written word form, or vice versa [18].

Table 1. Characteristics of the participants.

	N = 127
Age, mean ($\pm$ SD)	74.5 ($\pm$ 7.3)
Gender (Female), n (%)	99 (78.0%)
RDST, median (25th–75th percentile)	11.0 (10.0–12.0)
Days from baseline to follow-up, mean ($\pm$ SD)	370.0 (18.2)
Morbidity	
Hypertension	20 (15.7%)
Cardiac disease	9 (7.1%)
Diabetes mellitus	8 (6.3%)
Cancer	8 (6.3%)
Fracture	6 (4.7%)

SD, standard deviation; RDST, rapid dementia screening test.

Data were collected at two waves: baseline (January 2022 to September 2024) and 12-month follow-up (January 2023 to September 2025). At both waves, the assessments included falls, balance function, and frailty status. Formal sample size calculations were not performed prior to the study. The number of participants was determined using available data. Longitudinal data were collected between January 2022 and September 2025 as part of an ongoing community-based cohort project. All eligible participants with complete baseline and 1-year follow-up assessments were included in the present analysis. This study was conceived as part of a series of investigations, with the present analysis serving as an initial step towards informing and facilitating the design of future large-scale cohort studies.

2.3. Assessment

2.3.1. Fall Assessment

At follow-up, falls were assessed by asking the question, “Have you experienced any falls in the past year?” Falls were defined according to the World Falls Guidelines as “an unexpected event in which the participant comes to rest on the ground, floor, or lower level” [20]. Participants who reported one or more of these events were classified as having a history of falls. The same fall assessment was conducted at baseline; however, the participants were not asked to record the number of falls during the follow-up period, and the evaluation was based on their recall of the past year. If participants were uncertain about the criteria for a fall or the circumstances of their fall, they were encouraged to ask the researchers for clarification. We did not exclude falls based on their underlying causes (e.g., medical events or external factors).

2.3.2. Assessment of Balance Function

Balance was evaluated using the Brief-BESTest [10], a validated and condensed version of the original Balance Evaluation Systems Test. All assessments were conducted by licensed physical therapists who had received training on the Japanese version of the instrument [21]. The Brief-BESTest consists of eight items grouped into six components (Section S1: biomechanical constraints; S2: stability limits/verticality; S3: anticipatory postural adjustments; S4: postural responses; S5: sensory orientation; and S6: gait stability). Each item was scored on a 4-point scale (0–3), resulting in a total score ranging from 0 to 24. Among these, S3 and S4 involved bilateral assessments, and the scores were recorded separately for the better- and poorer-performing limbs. The test items included (S1) lateral strength of the hip/trunk; (S2) forward functional reach; (S3B) single-leg stance on the better side; (S3P) single-leg stance on the poorer side; (S4B) compensatory lateral stepping

on the better side; (S4P) compensatory lateral stepping on the poorer side; (S5) standing with eyes closed on a foam surface; and (S6) the TUG test.

2.3.3. Physical Frailty Assessment

Physical frailty status was evaluated using the Japanese version [22] of the Cardiovascular Health Study (J-CHS) criteria [23]. The J-CHS assesses frailty based on the following five clinical indicators: unintentional weight loss, exhaustion, low physical activity, slow gait speed, and weak grip strength. Participants were categorised as robust (meeting none of the indicators), pre-frail (meeting one or two indicators), or frail (meeting three or more indicators).

2.4. Statistical Analysis

The participants were categorised into fallers and non-fallers based on the presence or absence of falls reported at the follow-up assessment. Participants identified as frail at follow-up were defined as frail, whereas all others were defined as non-frail in accordance with previous studies that dichotomized frailty status to predict frailty characteristics in populations [24,25].

Participant characteristics were compared between fallers and non-fallers as well as between frail and non-frail individuals. Group differences were examined using t-tests or Mann–Whitney U tests for continuous variables and chi-square tests or Fisher’s exact tests for categorical variables, depending on the distribution.

To examine whether each item of the Brief-BESTest at baseline and its 1-year change are associated with the presence of falls over a 1-year period and frailty status after 1 year, the baseline scores and 1-year changes (calculated as the follow-up score minus the baseline score) for each item were treated as variables of interest. Differences between groups (fallers vs. non-fallers and frail vs. non-frail) were assessed using the Mann–Whitney U test. The *p* values were adjusted for multiple testing using the Benjamini–Hochberg false discovery rate correction. In addition to group comparisons, effect sizes were calculated to assess the magnitudes of the differences. Effect sizes were calculated based on the following variable types: Cohen’s *d* for age, Cramér’s *V* for sex, and Pearson’s *r* for the Brief-BESTest scores. Effect sizes were interpreted according to Cohen’s conventional thresholds, with 0.2, 0.5, and 0.8, indicating small, medium, and large effects for Cohen’s *d*; 0.1, 0.3, and 0.5 for Pearson’s *r*; and 0.1, 0.3, and 0.5, respectively, for Cramér’s *V* in the 2×2 contingency tables [26].

