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Brief Report

Physical Performance Predictor Measures in Older Adults With Falls-Related Emergency Department Visits

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A B S T R A C T

Objectives: Identifying strong predictors for falls and mobility limitations in older adults with a falls-related emergency department visit is crucial. This study aimed to compare, in this clinical population, the incremental predictive value of the Short Physical Performance Battery (SPPB) component tests for incident falls, injurious falls, and mobility limitations.
Design and measures: Prospective cohort study.
Setting and participants: A total of 323 community-dwelling older adults with a falls-related emergency department visit participated. Baseline physical performance was measured by the SPPB standing balance test, sit-to-stand test, and habitual gait speed test. Six-month prospective fall rate and self-reported mobility limitations at 6 months post baseline assessment were also measured. An injurious fall was defined as a fall for which the participant sought medical attention or that restricted his or her daily activities for at least 48 hours.
Results: In multivariable proportional odds analyses adjusted for demographics and clinical covariates, higher levels of full-tandem balance and sit-to-stand performance were significantly associated with fewer incident falls ($P = .04$ and .02, respectively) and lower odds of mobility limitations ($P = .05$ and .03, respectively) and marginally associated with lower odds of injurious falls ($P = .06$ and .07, respectively). Habitual gait speed was the weakest predictor of falls but the strongest predictor (odds ratio 0.24, 95% confidence interval 0.08-0.70; $P < .001$) of mobility limitations.
Conclusions/implications: In high-fall-risk older adults, the SPPB balance and sit-to-stand tests predicted falls whereas the SPPB gait speed test was adept at predicting mobility limitations. No one test is best across all situations, so the choice of test will depend on the goal of the assessment.
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Falls are a common reason older adults visit the emergency department (ED), and older adults with a falls-related ED visit have increased risk for subsequent falls, hospital readmission, mobility decline, and mortality.[1,2] Accordingly, identifying strong predictors for falls and mobility limitations in this population is crucial.[3]

Recent guidelines and reviews[4,5] recommend that standardized physical assessments of balance, muscle strength, and gait be used for assessing falls and mobility limitations risk, and the Short Physical Performance Battery (SPPB)[6] includes these 3 physical tests. Of these tests, muscle strength and gait function are related to individual components of sarcopenia.[7] Only 2 studies[8,9] from the same research group have evaluated the SPPB component tests against injurious falls, and none, to our knowledge, has evaluated the individual SPPB tests against incident falls, injurious falls, and mobility limitations within the same cohort. If it could be shown that one particular SPPB component test is a consistently strong predictor across all outcomes, this would provide support for its routine use in falls and disability risk assessment.

Therefore, this study aimed to compare the incremental predictive value of the SPPB component tests for incident falls, injurious falls, and mobility limitations in older adults with a falls-related ED visit.

Methods

Our study comprised 323 participants (248 women, 75 men; mean age 78 years, range 65-99) who completed the Steps to Avoid Falls in Elderly (SAFE) trial (ClinicalTrials.gov NCT01713543). Details on the SAFE randomized controlled trial, including patient flow, protocol, and

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main results, have been provided elsewhere.[10] In brief, the SAFE trial is a multicenter randomized trial that compared a home-based, customized program with usual care prescribed by physicians, which included the provision of an educational booklet.[10] Research personnel identified community-dwelling older adults (≥65 years) presenting to and discharged from the ED for a fall or fall-related injury. Exclusion criteria were an inability to follow the 3-step command test, nonambulatory status before the ED visit, and total blindness. Consenting participants were assessed using a battery of self-report and functional measures at 3 months (hereafter known as baseline measures) and 9 months following hospital discharge.

Outcomes

To assess incident[11] and injurious[12] falls, participants tracked, over a 6-month period, monthly fall incidence on fall calendars and were contacted through monthly telephone calls. To measure mobility limitations (assessed at baseline and after 6 months), participants rated their problems with walking on a 5-point scale: (1) no problems, (2) slight problems, (3) moderate problems, (4) severe problems, and (5) unable to walk.

