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Association Between Short Physical Performance Battery and Falls in Older People: The Progetto Veneto Anziani Study

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Abstract

It is known that weakness in the lower limbs is associated with recurrent falls in old people. Among the tests routinely used to assess lower extremity strength, the Short Physical Performance Battery (SPPB) is one of those used most often, but its relationship with recurrent falls is poorly investigated. We aimed to determine if SPPB scores are related to recurrent falling in a sample of 2710 older-aged people, and to ascertain which test in the SPPB is most strongly associated with a higher rate of falls. In this cross-sectional study, we demonstrated that participants scoring 0–6 in the SPPB were more likely to be recurrent fallers than those scoring 10–12 (odds ratio [OR] = 3.46, 95% confidence interval [CI] 2.04–5.88 in women; OR = 3.82, 95% CI 1.77– 8.52, in men). SPPB scores of 7–9 were only associated with women being more likely to be recurrent fallers (OR = 2.03, 95% CI 1.28–3.22). When the SPPB items were analyzed separately, even a lower score in gait speed for women was significantly associated with the presence of recurrent falls (OR = 2.11; 95% CI 1.04–4.30), whereas in men only a significant increase in the time taken to complete the five timed chair stands test was associated with a higher rate of falls (OR = 2.75; 95% CI 1.21–6.23). In conclusion, our study demonstrated that SPPB scores ≤ 6 are associated with a higher fall rate in old people of both genders; in females, even an SPPB score between 7 and 9 identifies subjects at a higher likelihood of being recurrent fallers. Among the single items of the SPPB, the most strongly associated with falls were gait speed in women and the five timed chair stands test in men.

Introduction

The risk of elderly people falling increases with age. Approximately 30% of people aged 65 years or older fall at least once a year, and about 15% of them experience more than one fall, with increasing disability and mortality rates related to hip fractures.[1–4] The risk of falling has been related to a number of factors, such as muscle weakness, gait and balance deficits, visual impairments, fear of falling, cognitive deterioration, depression, age, nutritional deficits, and other co-morbidities.[5,6] Older people are characterized by a higher incidence of falling compared to adults and a high susceptibility to injury,[7] leading to an increasing need to identify individuals at higher risk of falling repeatedly as soon as possible to take appropriate fall prevention measures and thereby prevent or delay the onset of disability.[7,8]

It is well known that balance disorders and weakness in the lower limbs are associated with recurrent falls in old people,[9,10] and several studies have confirmed that poor physical performance increases the risk of falling. People who experience recurrent falls also do not perform well in the tests commonly used to assess motor function.[10–15] Many different physical performance tests are believed to be sensitive to falling risk, and several research groups have investigated combinations of tests with a view to producing batteries of tests for addressing fall risk in the elderly.[16–18] Such a battery for assessing the risk of falls in a population

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of active elderly people should test both static and dynamic balance, as well as lower limb strength and gait speed. In many cases, falls are caused by a loss of balance during walking (dynamic balance) or the inability to maintain the body's center of gravity over its base of support (static balance). Lower limb muscle strength plays an important role in being essential for both static and dynamic balance.[19]

Among the several tests routinely used to assess lower extremity strength, the Short Physical Performance Battery (SPPB) is one of the those most often used with older-aged subjects. It consists of three simple motor tests (tandem tests, five timed chair stands, and a gait speed measurement) that provide information on several motor domains such as static and dynamic balance, coordination, and strength of lower limbs.[20]

Although poor scores in the SPPB have been associated with an increased short- and long-term disability risk,[21,22] very few studies have investigated the relationship between SPPB levels and the frequency of falls.[23,24] To our knowledge, moreover, no published studies have analyzed the association between falls and the impact of each separate SPPB test. The aims of the present study were: First, to verify in a large sample of older-aged people the relationship between SPPB and recurrent falling, and, second, to investigate which of the tests included in the SPPB tool is most strongly associated with recurrent falls, after controlling for a wide number of possible confounders.