Receiver operating characteristic (ROC) curve analysis was used to assess the predictive performance of each item of the Brief-BESTest, including sensitivity, specificity, minimal important change (MIC) values, and the area under the curve (AUC). In this study, we applied ROC analysis to both baseline scores and 1-year changes in each postural control system to identify optimal cutoff values for classifying participants one year later as fallers or non-fallers and as non-frail or frail. The AUC was classified as Failure (<0.6), Poor (0.6–0.7), and Fair (0.7–0.8) [27]. Following the approach described by Turner et al. [28], ROC analyses were conducted using the entire cohort to improve the precision and interpretability of minimally important change (MIC) values. The AUCs between balance systems were compared using established statistical methods [29]. To obtain confidence intervals (CIs) for the ROC-based statistics, 1000 bootstrap replications were performed. For each resampling, we computed the AUC, sensitivity, and specificity corresponding to the optimal cutoff score. The average of the bootstrap estimates was adopted as the point estimate, and the 95% CI was calculated using 1.96 times the standard deviation of the 1000 bootstrap estimates, in line with previous reports [30].

All statistical analyses were performed using R version 4.3.1 (R Foundation for Statistical Computing, Vienna, Austria). Statistical significance was set at $p < 0.05$. Generative

artificial intelligence (ChatGPT, GPT-5 model, OpenAI, San Francisco, CA, USA; version released in 2025; accessed in September 2025) assisted in writing the analysis code. No content generated by the tool itself was used without human review, and all statistical analyses and interpretations were performed solely by the authors.

3. Results

3.1. Overview of the Follow-Up

Of the 177 participants assessed at baseline, 127 (71.8%) completed follow-up and were included in the analyses. Among them, 32 (25.2%) had experienced at least one fall during the year. The mean age ($\pm$ SD) was 74.2 ± 7.4 years in the non-faller group and 75.6 ± 7.3 years in the faller group, with no significant difference observed ($p = 0.365$, Cohen's $d = 0.185$). The sex distribution (female/male) was 71/24 in non-fallers and 28/4 in fallers, with no significant difference ($p = 0.208$, Cramér's $V = 0.100$). The median RDST score (interquartile range) was 11.0 (10.0–12.0) in non-fallers and 11.5 (9.0–12.0) in fallers, with no significant difference observed ($p = 0.974$, $r = 0.003$).

At follow-up, frailty was observed in 10 individuals (7.9%). The mean age ($\pm$ SD) was 74.1 ± 7.1 years in the non-frail group and 79.9 ± 8.3 years in the frail group, with no significant difference ($p = 0.056$, Cohen's $d = 0.808$). The sex distribution (female/male) was 91/26 in the non-frail group and 8/2 in the frail group, again showing no significant difference ($p = 1.000$, Cramér's $V = 0.000$). The median RDST score (interquartile range) was 11.0 (10.0–12.0) in the non-frail and 10.0 (8.0–11.0) in the frail group, with no significant difference observed ($p = 0.086$, $r = 0.152$).

3.2. Associations Between Falls and Balance Functions

In the comparison between non-fallers and fallers, significant differences were observed at baseline for items S3B, S3P, and S6 of the Brief-BESTest (Table 2). The largest effect size was found for S3P ($r = 0.253$), but all effect sizes were below 0.3. No significant differences were observed for any of the items in the 1-year change.

Table 2. Difference for the Brief-Balance Evaluation Systems Test between non-fallers and fallers.

	Item	Non-Fallers n = 97	Fallers n = 32	p-Value [†]	Effect Size r
Baseline	S1	3.0 [1.0–3.0]	2.5 [0.8–3.0]	0.559	0.086
	S2	2.0 [2.0–3.0]	2.0 [2.0–2.2]	0.559	0.077
	S3B	3.0 [3.0–3.0]	3.0 [1.0–3.0]	0.036 *	0.194
	S3P	3.0 [2.0–3.0]	1.5 [1.0–3.0]	0.018 *	0.253
	S4B	3.0 [3.0–3.0]	3.0 [2.0–3.0]	0.275	0.107
	S4P	3.0 [2.0–3.0]	2.0 [2.0–3.0]	0.054	0.187
	S5	3.0 [2.0–3.0]	3.0 [2.0–3.0]	0.947	−0.005
	S6	3.0 [3.0–3.0]	3.0 [2.0–3.0]	0.045 *	0.159
One-year change	S1	0.0 [−1.0–0.0]	0.0 [−1.0–1.0]	0.697	0.062
	S2	0.0 [0.0–0.0]	0.0 [0.0–0.0]	0.723	0.039
	S3B	0.0 [0.0–0.0]	0.0 [0.0–0.0]	0.697	−0.043
	S3P	0.0 [0.0–0.0]	0.0 [0.0–0.0]	0.559	−0.080
	S4B	0.0 [0.0–0.0]	0.0 [0.0–0.0]	0.697	−0.043
	S4P	0.0 [−0.5–0.0]	0.0 [−0.2–0.0]	0.767	−0.033
	S5	0.0 [0.0–0.0]	0.0 [−1.2–0.0]	0.159	0.151
	S6	0.0 [0.0–0.0]	0.0 [0.0–0.0]	0.947	0.004

S1, lateral strength of the hip/trunk; S2, forward functional reach; S3B, single-leg stance on the better side; S3P, single-leg stance on the poorer side; S4B, compensatory lateral stepping on the better side; S4P, compensatory lateral stepping on the poorer side; S5, standing with eyes closed on a foam surface; S6, the Timed Up and Go (TUG) test. *, $p < 0.05$; †, each item was analyzed using the Mann–Whitney U test. Multiple comparisons were adjusted with the Benjamini–Hochberg procedure.