Short Physical Performance Battery

The SPPB[6] comprises the standing balance test, 4-m gait speed test, and 5-times sit-to-stand test, and it yields a total score from 0 to 12, where higher scores indicate better physical function. Of note, the standing balance test battery includes the side-by-side, semitandem, and full-tandem balance tests, and we treated them as separate predictors in our analyses. We analyzed the gait speed and sit-to-stand tests as continuous predictors to maximize statistical power for detecting associations of these tests with fall and mobility outcomes,[13] and we inverse-transformed the sit-to-stand test time to calculate sit-to-stand speed (dividing the number of sit-to-stand repetitions by the time taken to complete the test).[14] This data transformation reduces the influence of extreme values and accommodates participants (n = 63) who were unable to perform the sit-to-stand test.

Statistical Methods

We used separate multivariable proportional odds regression models[15] to evaluate the associations of the various SPPB measures with the number of falls and the level of mobility limitations. When evaluating the SPPB predictors of injurious falls, we used penalized binary logistic regression to account for potential model overfitting.[15] We adjusted all regression models for 12 covariates, which were chosen on the basis of existing published research, and these covariates included randomization group assignment, sex, age, ethnicity,[16] a history of stroke or Parkinson's disease, falls history, vision, bodily pain,[17] Modified Falls Efficacy Scale score,[18] Montreal Cognitive Assessment score,[19] baseline self-reported mobility limitations, and the type of gait aids used. To avoid assuming linearity, we modeled all continuous predictors as restricted cubic splines.[15] To evaluate the predictive value of each SPPB measure, we used the likelihood ratio χ^2 statistic minus the degrees of freedom ($\chi^2 - df$).[15] All analyses were done using R software, version 3.5.1 (http://www.r-project.org).

Ethical Approval

The study was approved by SingHealth Centralised Institutional Review Board, and all participants provided written informed consent.

Table 1
Patient Demographics and Clinical Characteristics

Variables	All Participants
Intervention group	50 (160)
Women	77 (248)
Age, y	73.0, 78.0, 83.0 (77.8 ± 7.1)
Fall history	50 (160)
Bodily pain	
None	63 (204)
Slight	31 (100)
Moderate	5 (15)
Severe	1 (3)
MOCA score	14.0, 21.0, 27.0 (20.1 ± 7.3)
Gait aids	
None	80 (257)
Walking stick/Quadstick	10 (33)
Waking frame	10 (32)
Mobility limitations	
None	74 (238)
Slight	15 (49)
Moderate	7 (23)
Severe	3 (9)
Unable	1 (3)
Vision	
Excellent	1 (3)
Good	43 (139)
Fair	52 (168)
Poor	4 (12)
Ethnicity	
Chinese	83 (266)
Others	3 (9)
Indian	5 (16)
Malay	10 (31)
Stroke or Parkinson's disease	16 (53)
MFES score	67, 108, 125 (94 ± 37)
SPPB test	
Side-by-side balance test	
≥10 s	83 (268)
Semitandem balance test	
Not attempted	15 (49)
<10 s/unable	13 (43)
≥10 s	71 (230)
Full-tandem balance test	
<3 s/unable/not attempted	57 (184)
3-9.99 s	7 (21)
≥10 s	36 (117)
Sit-to-stand test, s	13, 16, 26 (25 ± 18)
Habitual gait speed test, m/s	0.3, 0.5, 0.7 (0.5 ± 0.3)
Total SPPB score	3, 6, 9 (6.2 ± 3.3)
Follow-up	
Incident falls	
None	76 (243)
Once	16 (53)
Twice or more	8 (27)
Injurious falls	13 (42)
Mobility limitations	
None	74 (238)
Slight	15 (49)
Moderate	7 (22)
Severe	2 (7)
Unable	2 (6)

MFES, modified falls efficacy scale.
Continuous variables are summarized as 25th, 50th, 75th percentiles and mean ± standard deviation within parentheses. Categorical variables are summarized as percentages and counts (n).

