Functional Performance As a Predictor of Injurious Falls Among Older Adults

Rachel E. Ward, PhD, MPH[1,2,3], **Suzanne G. Leveille, RN, PhD**[4], **Marla K. Beauchamp, PT, PhD**[1,2], **Thomas Travison, PhD**[5], **Neil Alexander, MD**[6], **Alan M. Jette, PT, PhD**[3], and **Jonathan F. Bean, MD, MS, MPH**[1,2]

[1]Spaulding Rehabilitation Hospital, Harvard Medical School, Cambridge, MA

[2]Department of PM&R, Harvard Medical School, Cambridge, MA

[3]Health and Disability Research Institute, Boston University School of Health, Boston, Massachusetts

[4]College of Nursing and Health Sciences, University of Massachusetts Boston, Boston, Massachusetts

[5]Institute for Aging Research, Hebrew SeniorLife, Boston, Massachusetts

[6]Division of Geriatric and Palliative Medicine, Department of Internal Medicine, University of Michigan and Geriatric Research Education and Clinical Center (GRECC), Veterans Affairs Ann Arbor Health Care System, Ann Arbor, Michigan

Abstract

OBJECTIVES—Guidelines for falls risk assessment include functional performance although evidence supporting specific tests for predicting injurious falls is lacking. We investigated whether a performance battery/its components aid in predicting injurious falls.

DESIGN—Longitudinal analysis; prospective cohort study.

SETTING—Clinical site.

PARTICIPANTS—755 Boston area community-dwelling adults (mean ± SD: age=78.1 ± 5.4, 64.1% women, 77.6% white).

Corresponding Author: Rachel E. Ward, PhD, MPH, Postdoctoral Fellow, Spaulding Hospital Cambridge, 1575 Cambridge St., Cambridge, MA 02138, Phone: 954-461-4421, Fax: 617-952-6965, reward@partners.org. Alternate Corresponding Author: Jonathan F. Bean MD, MS, MPH, jfbean@partners.org.

MEASUREMENTS—Baseline functional performance was determined by the SPPB measuring balance, gait speed, and 5 repeated chair stands. Fall history (past year) and efficacy in performing 10 daily activities without falling were assessed. Falls were assessed using a daily calendar over 4 years. Injurious falls were defined by fractures, sprains, dislocations, pulled or torn muscles, ligaments, or tendons or by seeking medical attention.

RESULTS—Poorest chair stand performance was associated with greater hazard of injurious falls compared to all other groups (HR [95% CI]: 1.96 [1.18–3.26], 1.65 [1.07–2.55], and 1.60 [1.03–2.48] for 16.7s vs. 13.7–16.6s, 11.2–13.6s, and <11.2s). SPPB did not predict injurious falls. Fall history predicted injurious falls (HR [95% CI]: 1.82 [1.39–2.39]); falls efficacy did not. Fall history and a slow chair stand (<16.7s) compounded 2-year cumulative incidence of an injurious fall (0.46, [0.34–0.58]) compared to positive fall history (0.29, [0.25–0.34]) or a slow chair stand alone (0.21, [0.13–0.30]).

CONCLUSION—An easily administered chair stand test may be sufficient for evaluating performance as part of a risk stratification strategy for injurious falls.

Keywords

falls; injury; aged; risk assessment

INTRODUCTION

Fall-related injuries among older adults are a major public health problem. Annually, 35–40% of community-dwelling adults aged 65 years fall, with 10% suffering serious injury.[1] Fall-related injuries are a major source of mortality, morbidity, and disability and can lead to loss of independence.[2,3] In 2000, $19.2 billion was spent on fall-related injuries in the U.S.[4] This is expected to climb $32.4 billion by 2020.[5]

The Centers for Disease Control (CDC) has released an algorithm for Falls Risk Assessment and Interventions to aid in care planning and prevention.[6] This algorithm recommends assessing fall history, falls self-efficacy (e.g. worrying about falling), and functional performance. These may inform clinical decisions on patient education, referral to exercise or prevention programs, or conduction of multifactorial risk assessments and interventions. Importantly, this algorithm was created to assess overall falls risk, although serious fall-related injuries have more direct consequences for health, function, and healthcare expenditures.