3.3. Associations Between Physical Frailty and Balance Functions

In the comparison between the non-frail and frail groups, significant differences were found at baseline for items S1, S2, S3B, S3P, S4P, and S6 (Table 3). Only S3P had an effect size greater than 0.3 ($r = 0.309$). For the 1-year change, S5 and S6 showed significant differences; however, the effect sizes for both were less than 0.3.

Table 3. Difference for the Brief-Balance Evaluation Systems Test between non-frail and frail.

	Item	Non-Frailty n = 117	Frailty n = 10	p-Value [†]	Effect Size r
Baseline	S1	3.0 [1.0–3.0]	0.0 [0.0–1.0]	0.003 *	0.259
	S2	2.0 [2.0–3.0]	2.0 [2.0–2.0]	0.026 *	0.191
	S3B	3.0 [3.0–3.0]	1.0 [1.0–2.5]	0.001 **	0.261
	S3P	3.0 [2.0–3.0]	1.0 [1.0–1.0]	0.001 **	0.309
	S4B	3.0 [3.0–3.0]	2.5 [2.0–3.0]	0.050	0.144
	S4P	3.0 [2.0–3.0]	1.5 [0.2–2.0]	0.001 **	0.272
	S5	3.0 [2.0–3.0]	2.0 [1.0–3.0]	0.100	0.133
	S6	3.0 [3.0–3.0]	2.0 [2.0–2.8]	0.000 **	0.259
One-year change	S1	0.0 [−1.0–0.0]	0.0 [−0.8–0.8]	1.000	−0.003
	S2	0.0 [0.0–0.0]	0.0 [0.0–0.0]	1.000	0.006
	S3B	0.0 [0.0–0.0]	0.0 [0.0–0.0]	1.000	0.000
	S3P	0.0 [0.0–0.0]	0.0 [−0.8–0.0]	0.573	0.056
	S4B	0.0 [0.0–0.0]	0.0 [−0.8–0.0]	0.285	0.086
	S4P	0.0 [0.0–0.0]	0.0 [−0.8–0.0]	1.000	0.000
	S5	0.0 [0.0–0.0]	−1.0 [−2.0–0.0]	0.010 *	0.219
	S6	0.0 [0.0–0.0]	−0.5 [−2.0–0.0]	0.002 **	0.205

S1, lateral strength of the hip/trunk; S2, forward functional reach; S3B, single-leg stance on the better side; S3P, single-leg stance on the poorer side; S4B, compensatory lateral stepping on the better side; S4P, compensatory lateral stepping on the poorer side; S5, standing with eyes closed on a foam surface; S6, the Timed Up and Go (TUG) test. *, $p < 0.05$; **, $p < 0.01$; [†], Each item was analyzed using the Mann–Whitney U test. Multiple comparisons were adjusted with the Benjamini–Hochberg procedure.

3.4. Predictive Ability of 1-Year Changes Anchored to Fall Status

Based on the ROC analyses using each item of the Brief-BESTest to discriminate fallers, all AUC values, except for S5, were below 0.6, indicating low discriminatory ability (Table 4). In the estimation of the MIC, item S6 showed an MIC of −1.285 (95% CI: −2.296 to −0.273), suggesting that a decline of at least 2 points was associated with falling. However, the AUC was low (0.504), and the sensitivity of this method was also very low (0.159). For the other items, the MIC estimates ranged from negative to positive, indicating that score reductions did not consistently correspond to the presence of falls.

Table 4. Discrimination of fall status based on changes in the Brief-Balance Evaluation Systems Test scores.

Item	AUC (95%CI)		MIC (95%CI)		Sensitivity (95%CI)		Specificity (95%CI)	
S1	0.542	(0.424–0.661)	−0.773	(−2.486–0.941)	0.397	(0.021–0.773)	0.753	(0.384–1.000)
S2	0.537	(0.452–0.622)	−0.152	(−1.086–0.782)	0.454	(0.000–1.000)	0.634	(0.000–1.000)
S3B	0.489	(0.399–0.578)	−0.812	(−1.786–0.161)	0.188	(0.000–0.463)	0.878	(0.632–1.000)
S3P	0.467	(0.379–0.555)	−0.931	(−2.329–0.467)	0.245	(0.000–0.827)	0.798	(0.219–1.000)
S4B	0.477	(0.385–0.569)	−1.266	(−3.581–1.048)	0.219	(0.000–0.833)	0.842	(0.216–1.000)
S4P	0.489	(0.393–0.585)	−0.208	(−2.457–2.041)	0.472	(0.000–1.000)	0.591	(0.000–1.000)
S5	0.601	(0.498–0.704)	−0.698	(−2.154–0.758)	0.438	(0.000–0.908)	0.743	(0.236–1.000)
S6	0.504	(0.410–0.599)	−1.285	(−2.296–−0.273)	0.159	(0.000–0.346)	0.947	(0.797–1.000)

AUC, area under the receiver operating characteristic curve; CI, confidence interval; MIC, minimal important change. S1, lateral strength of the hip/trunk; S2, forward functional reach; S3B, single-leg stance on the better side; S3P, single-leg stance on the poorer side; S4B, compensatory lateral stepping on the better side; S4P, compensatory lateral stepping on the poorer side; S5, standing with eyes closed on a foam surface; S6, the Timed Up and Go (TUG) test.