Results

Table 1 shows the clinical characteristics of the sample. Over a 6-month follow-up, 80 (24%) participants had fallen at least once. Around 13% (42/323) of participants had an injurious fall, and 11% of participants reported having at least moderate problems with walking.

Table 2 shows that after adjustment for covariates, higher levels of full-tandem balance and sit-to-stand performance were significantly

Table 2
Associations of SPPB Component Tests With Fall Risk and Mobility Limitations

Variables	Comparison	Incident Falls			Injurious Falls			Mobility Limitations		
		OR (95% CI)	*P* Value	$\chi^2 - df$	OR (95% CI)	*P* Value	$\chi^2 - df$	OR (95% CI)	*P* Value	$\chi^2 - df$
Side-by-side test	≥10 s vs <10 s/unable/not attempted (ref)	0.40 (0.18-0.87)	.02	4.3	0.82 (0.45-1.49)	.52	0.2	0.40 (0.19-0.85)	.02	4.6
Semitandem test			.01	6.5		.86	0.3		.07	3.4
	<10 s/unable vs not attempted (ref)	0.27 (0.10-0.71)			0.90 (0.59-1.36)			0.80 (0.33-1.92)		
	≥10 s vs not attempted (ref)	0.36 (0.16-0.82)			0.92 (0.61-1.39)			0.40 (0.18-0.90)		
Full-tandem test			.04	3.5		.06	5.6		.05	2.9
	3-9.99 s vs <3 s/unable/not attempted	0.69 (0.49-0.98)			0.75 (0.55-1.01)			0.61 (0.37-1.00)		
	≥10 s vs <3 s/unable/not attempted (ref)	0.48 (0.24-0.95)			0.56 (0.31-1.03)			0.38 (0.14-1.02)		
Sit-to-stand test	13 s vs 26 s	0.57 (0.36-0.91)	.02	4.8	0.71 (0.49-1.02)	.07	5.7	0.52 (0.30-0.89)	.02	4.9
Gait speed test	0.70 m/s vs 0.30 m/s	0.76 (0.41-1.44)	.41	−0.3	0.85 (0.58-1.26)	.43	0.6	0.24 (0.08-0.70)	.03	8.4
Total SPPB score	9 points vs 3 points	0.33 (0.15-0.70)	<.01	7.3	0.55 (0.30-1.01)	.05	6.6	0.18 (0.07-0.47)	<.001	11.7

Adjusted ORs with 95% CIs and $\chi^2 - df$ statistics from ordinal regression models examining the associations of each SPPB test with fall risk and the severity of mobility limitations over a 6-month follow-up period. To facilitate comparisons of results, we computed the ORs to represent the odds of having poorer outcomes at the 75th versus the 25th percentile values of each continuous SPPB predictor. As an illustrative example, other variables being equal, patients with a habitual gait speed of 0.70 m/s (75th percentile) had, on average, 0.24 times (95% CI 0.08-0.70) the odds of having greater mobility limitations relative to patients with a habitual gait speed of 0.30 m/s (25th percentile).

associated with fewer incident falls ($P = .04$ and .02, respectively) and lower odds of mobility limitations ($P = .05$ and .03, respectively) and marginally associated with lower odds of injurious falls ($P = .06$ and .07, respectively). In terms of both odds ratios (ORs) and $\chi^2 - df$ (a measure of variable importance that shows the contribution of the predictor in the model), habitual gait speed was the weakest predictor of incident and injurious falls [OR comparing gait speed at the 75th and 25th percentiles = 0.76, 95% confidence interval (CI) 0.41-1.44, and OR 0.85, 95% CI 0.58-1.26, for incident and injurious falls, respectively] but the strongest predictor of future mobility limitations (OR 0.24, 95% CI 0.08-0.70) (Figure 1). Total SPPB score was consistently and significantly associated with all outcomes.