The algorithm evaluates three functional performance domains associated with falls[7] and fall-related injuries[2]: gait, lower-extremity strength or chair stand performance, and balance. Various tests assess these domains, although limited evidence exists on which test is most predictive of injurious falls. Few studies have investigated how these tests perform in combination with other brief assessments like fall history or self-efficacy.[8,9]

The Short Physical Performance Battery (SPPB) captures each of these functional domains with established cutpoints predictive of disability and mortality in older adults.[10,11] The SPPB is easily administered, requires little equipment, and can be completed in <10 minutes. Despite this, it has not been evaluated longitudinally as a predictor of fall-related

injuries. Using the CDC Falls Risk Assessment and Interventions algorithm as a guide, we examined whether functional performance, with fall history and falls efficacy, predicts time to incident injurious falls. We hypothesized that with fall history and falls efficacy, the SPPB and/or its components would predict injurious falls.

METHODS

The Maintenance of Balance, Independent Living, Intellect and Zest in the Elderly (MOBILIZE) Boston study was designed to assess risk factors and mechanisms of falls in a cohort of 765 community-dwelling older adults living in the Boston area.[12] Eligibility included age 70 years, ability to walk 20 feet without the aid of another person, and intention to stay in the Boston area for 2 years.[13] Exclusions included moderate to severe cognitive impairment (Mini-Mental State Examination [MMSE]<18). Our analysis included 755 (98.7%) participants. Participants with <90 days of follow-up due to withdrawal (n=8) from the study or death (n=2) were excluded.

Injurious falls

Falls were defined as unintentionally coming to rest on the ground or another lower level not resulting from major health event (e.g. myocardial infarction) or an overwhelming external hazard (e.g. vehicular accident).[14] Participants mailed daily falls calendars to the study site monthly.[15] Falls were assessed during a maximum follow-up of 4.3 years. Associated injuries were ascertained via structured interview. Injurious falls were defined by fractures, sprains, dislocations; pulled or torn muscles, ligaments, or tendons; or by seeking medical attention. Falls data were obtained for 98.5% of follow-up months in the first year, 90.8% in the second year, 88.2% in the third year, and 81.2% in the fourth year.[16]

The SPPB

The SPPB is a well-established, reliable, and valid measure of lower-extremity performance.[10,11] The battery includes a test of standing balance, a timed 4-meter usual paced walk, and a timed test of 5 repeated chair stands. Each test is scored from 0–4, with a maximum summed score of 12 for the 3 tests and higher scores representing better functioning. Scores were categorized based on previously validated cutpoints (Tables 1–2).[10] The SPPB is predictive of disability, hospitalizations, and mortality in older populations.[10,11]

Baseline characteristics

Baseline assessments included a home interview conducted by a trained research assistant, followed by a clinic assessment visit conducted within approximately 2 weeks of the interview. Fall history (yes/no) within the past year was assessed by self-report. Falls self-efficacy was measured using the Falls Efficacy Scale,[17] for which participants were asked to rate their level of confidence from 1 (not at all confident) to 10 (extremely confident) to perform 10 daily activities without falling.

Covariates such as age, sex, race, body mass index (BMI), and baseline health conditions known and hypothesized to be related to falls and fall-related injuries were considered in the

analysis.[2,6] Psychotropic medication use (yes/no) included use of antidepressants, antipsychotics, hypnotics, benzodiazepines, and other sedatives. Cognitive impairment was defined as a score of <24 on the MMSE.[13] Depression was assessed using a modified Center for Epidemiologic Studies-Depression (CES-D) scale.[18,19] Vision was assessed with the Good-Light Chart Model 600A light box at a 10-foot distance;[20] visual deficit was defined as scoring in the lowest quartile. Orthostatic hypotension was defined as a reduction of systolic blood pressure 20 mmHg or of diastolic blood pressure 10 mmHg within 3 minutes of standing.[21] Sensory impairment was defined as being unable to feel a 10-g Semmes-Weinstein monofilament on the dorsum of either great toe.[22]