3.5. Predictive Ability of 1-Year Changes Anchored to Frail Status

The AUC values for S5 and S6 were ≥ 0.70 , indicating fair discriminative ability (Table 5). Among them, S5 demonstrated fair discriminative ability, with a sensitivity of 0.638 and a specificity of 0.777. However, the MIC estimates for individual items did not sufficiently support a clear relationship between score reduction and frailty.

Table 5. Discrimination of frail status based on changes in the Brief-Balance Evaluation Systems Test scores.

Item	AUC (95%CI)		MIC (95%CI)		Sensitivity (95%CI)		Specificity (95%CI)	
S1	0.497	(0.317–0.677)	0.280	(−2.781–3.341)	0.684	(0.058–1.000)	0.458	(0.000–1.000)
S2	0.540	(0.395–0.686)	−0.200	(−1.099–0.699)	0.479	(0.000–1.000)	0.655	(0.034–1.000)
S3B	0.524	(0.379–0.669)	−0.948	(−2.345–0.448)	0.318	(0.000–0.879)	0.822	(0.228–1.000)
S3P	0.563	(0.421–0.705)	−0.011	(−0.991–0.969)	0.706	(0.122–1.000)	0.439	(0.000–1.000)
S4B	0.592	(0.448–0.736)	−0.461	(−1.818–0.895)	0.502	(0.000–1.000)	0.670	(0.000–1.000)
S4P	0.507	(0.310–0.703)	−0.191	(−2.804–2.422)	0.514	(0.000–1.000)	0.620	(0.000–1.000)
S5	0.734	(0.593–0.875)	−0.598	(−1.519–0.323)	0.638	(0.305–0.970)	0.777	(0.452–1.000)
S6	0.716	(0.543–0.889)	−0.981	(−2.029–0.067)	0.490	(0.150–0.830)	0.925	(0.747–1.000)

AUC, area under the receiver operating characteristic curve; CI, confidence interval; MIC, minimal important change. S1, lateral strength of the hip/trunk; S2, forward functional reach; S3B, single-leg stance on the better side; S3P, single-leg stance on the poorer side; S4B, compensatory lateral stepping on the better side; S4P, compensatory lateral stepping on the poorer side; S5, standing with eyes closed on a foam surface; S6, the Timed Up and Go (TUG) test.

4. Discussion

In this study, we hypothesized that certain postural control systems, assessed at baseline and throughout their 1-year changes, were associated with falls and predict the presence of falls and frailty after 1 year and that the systems involved may differ between the two conditions. Our analysis revealed that baseline scores for the subsystems of APA and gait stability were associated with falls. Moreover, a decline in walking ability over 1 year was associated with the presence of falls, and MIC analysis suggested that a decrease of 2 or more points in item S6 may serve as a potential indicator of falls, although the predictive accuracy was limited. At the same time, several postural control systems at baseline were significantly associated with frailty status after 1 year. Finally, declines in sensory orientation and gait stability were also significantly associated with frailty status after 1 year and demonstrated predictive value.

The 1-year fall incidence rate in the study population was 25.2%. In contrast, a global meta-analysis reported a fall prevalence of 26.5% [31], while several other studies involving older Japanese adults have reported 1-year fall rates of 24.3% for at least one fall [32] and 7.1% for recurrent falls (≥ 2 falls) [33]. Although fall rates vary according to population characteristics, the incidence observed in this study was not unusually high. Conversely, frailty after 1 year in this study was 7.9%. A systematic review reported a 1-year frailty transition rate of 4.3% [34], whereas previous Japanese studies reported rates of 2.8% over 3 years [35] and 2.6% over 4 years [36]. The slightly higher rate observed in our study may be attributable to the older age of our participants compared with those in previous studies. It is well established that the risk of transition to frailty increases with age [37]. Moreover, at baseline, there were no significant differences in age, sex, or cognitive function between the non-faller and faller groups or between the non-frail and frail groups. Thus, the risk of selection bias related to the presence of falls or frailty was relatively low.

In the analysis of fall-related outcomes, lower scores in S3 (single-leg stance: APA) and S6 (TUG: gait stability) associated with falls occurring within 1 year. Regarding the single-leg stance, Muir et al. [38] reported that a shorter stance time among various balance tests was linked to increased fall risk. Similarly, Oliveira et al. [39] demonstrated that the

behaviour of the center of pressure during a single-leg stance was associated with a fall history over the previous year. The TUG is widely used as a fall screening tool; however, its predictive value is limited [40], particularly among women [41,42]. Although the TUG test is typically evaluated based on the time required (in seconds), the TUG item in the Brief-BESTest also incorporates an assessment of trunk sway. By combining chronometric and observational evaluations of postural stability, their association with future falls may have been better captured in our analysis. Furthermore, MIC analysis suggested that a 2-point decrease in the S6 score could serve as a possible indicator of falls, although the predictive accuracy was limited. The TUG test requires the most dynamic movements, including sit-to-stand transitions and turning. Although it has not been clearly established whether the TUG test has a predictive ability for falls [43,44], our findings suggest that, among the six postural control systems evaluated, gait stability (as assessed by the TUG item) showed potential for predicting falls. However, the AUC and sensitivity were 0.504 and 0.159, respectively, indicating limited clinical utility. This may suggest that falls in our study population were not primarily attributable to measurable declines in balance, or the Brief-BESTest did not sufficiently detect that balance deterioration relevant to fall risk. Although the Brief-BESTest does not demonstrate responsiveness to fall events when used as an anchor, specific balance components (APA and gait stability) can associate with future falls, suggesting that targeted interventions in these domains may contribute to fall prevention.