Discussion

In 323 older adults with falls-related ED visits, poorer full-tandem balance and sit-to-stand performance were significantly associated with incident falls and mobility limitations and marginally associated with injurious falls. In contrast, habitual gait speed was not statistically significantly associated with incident and injurious falls. However, it was strongly associated with future mobility limitations.

Of the 3 SPPB balance tests, the full-tandem balance test provided the narrowest base-of-support and was the most consistent predictor of falls and mobility limitations in our study. Our findings that the full-tandem balance test was associated with fall risk are consistent with current falls assessment guidelines[4] and with those of the English Longitudinal Study of Ageing cohort study[20] and the Hawaii Osteoporosis Study.[21] The study that was most similar in method to ours was reported by Ward et al,[8] and they reported that the (overall) SPPB balance test was not predictive of injurious falls in the Boston MOBILIZE study. In our study, we analyzed components of the SPPB balance test and found that the side-by-side and semitandem balance tests had limited predictive abilities and that only the full-tandem balance test was (marginally) associated with injurious falls. Thus, these essentially null findings are in agreement with those from Ward et al.[8] However, because our findings also suggest that the various SPPB balance tests may have different predictive abilities, we believe it may be premature to dismiss them, and future studies should assess components of the SPPB balance tests separately and in combination.

Sufficient evidence exists revealing the associations of the sit-to-stand test with incident falls,[21] injurious falls,[8,9,21] and functional disability[22] in older adults. Our results expand on previous findings indicating that the 5-times sit-to-stand test is a robust predictor of falls and mobility limitations in older adults with a recent falls-related ED visit. Because the sit-to-stand test performance depends on lower extremity muscle strength and standing balance,[23] and given also that healthcare providers often have competing demands on their time and resources, a natural question is, "Is the sit-to-stand test, by itself, sufficient to assess physical performance as part of a falls risk assessment?" In the incident falls analyses, total SPPB score was the strongest predictor, indicating that there may be meaningful improvement in predictive power with the combination of both standing balance and sit-to-stand tests compared with the sit-to-stand test alone. Furthermore, from the treatment perspective, the evaluation of both tests may better disaggregate at-risk older adults into distinct subgroups based on muscle strength and balance levels. Based on these considerations, future large-sample studies are needed to more definitively answer this critical question.

Regarding the gait speed test, our findings are consistent with a well-established body of literature[24,25] demonstrating the prognostic significance of gait speed with physical disability in older adults. Although the gait speed test was a strong predictor of mobility limitations, it provided no substantive additive predictive value in the fall risk models. Reviewing the literature, our null findings are consistent with several,[8,9,20,21] but not all,[24,26,27] studies reporting on community-dwelling older adults. As gait speed and the timed-up-and-go tests are closely correlated,[24] our null findings are also in conceptual agreement with a recent systematic review[28] that concludes that the predictive ability of the timed-up-and-go test is at best moderate.

What explains these findings? Previous large-scale studies have indicated that gait speed was nonlinearly related to fall risk[27]; however, we modeled gait speed flexibly using cubic splines in our analyses. Hence, underfitting bias is not likely to be at play here. In our study, the type of gait aids used was a strong predictor of falls ($\chi^2 - df = 5.7$, $P < .001$) and was closely related to habitual gait speed (Spearman correlation = −0.62). Thus, it may be difficult for gait speed to provide significant incremental predictive value. Regardless of the eventual explanation, it is interesting to interpret our findings in light of the Centers for Disease Control and Prevention's STEADI (Stopping Elderly Accidents, Deaths & Injuries) falls risk algorithm[4] in which the gait-based timed-up-and-go test is recommended and the standing balance and sit-to-stand tests are treated as alternatives. Our findings suggest that the latter tests may, in fact, have more predictive value; hence, head-to-head studies are clearly needed to compare the predictive value of the various physical performance tests.