Statistical analysis

Multivariable Cox proportional hazards models were built to predict incident injurious falls. Covariates univariately related to injurious falls (alpha=0.1) were included in the models to prevent overfitting. Predictors fall history and falls efficacy score were adjusted for age, sex, race, psychotropic medication use, and depression;[2,6] then SPPB or SPPB component scores were added as ordinal predictors in separate models. The Akaike information criterion (AIC) was used to determine goodness of fit. The proportional hazards assumption was checked by testing the relationship of the interaction between the predictors or covariates and the log of survival time with injurious falls (alpha=0.05). Cumulative incidence was calculated by risk group and plotted against follow-up time. Two sensitivity analysis were performed: one assessing the relationships between continuous functional performance (gait speed and chair rise time) and injurious falls using Cox proportional hazards regression; and a second using classification and regression tree (CART) analysis in R statistical software[23] to determines the cutpoint from continuous performance most predictive of injurious falls. Analyses other than CART were performed using SAS version 9.3 (SAS Institute Inc., Cary, NC, USA).

RESULTS

The proportional hazards assumption was met. Participants had a median follow up time of 2.43 years (IQR: 1.40–3.23). Over the follow-up, 221 participants (29%) experienced 1 injurious fall. Out of the 755 participants 64.1% were women, 77.6% were white and the mean age was 78.1 ± 5.4 (mean ± SD) years.

Adjusting for covariates, fall history predicted incident injurious falls (HR [95% CI]: 1.82 [1.39–2.39]), while falls efficacy and SPPB score did not (Table 1). The group with the poorest chair stand performance (16.7s) had the greatest hazard of injurious falls compared to any other group (HR [95% CI]: 1.96 [1.18–3.26], 1.65 [1.07–2.55], and 1.60 [1.03–2.48] for 1 vs. 2, 3, and 4, respectively) (Table 2). However, inability to complete the chair stand (n=64) was not associated with greater hazard of injurious fall (HR [95% CI]: 1.07 [0.66–1.73] for 0 vs. 1–4). The second poorest performing gait speed group had a greater hazard of injurious fall than the highest performing group (HR [95% CI]: 1.66 [1.05–2.63]).

Since the worst performing chair stand group had the highest hazard of injurious falls and the chair stand model had the best goodness of fit, we assessed the cumulative incidence of an injurious falls when having a slow chair stand (score=1; 16.7s) and a fall history together and separately (Figure 1). A positive fall history and slow chair stand were

associated with a 2-year cumulative incidence of 46% for an injurious fall compared to 12% for neither risk factor, 29% for a fall history alone, and 21% for a slow chair stand alone. Neither gait speed nor chair rise time were significant as continuous predictors of injurious falls (HR [95% CI]: 0.63 [0.33–1.20] and 1.02 [0.99–1.02], respectively). Using CART, the most predictive cutpoint of injurious falls in chair stand time was 15.5s.

DISCUSSION

We determined the utility of a lower-extremity function measure as part of an injurious falls risk assessment strategy in older adults. Although SPPB score was not predictive of injurious falls in this cohort, a 16.7s cutpoint for the 5 repetition chair stand test was an independent predictor. Performing slower than this threshold and reporting 1 falls in the preceding year was associated with a compounded risk of injurious falls over 4 years. These findings both inform fall risk assessment recommendations and stratification guidelines and extend them to include fall-related injuries.

Multiple components of functional performance were assessed separately and in combination using the SPPB to evaluate injurious falls risk. Interestingly, the chair stand component of the SPPB performed better than the combined score, which includes balance and gait speed. This has important clinical implications, suggesting that a short, simple chair stand test, which may identify lower-extremity weakness, poor muscle power, and limitations in dynamic balance, may be sufficient for evaluating performance as part of a risk stratification strategy for injurious falls.