Regarding the physical frailty after 1 year, with the exception of sensory orientation at baseline, most postural control systems—biomechanical constraints, stability limits/verticality, APA, postural responses, and gait stability—were significantly associated with frailty status after 1 year. Furthermore, postural responses and gait stability showed fair discriminative ability for predicting frailty. The frailty assessment used in this study, the CHS criteria, focuses on physical frailty, including grip strength and gait speed. This may explain the strong associations observed in balance function. In a cross-sectional study, Shinohara et al. [14] reported that frail individuals scored lower on the systems for stability limit, APA, sensory orientation, and gait stability. Similarly, Marques et al. [13] reported that all six balance components of the full BESTest were impaired in frail individuals. Our findings support these results. Changes in sensory orientation and gait stability demonstrated AUC values greater than 0.7, suggesting that preventing the deterioration of these specific postural control systems may contribute to frailty prevention.

Regarding the associations between balance function and falls/frailty, some relationships evaluated by effect sizes were observed, with values around 0.3 at most, indicating a moderate magnitude. This suggests that falls and frailty are not solely related to balance function but also to multiple physical and psychological conditions, highlighting the need for comprehensive assessment and intervention in clinical practice.

A notable strength of this study was its systematic assessment of postural control using the Brief-BESTest, in contrast to previous approaches that relied on composite indices or single balance measures. This comprehensive approach suggested that the involvement of postural control systems may differ between two health-related outcomes directly linked to residents' health and quality of life: falls and frailty. While multiple systems appeared to be associated with frailty, APA and gait stability seemed more closely related to falls. Furthermore, sensory orientation showed potential predictive ability for frailty, a relationship that was not observed for falls. These findings indicate that interventions targeting balance functions for the prevention and improvement of falls and frailty may need to be tailored specifically to each outcome.

This study had some limitations. First, the small sample size, including only 10 participants who were frail at the 1-year follow-up, may limit the precision of the estimates and

preclude adjustment for potential confounders such as underlying diseases and exercise habits. Future studies should include larger sample sizes for a more robust analysis. Second, the follow-up period was relatively short (over 1 year), and long-term associations between postural control systems, falls, and frailty should be verified in future studies. Third, because falls were assessed based on the participants' recall without distinguishing between single and multiple events, there is a possibility of recall bias and misclassification. In addition, no specific strategies were implemented to minimize recall bias in the assessment of falls. Fourth, although data collection was conducted at multiple sites, the geographic coverage was limited, and participants were recruited from a relatively narrow region of Japan. To enhance the generalizability of our findings, future studies should include more diverse and geographically dispersed populations.

The clinical implication of this study is that certain postural control systems, as assessed by system theory-based balance function scales such as the Brief-BESTest, may have predictive value for the presence of falls and physical frailty. In particular, a ≥ 2 -point decline in the TUG-based item (gait stability) may flag individuals at risk of falling over 1 year; however, the low AUC and sensitivity indicate limited predictive accuracy and the need for cautious interpretation. Because the systems associated with falls and those associated with frailty only partially overlap, prevention and intervention may need to be tailored to the outcome of interest.

5. Conclusions

A 1-year cohort study was conducted among community-dwelling older adults to examine whether baseline status and 1-year changes in the six systems of postural control were associated with and could predict the presence of falls over a 1-year period and frailty status after 1 year. The results suggested that lower baseline scores in APA and gait stability were related to falls, and that a decrease of ≥ 2 points on the TUG-based gait stability was identified as a significant MIC; however, the low AUC indicates limited predictive accuracy and clinical utility. At baseline, several postural control systems—biomechanical constraints, stability limits/verticality, APA, postural responses, and gait stability—were significantly associated with frailty status after 1 year. Furthermore, 1-year declines in sensory orientation and gait stability were also significantly associated with frailty status after 1 year and showed potential predictive ability for it. Taken together, these preliminary findings suggest that certain systems of postural control may be differentially related to falls and frailty, highlighting the need for outcome-specific approaches to intervention.

Author Contributions: Conceptualization, T.S.; Methodology, T.S.; Formal analysis, T.S.; Investigation, T.S., A.M., Y.Y., M.K. and S.S.; Data curation, T.S., A.M., Y.Y. and M.K.; Writing—Original Draft Preparation, T.S.; Writing—Review and Editing, A.M., Y.Y., M.K. and S.S.; Visualisation, T.S.; Supervision, T.S.; Project Administration, T.S.; Funding Acquisition, T.S. All authors have read and agreed to the published version of the manuscript.

Funding: This research was funded by the Japan Society for the Promotion of Science (JSPS) KAKENHI (Grant Number JP22K11154).

Institutional Review Board Statement: The study was approved by the Research Ethics Committee of Takasaki University of Health and Welfare (Approval No. 2216, 2240, 2358; Approval date: 5 January 2023).

Informed Consent Statement: Written informed consent was obtained from the patient for publication of this paper.