Our study has limitations. First, although our analyses were adjusted for several covariates known to be associated with falls and functional disability, we acknowledge that the inclusion of other covariates[4]—for example, polypharmacy (including psychotropic medication uses), self-reported measures of walking unsteadiness,

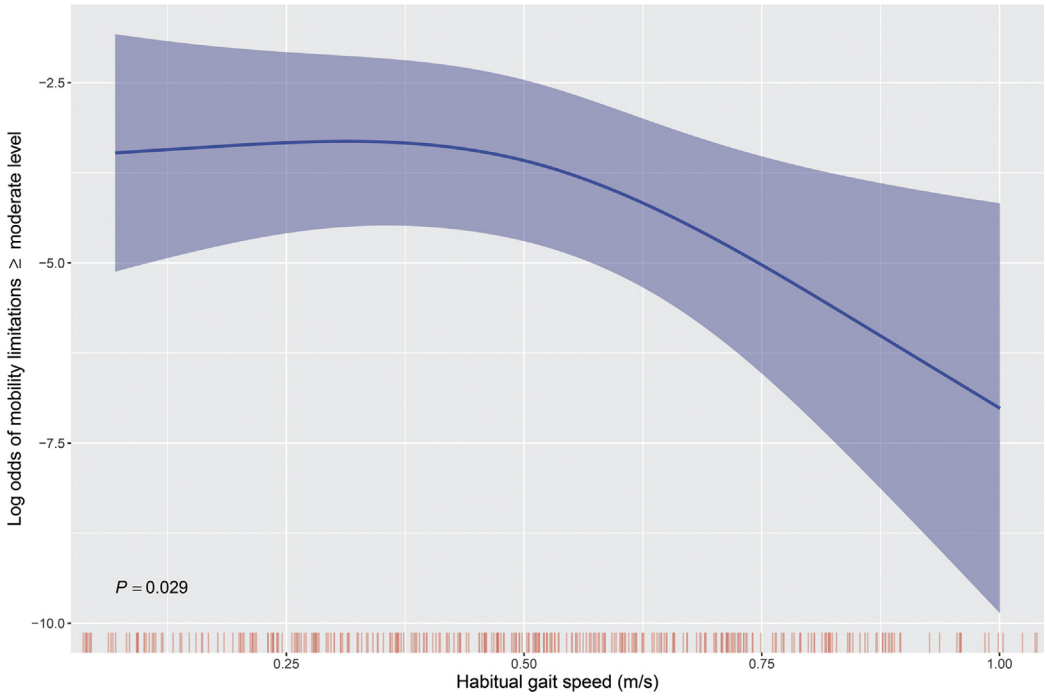

Fig. 1. Faster habitual gait speed was independently associated with lower odds of moderate (or worse) mobility limitations at 6 months post baseline assessment, after adjustment for randomization group assignment, sex, age, ethnicity, a history of stroke or Parkinson's disease, falls history, vision, bodily pain, Modified Falls Efficacy Scale score, Montreal Cognitive Assessment score, baseline self-reported mobility limitations, and the type of gait aids used. Habitual gait speed was modeled flexibly using a restricted cubic spline to allow for potential nonlinear associations. Shaded regions represent 95% CI for the point estimates. Rug plots show the observed baseline habitual gait speed values.

lower extremity muscle weakness, and sensory impairment of the feet—may potentially provide more challenge to the predictive capabilities of the SPPB balance and sit-to-stand tests. Second, mobility limitation was assessed with a single question, which, although providing information that is immediately comprehensible, may not capture the full complexity of the mobility construct. Third, our study used data from a randomized treatment trial and this may limit the generalizability and validity of our findings. However, this potential limitation is mitigated by (1) the broad inclusion criteria that recruited a heterogeneous group of high-risk older adults and (2) the lack of statistically significant differences in fall rate between the 2 treatment groups during the study period.[10]

Conclusions/Relevance

In summary, in a sample of high-fall-risk older adults, the SPPB full-tandem balance and sit-to-stand tests predicted falls while the SPPB gait speed test was adept at predicting mobility limitations. No one test is best across all situations, so the choice of test will depend on the goal of the assessment. Future studies are needed to assess whether including these physical performance tests in falls and disability risk prediction algorithms leads to a meaningful change in clinical outcomes.

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