While to our knowledge, the SPPB has not been assessed as a predictor of injurious falls using prospective data, the chair stand test was evaluated as a predictor of falls and fall-related fractures retrospectively.[24] The test was predictive of falls but not fall-related fractures; although only 10 out of 101 participants experienced fractures, therefore lack of statistical power cannot be ruled out. In addition, previous studies have found that chair stand performance has been associated with recurrent falls,[3,25,26] with one study reporting that chair stand performance was a better predictor of multiple falls than the one leg standing balance test and the Timed Up and Go test,[26] and another study reporting that it had similar predictive validity to the alternate-step test and the six-meter-walk test.[25] None of these studies evaluated the association of these tests with injurious falls.

When we examined the magnitude of the hazard ratios for chair stand performance predicting injurious falls, we noted a hazard ratio closer to 1 in the comparison of the poorest to the best performing group (1 vs. 4) than in the comparison of the poorest to the second poorest performing group (1 vs. 2). Previous findings from this study show that both those with high and low performance have higher rates of falls than those in the middle categories,[27] perhaps suggesting that higher functioning may contribute to increased falls due to greater exposure to activities that may precipitate falls. Possibly those with poorer function are driving the significant relationship observed, while those with higher function are responsible for the unexpected trend in magnitude of the hazard ratios. Additionally, those unable to complete the chair stand test did not have an increased hazard of fall-related injury, which was unexpected since this group is likely the most impaired. One potential

explanation is that this group's impairment may decrease their mobility, which could lead to decreased exposure to situations in which falls might occur. Further investigation of fall-related injury risk is needed in these groups.

Having a slow chair stand and a fall history together was not only associated with a greater incidence of injurious falls compared to having neither risk factor, but also compounded a person's risk of having an injurious fall compared to having either risk factor alone. This emphasizes the importance of assessing both fall history and functional performance when estimating risk for fall-related injury. Though there was some overlap in the confidence intervals for cumulative incidence in these risk groups, this is likely due to the relatively small number of participants in the slow chair stand and fall history risk group (n=35). Having only a positive fall history was also associated with a higher cumulative incidence of having an injurious fall compared to having neither risk factor. A slow chair stand without a positive fall history was associated with a marginally higher incidence, and was not significantly different than that of the low risk group, although this group may still include older adults with poor function who may be at future risk for injurious falls and other unfavorable outcomes. This group also had large confidence intervals likely due to fewer participants (n=49).

Once patients are stratified by basic risk factors, those identified as high risk should undergo a more comprehensive multifactorial risk assessments and treatment, if needed.[6,28] Multifactorial assessments and treatment of patients identified as high risk of falling can lead to a 30–40% reduction of falls.[29] Consistent with this multifactorial approach, we included additional risk factors for fall-related injury in our analysis and found that psychoactive medication use and depression were predictive, although they did not attenuate the effects of functional performance. More research is needed to evaluate whether multifactorial treatment strategies are similarly effective at preventing fall-related injuries.

A major strength of this study is the collection of longitudinal falls data through monthly calendars over a maximum follow-up of 4.3 years. For functional performance, we used previously defined cutpoints that have been validated in large populations of older adults, which may make them more generalizable.[10] We performed sensitivity analyses testing whether continuous chair rise time and gait speed predicted injurious falls, which they did not, supporting our findings of a threshold effect with chair rise time. We also performed a CART analysis, which determines the most predictive cutpoint from a continuous measure. This resulted in a similar cutpoint of 15.5s in chair rise time. A potential future direction is to determine the predictive validity of each of these cutpoints in a separate study population.

Given its direct relationship with poor health, function, and increased healthcare expenditures, our outcome of serious fall-related injury is particularly salient to older adults, the healthcare system, and the economy at large. Much of the literature focuses solely on falls, ignoring resulting injuries. Risk factors that are specific to or have more relative importance with regard to fall-related injuries are crucial to include in studies focusing on risk assessment and treatment.

Limitations to this study include that specific findings may be limited to community-dwelling older adults and may not be generalizable to other populations, such as institutionalized or frail older adults, or those with significant cognitive impairments. Due to the small number of participants in the slow chair stand, fall history group and the slow chair stand, no fall history group, we may have had insufficient power to fully detect differences in cumulative incidence of injurious falls between these and other groups. In addition, injurious falls risk was only assessed at baseline and we acknowledge that participants' functional status can fluctuate over time. However, our baseline assessment may help shed light on what can be predicted from a onetime medical assessment anywhere from 0 to 4 years down the line, as our figure illustrates. Finally, our analysis was designed to assess time to first injurious fall. An important future direction is to assess whether the SPPB or its components can stratify individuals at risk for multiple future injurious falls.