Data Availability Statement: The data presented in this study are available from the corresponding author upon request. Because of ethical and privacy restrictions, the data are not publicly available.

Acknowledgments: We express our sincere gratitude to Shizuko Nakajima, Masami Ashikaga, Noriko Takizawa, Kazuhiro Suto, Yoshiko Yamada, Hiroshi Akiyama, Jinko Aoyagi, Akemi Yoshii and Katsumi Goto for their assistance. The authors gratefully acknowledge the JSPS KAKENHI (Grant Number JP22K11154) for financial support. During the preparation of this manuscript, the authors used ChatGPT to assist in drafting the R analysis code.

Conflicts of Interest: The authors declare no conflicts of interest.

References

1. Nippon Communications Foundation. Japan's Senior Population Ratio World's Highest by Far at Nearly 30%. Nippon.com. 4 October 2021. Available online: <https://www.nippon.com/en/japan-data/h01120/> (accessed on 22 June 2025).
2. Rakugi, H.; Sugimoto, K.; Arai, H.; Kozaki, K.; Matsui, Y.; Mizukami, K.; Ohyagi, Y.; Okochi, J.; Akishita, M. Statement on falls in long-term care facilities by the Japan Geriatrics Society and the Japan Association of Geriatric Health Services Facilities. *Geriatr. Gerontol. Int.* **2022**, *22*, 193–205. [\[CrossRef\]](#)
3. Kojima, G. Frailty as a predictor of future falls among community-dwelling older people: A systematic review and meta-analysis. *J. Am. Med. Dir. Assoc.* **2015**, *16*, 1027–1033. [\[CrossRef\]](#)
4. Yang, Z.C.; Lin, H.; Jiang, G.H.; Chu, Y.H.; Gao, J.H.; Tong, Z.J.; Wang, Z.H. Frailty is a risk factor for falls in older adults: A systematic review and meta-analysis. *J. Nutr. Health Aging* **2023**, *27*, 487–595. [\[CrossRef\]](#) [\[PubMed\]](#)
5. Ellmers, T.J.; Delbaere, K.; Kal, E.C. Frailty, falls and poor functional mobility predict new onset of activity restriction due to concerns about falling in older adults: A prospective 12-month cohort study. *Eur. Geriatr. Med.* **2023**, *14*, 345–351. [\[CrossRef\]](#) [\[PubMed\]](#)
6. Baek, W.; Min, A.; Ji, Y.; Park, C.G.; Kang, M. Impact of activity limitations due to fear of falling on changes in frailty in Korean older adults: A longitudinal study. *Sci. Rep.* **2024**, *14*, 19121. [\[CrossRef\]](#) [\[PubMed\]](#)
7. Horak, F.B.; Wrisley, D.M.; Frank, J. The Balance Evaluation Systems Test (BESTest) to differentiate balance deficits. *Phys. Ther.* **2009**, *89*, 484–498. [\[CrossRef\]](#) [\[PubMed\]](#)
8. Marques, A.; Almeida, S.; Carvalho, J.; Cruz, J.; Oliveira, A.; Jácome, C. Reliability, validity, and ability to identify fall status of the Balance Evaluation Systems Test, Mini-Balance Evaluation Systems Test, and Brief-Balance Evaluation Systems Test in older people living in the community. *Arch. Phys. Med. Rehabil.* **2016**, *97*, 2166–2173. [\[CrossRef\]](#)
9. Franchignoni, F.; Horak, F.; Godi, M.; Nardone, A.; Giordano, A. Using psychometric techniques to improve the Balance Evaluation Systems Test: The Mini-BESTest. *J. Rehabil. Med.* **2010**, *42*, 323–331. [\[CrossRef\]](#)
10. Padgett, P.K.; Jacobs, J.V.; Kasser, S.L. Is the BESTest at its best? A suggested brief version based on interrater reliability, validity, internal consistency, and theoretical construct. *Phys. Ther.* **2012**, *92*, 1197–1207.
11. Shinohara, T.; Saida, K.; Miyata, K. Ability of the Brief-Balance Evaluation Systems Test to evaluate balance deficits in community-dwelling older adults: A cross-sectional study. *Physiother. Theory Pract.* **2021**, *37*, 1326–1335. [\[CrossRef\]](#)
12. Magnani, P.E.; Genovez, M.B.; Porto, J.M.; Zanellato, N.F.G.; Alvarenga, I.C.; Freire Jr, R.C.; de Abreu, D.C.C. Use of the BESTest and the Mini-BESTest for fall risk prediction in community-dwelling older adults between 60 and 102 years of age. *J. Geriatr. Phys. Ther.* **2020**, *43*, 179–184. [\[CrossRef\]](#) [\[PubMed\]](#)
13. Marques, L.T.; Rodrigues, N.C.; Angeluni, E.O.; Dos Santos Pessanha, F.P.A.; da Cruz Alves, N.M.; Freire Júnior, R.C.; Ferrioli, E.; de Abreu, D.C.C. Balance evaluation of prefrail and frail community-dwelling older adults. *J. Geriatr. Phys. Ther.* **2019**, *42*, 176–182. [\[CrossRef\]](#) [\[PubMed\]](#)
14. Shinohara, T.; Saida, K.; Miyata, K.; Usuda, S. The balance function is associated with frailty in community-dwelling older women. *Int. J. Rehabil. Res.* **2021**, *44*, 51–56. [\[CrossRef\]](#) [\[PubMed\]](#)
15. Takeda, R.; Miyata, K.; Igarashi, T. The minimal clinically important difference of the Mini-Balance Evaluation Systems Test in patients with early subacute stroke. *Top. Stroke Rehabil.* **2023**, *30*, 672–680. [\[CrossRef\]](#)
16. Godi, M.; Arcolin, I.; Giardini, M.; Corna, S.; Schieppati, M. Responsiveness and minimal clinically important difference of the Mini-BESTest in patients with Parkinson's disease. *Gait Posture* **2020**, *80*, 14–19. [\[CrossRef\]](#)
17. Godi, M.; Franchignoni, F.; Caligari, M.; Giordano, A.; Turcato, A.M.; Nardone, A. Comparison of reliability, validity, and responsiveness of the Mini-BESTest and Berg Balance Scale in patients with balance disorders. *Phys. Ther.* **2013**, *93*, 158–167. [\[CrossRef\]](#)
18. Kalbe, E.; Calabrese, P.; Schwalen, S.; Kessler, J. The Rapid Dementia Screening Test (RDST): A New Economical Tool for Detecting Possible Patients with Dementia. *Dement. Geriatr. Cogn. Disord.* **2003**, *16*, 193–199. [\[CrossRef\]](#)
19. Sakai, Y.; Kotaka, A.; Murayama, N.; Takano, M.; Hirose, K.; Eto, K.; Arai, H. Japanese version of the Rapid Dementia Screening Test—Effectiveness in detecting possible patients with dementia. *Ronen Seishin Igaku Zasshi* **2006**, *17*, 539–549, (In Japanese with English Abstract).

20. Montero-Odasso, M.; Van Der Velde, N.; Martin, F.C.; Petrovic, M.; Tan, M.P.; Ryg, J.; Aguilar-Navarro, S.; Alexander, N.B.; Becker, C.; Blain, H.; et al. World guidelines for falls prevention and management for older adults: A global initiative. *Age Ageing* **2022**, *51*, afac205. [[CrossRef](#)]
21. Otaka, E.; Otaka, Y.; Morita, M.; Yokoyama, A.; Kondo, T.; Liu, M. Validation of the Japanese version of the Mini-Balance Evaluation Systems Test (Mini-BESTest). *Jpn. J. Rehabil. Med.* **2014**, *51*, 565–573. [[CrossRef](#)]
22. Satake, S.; Arai, H. The revised Japanese version of the Cardiovascular Health Study criteria (revised J-CHS criteria). *Geriatr. Gerontol. Int.* **2020**, *20*, 992–993. [[CrossRef](#)] [[PubMed](#)]
23. Fried, L.P.; Tangen, C.M.; Walston, J.; Newman, A.B.; Hirsch, C.; Gottdiener, J.; Seeman, T.; Tracy, R.; Kop, W.J.; Burke, G.; et al. Frailty in older adults: Evidence for a phenotype. *J. Gerontol. A Biol. Sci. Med. Sci.* **2001**, *56*, M146–M156. [[CrossRef](#)] [[PubMed](#)]
24. Chang, S.S.; Weiss, C.O.; Xue, Q.L.; Fried, L.P. Association between Inflammatory-Related Disease Burden and Frailty: Results from the Women’s Health and Aging Studies (WHAS) I and II. *Arch. Gerontol. Geriatr.* **2012**, *54*, 9–15. [[CrossRef](#)] [[PubMed](#)]
25. Yang, Y.; Hao, Q.; Flaherty, J.H.; Cao, L.; Zhou, J.; Su, L.; Shen, Y.; Dong, B. Comparison of Procalcitonin, a Potentially New Inflammatory Biomarker of Frailty, to Interleukin-6 and C-Reactive Protein among Older Chinese Hospitalized Patients. *Aging Clin. Exp. Res.* **2018**, *30*, 1459–1464. [[CrossRef](#)]
26. Cohen, J. *Statistical Power Analysis for the Behavioral Sciences*, 2nd ed.; Lawrence Erlbaum Associates: Hillsdale, NJ, USA, 1988.
27. Çorbacioğlu, Ş.K.; Aksel, G. Receiver operating characteristic curve analysis in diagnostic accuracy studies: A guide to interpreting the area under the curve value. *Turk. J. Emerg. Med.* **2023**, *23*, 195–198. [[CrossRef](#)]
28. Turner, D.; Schünemann, H.J.; Griffith, L.E.; Beaton, D.E.; Griffiths, A.M.; Critch, J.N.; Guyatt, G.H. Using the entire cohort in the receiver operating characteristic analysis maximizes precision of the minimal important difference. *J. Clin. Epidemiol.* **2009**, *62*, 374–379. [[CrossRef](#)]
29. DeLong, E.R.; DeLong, D.M.; Clarke-Pearson, D.L. Comparing the areas under two or more correlated receiver operating curves: A nonparametric approach. *Biometrics* **1988**, *44*, 837–845. [[CrossRef](#)]
30. Terwee, C.B.; Roorda, L.D.; Dekker, J.; Bierma-Zeinstra, S.M.A.; Peat, G.; Jordan, K.P.; Croft, P.; de Vet, H.C.W. Mind the MIC: Large variation among populations and methods. *J. Clin. Epidemiol.* **2010**, *63*, 524–534. [[CrossRef](#)]
31. Salari, N.; Darvishi, N.; Ahmadipana, M.; Shohaimi, S.; Mohammadi, M. Global Prevalence of Falls in the Older Adults: A Comprehensive Systematic Review and Meta-Analysis. *J. Orthop. Surg. Res.* **2022**, *17*, 334. [[CrossRef](#)]
32. Yamada, M.; Terao, Y.; Kojima, I.; Tanaka, S.; Saegusa, H.; Nanbu, M.; Soma, S.; Matsumoto, H.; Saito, M.; Okawa, K.; et al. Characteristics of Falls in Japanese Community-Dwelling Older Adults. *Geriatr. Gerontol. Int.* **2024**, *24*, 1181–1188. [[CrossRef](#)]
33. Hayashi, T.; Kondo, K.; Suzuki, K.; Yamada, M.; Matsumoto, D. Factors Associated with Falls in Community-Dwelling Older People with Focus on Participation in Sport Organizations: The Japan Gerontological Evaluation Study Project. *Biomed. Res. Int.* **2014**, *2014*, 537614. [[CrossRef](#)] [[PubMed](#)]