CONCLUSION

Our results show that the chair stand assessment predicts injurious falls and may have clinical utility when implementing a risk assessment and treatment strategies. This assessment is easy and quick to employ within a busy clinical practice. Our findings both support the use of current algorithms including measures of fall history and functional performance, and extend the use of these tools to risk estimation of fall-related injury. Estimation of injurious falls risk has particularly important implications for prevention of disability and mortality in older adults [30] and reducing healthcare utilization and expenditures.[4] Future studies should investigate the effectiveness of intervening on groups stratified by injurious falls risk and how treatment strategies should differ based on results from risk assessment.

Acknowledgments

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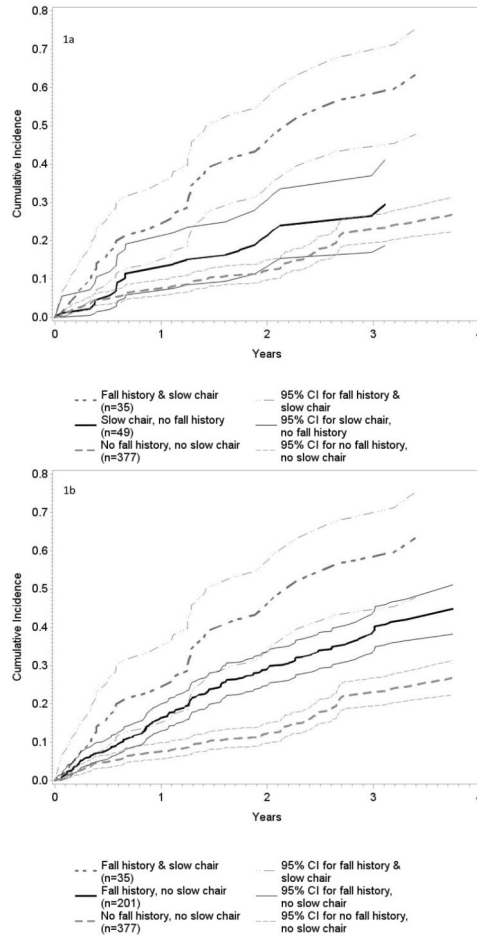
Figure 1.

Figures 1a-1b: Cumulative Incidence of Injurious Falls by Risk Groups

Figure 1a shows the cumulative incidence rates of injurious falls across 4 years for the slow chair stand, no fall history risk group and Figure 1b shows the cumulative incidence rates for the fall history, no slow chair stand risk group. Both figures additionally show the cumulative incidence rates of the fall history & slow chair risk group and the no fall history, no slow chair risk group for comparison. Bold lines represent cumulative incident rates and fine lines represent upper and lower bounds for 95% confidence intervals (CI) of the cumulative incidence rates.

Table 1

Hazard ratios for SPPB score, fall history, and falls efficacy predicting injurious falls

	Model 1: Without SPPB AIC= 2696.4 HR (95% CI)	Model 2: With SPPB AIC= 2699.1 HR (95% CI)
Fall History (yes vs. no)	1.82 (1.39–2.39)[*]	1.84 (1.40–2.42)[*]
Falls Efficacy Scale (per SD)	0.90 (0.80–1.02)	0.92 (0.81–1.04)
SPPB Score (1–12)		
1–3 vs. 4–6	--	0.63 (0.30–1.34)
1–3 vs. 7–9	--	0.89 (0.44–1.79)
1–3 vs. 10–12	--	0.98 (0.48–1.99)
4–6 vs. 7–9	--	1.39 (0.87–2.22)
4–6 vs. 10–12	--	1.53 (0.96–2.44)
7–9 vs. 10–12	--	1.10 (0.80–1.52)
Age	1.03 (1.00–1.05)[*]	1.02 (1.00–1.05)
Male sex	0.77 (0.58–1.03)	0.77 (0.58–1.03)
White race	1.61 (1.11–2.33)[*]	1.61 (1.11–2.33)[*]
Psychoactive drug use	1.76 (1.11–2.80)[*]	1.76 (1.11–2.80)[*]
Depression	1.60 (1.03–2.74)[*]	1.60 (1.03–2.47)[*]