34. Ofori-Asenso, R.; Chin, K.L.; Mazidi, M.; Zomer, E.; Ilomaki, J.; Zullo, A.R.; Gasevic, D.; Ademi, Z.; Korhonen, M.J.; LoGiudice, D.; et al. Global Incidence of Frailty and Prefrailty Among Community-Dwelling Older Adults: A Systematic Review and Meta-Analysis. *JAMA Netw. Open* **2019**, *2*, e198398. [[CrossRef](#)] [[PubMed](#)]
35. Noguchi, T.; Murata, C.; Hayashi, T.; Watanabe, R.; Saito, M.; Kojima, M.; Kondo, K.; Saito, T. Association between Community-Level Social Capital and Frailty Onset among Older Adults: A Multilevel Longitudinal Study from the Japan Gerontological Evaluation Study (JAGES). *J. Epidemiol. Community Health* **2022**, *76*, 182–189. [[CrossRef](#)] [[PubMed](#)]
36. Doi, T.; Makizako, H.; Tsutsumimoto, K.; Nakakubo, S.; Kim, M.J.; Kurita, S.; Hotta, R.; Shimada, H. Transitional Status and Modifiable Risk of Frailty in Japanese Older Adults: A Prospective Cohort Study. *Geriatr. Gerontol. Int.* **2018**, *18*, 1562–1566. [[CrossRef](#)]
37. Hopewell, S.; Adedire, O.; Copsey, B.J.; Boniface, G.J.; Sherrington, C.; Clemson, L.; Close, J.C.; Lamb, S.E. Multifactorial and multiple component interventions for preventing falls in older people living in the community. *Cochrane Database Syst. Rev.* **2018**, *7*, CD012221. [[CrossRef](#)]
38. Muir, S.W.; Berg, K.; Chesworth, B.; Klar, N.; Speechley, M. Balance Impairment as a Risk Factor for Falls in Community-Dwelling Older Adults Who Are High Functioning: A Prospective Study. *Phys. Ther.* **2010**, *90*, 338–347. [[CrossRef](#)]
39. Oliveira, M.R.; Vieira, E.R.; Gil, A.W.O.; Fernandes, K.B.P.; Teixeira, D.C.; Amorim, C.F.; da Silva, R.A. One-Legged Stance Sway of Older Adults with and without Falls. *PLoS ONE* **2018**, *13*, e0203887. [[CrossRef](#)]
40. Kojima, G.; Masud, T.; Kendrick, D.; Morris, R.; Gawler, S.; Trembl, J.; Iliffe, S. Does the Timed Up and Go Test Predict Future Falls among British Community-Dwelling Older People? Prospective Cohort Study Nested within a Randomised Controlled Trial. *BMC Geriatr.* **2015**, *15*, 38. [[CrossRef](#)]
41. Thrane, G.; Joakimsen, R.M.; Thornquist, E. The Association between Timed Up and Go Test and History of Falls: The Tromsø Study. *BMC Geriatr.* **2007**, *7*, 1. [[CrossRef](#)]
42. Kim, J.; Choi, S. Association of Timed Up and Go Test Results with Future Injurious Falls among Older Adults by Sex: A Population-Based Cohort Study. *BMC Geriatr.* **2024**, *24*, 1035. [[CrossRef](#)]

43. Rydwick, E.; Bergland, A.; Forsén, L.; Frändin, K. Psychometric properties of Timed Up and Go in elderly people: A systematic review. *Phys. Occup. Ther. Geriatr.* **2011**, *29*, 102–125. [[CrossRef](#)]
44. Christopher, A.; Kraft, E.; Olenick, H.; Kiesling, R.; Doty, A. The reliability and validity of the Timed Up and Go as a clinical tool in individuals with and without disabilities across a lifespan: A systematic review. *Disabil. Rehabil.* **2021**, *43*, 1799–1813. [[CrossRef](#)]

Disclaimer/Publisher’s Note: The statements, opinions and data contained in all publications are solely those of the individual author(s) and contributor(s) and not of MDPI and/or the editor(s). MDPI and/or the editor(s) disclaim responsibility for any injury to people or property resulting from any ideas, methods, instructions or products referred to in the content.