[*] $p < 0.05$. SPPB = Short Physical Performance Battery; a greater score indicates better physical functioning. AIC = Akaike information criterion: lower values indicate better model performance. N= 32 (4.3%) for SPPB = 1–3, N = 68 (9.1%) for SPPB = 4–6, N = 204 (27.3%) for SPPB = 7–9, and N = 443 (59.3%) for SPPB = 10–12. Falls Efficacy Scale range: 1 (not at all confident) to 10 (extremely confident).

Table 2

Hazard ratios for SPPB component scores, fall history, and falls efficacy predicting injurious falls

	Model 1: Gait speed AIC=2697.7 HR (95% CI)	Model 2: Chair stands AIC=2309.5 HR (95% CI)	Model 3: Balance AIC=2670.4 HR (95% CI)
Fall History (yes vs. no)	1.80 (1.37–2.36)*	1.79 (1.33–2.40)*	1.79 (1.36–2.35)*
Falls Efficacy Scale (per SD)	0.93 (0.82–1.06)	0.93 (0.79–1.08)	0.91 (0.79–1.03)
SPPB Component Scores (1–4)			
1 vs. 2	0.61 (0.25–1.50)	1.96 (1.18–3.26)*	1.54 (0.87–2.75)
1 vs. 3	0.85 (0.35–2.06)	1.65 (1.07–2.55)*	1.08 (0.64–1.81)
1 vs. 4	1.01 (0.41–2.47)	1.60 (1.03–2.48)*	1.35 (0.82–2.22)
2 vs. 3	1.40 (0.87–2.26)	0.84 (0.54–1.31)	0.70 (0.43–1.15)
2 vs. 4	1.66 (1.05–2.63)*	0.81 (0.52–1.27)	0.88 (0.56–1.39)
3 vs. 4	1.19 (0.83–1.69)	0.97 (0.68–1.37)	1.26 (0.90–1.75)
Age	1.02 (1.00–1.05)	1.03 (1.01–1.06)*	1.03 (1.00–1.05)
Male sex	0.80 (0.60–1.07)	0.69 (0.50–0.94)	0.80 (0.60–1.07)
White race	1.67 (1.15–2.42)*	1.59 (1.07–2.38)*	1.50 (1.04–2.17)*
Psychoactive drug use	1.75 (1.10–2.79)*	1.87 (1.16–3.01)*	1.66 (1.04–2.64)*
Depression	1.58 (1.02–2.44)*	1.57 (0.93–2.64)	1.59 (1.03–2.47)*

*
 p<0.05. SPPB=Short Physical Performance Battery; greater scores indicate better physical function. AIC=Akaike information criterion; lower scores indicate better model performance. Falls Efficacy Scale range: 1 (not at all confident) to 10 (extremely confident). Balance: 1=held side-by-side stand for 10s and semi-tandem stand for <10s (N= 57, 7.7%); 2=held semi-tandem stand for 10s and full-tandem for 3s (N=96, 13.0%); 3=held full-tandem for >3s and <10s (N=156, 21.1%); and 4=held full tandem for 10s (N=430, 58.2%). Gait speed: 1=<0.46 m/s (N=21, 2.8%); 2= 0.46 and <0.65 m/s (N=70, 9.4%); 3= 0.65 and <0.83 m/s (N=140, 18.7%); and 4= 0.83 (N=516, 69.1%). Chair stand: 1=completed 5 in 16.7s (N=85, 12.8%); 2=completed 5 in 13.7 and <16.7s (N=129, 19.5%); 3=completed 5 in 11.2 and <13.7s (N=232, 32.7%), and 4=completed 5 in <11.2s (N=217, 32.7%).