Methods

Data source and subjects

The data for this analysis came from the Progetto Veneto Anziani (Pro.V.A.), an observational cohort study of the Italian population aged ≥ 65 years, living in two geographical areas in the northeast of Italy (Camposampiero and Rovigo). The study population included 3099 age- and sex-stratified Caucasian participants (1245 men and 1854 women), who were randomly selected between 1995 and 1997, using a multistage stratified method. Sampling procedures and data collection methods have been described elsewhere.[25]

For the present study, participants with a history of hip fracture ($n = 116$) and those with disabilities in the activities of daily living (ADL) ($n = 273$) severe enough to limit their completion of the physical performance tests were excluded. The final sample consisted of 2710 subjects. The local ethical committees at Padua University and the Veneto Region's Local Public Health Units (ULSS) no. 15 and no. 18 approved the study protocol, and participants gave their written informed consent. Subjects unable to give their informed consent were not enrolled.

Clinical and laboratory data

Participants were examined at the city hospitals by trained physicians and nurses. Information was collected during a face-to-face individual interview on their physical activity, alcohol drinking, smoking, number and types of drugs taken, and fear of falling. Regular physical activity was defined as ≥ 4 hr/week in the previous month of at least moderate physical activity (brisk walking, biking, gardening, dancing, or other physical exercise). Smoking status was categorized as ''never/former'' (for at least 1 year in the past) versus ''current'' smokers. Body weight and height were measured by trained physicians, and body mass index (BMI, kg/m^2) was calculated. Any diseases at the baseline were assessed by board-certified physicians involved in the study, who examined all of the clinical information collected for each participant, including disease history, self-reported symptoms (using standardized questionnaires), medical and hospital records, blood tests, and a physical examination. Previous major diseases included any of the following: Visual impairments, cardiovascular diseases (CVD; congestive heart failure, angina and myocardial infarction, stroke, or peripheral artery disease), diabetes, chronic pulmonary diseases (COPD), cancer, hand/knee/hip osteoarthritis, and osteoporosis. Orthostatic hypotension was defined as a drop of at least 20 mmHg in systolic blood pressure (SBP), or at least 10 mmHg in diastolic blood pressure (DBP) within 3 min of standing up.[26] Cognitive function was assessed by administering the 30-item Mini-Mental State Examination (MMSE).[27] Depression was assessed using the Geriatric Depression Scale, and a score of ≥ 11 was indicative of the presence of depressive symptoms.[28] Disability was defined as the inability or the need for assistance to perform one or more of the ADLs—bathing, dressing, eating, using the toilet, or transferring.

Venous blood samples were obtained after an overnight fast, centrifuged, and stored at $-80°C$. 25-Hydroxyvitamin D (25OHD) and parathyroid hormone (PTH) tests were performed at the university laboratory in Padua. Serum 25OHD levels were measured by radioimmunoassay (RIA kit; DiaSorin). The intra-assay and inter-assay coefficients of variation for 25OHD were 8.1% and 10.2%, respectively. Serum intact PTH levels were measured using a two-site immunoradiometric assay kit (N-tact PTHSP; DiaSorin); the intra-assay and inter-assay coefficients of variation for PTH were 3.0% and 5.5%, respectively. Serum albumin was measured using an agarose electrophoretic technique (Hydragel Protein(E) 15/30; Sebia, France).

Falls definition and assessment

A fall was defined as ''an event that results in a person coming to rest unintentionally on the ground or a lower level, not due to a major intrinsic event (such as a stroke) or overwhelming hazard.''[3] The assessment of falls was performed only by physicians expert in geriatric medicine during the baseline examination through a person-by-person interview and also involving the relatives of the participants. Any medical documentation on falls outcomes (*e.g.*, access to emergency department or to health care physician) with date and time of falls was also recorded, and the self-reported falls during the 12 months preceding the interview were considered as part of the medical history review. Recurrent fallers were defined as individuals who had experienced more than one fall, and non-fallers as those who had suffered one or no falls during the previous year.

Physical performance measures

Physical performance measures were assessed by means of standardized performance tests, as described in other works in the Pro.V.A. setting[29]:

- Gait speed. The best performance achieved in two walks at the participant's usual pace along a corridor 4 meters long was recorded in meters/sec. Participants were allowed to use canes or walkers. The scores and corresponding cutoffs were: ≤0.42 meter/sec (1 point); between 0.42 and 0.58 meter/sec (2 points); between 0.58 and 0.75 meter/sec (3 points); more than 0.75 meter/sec (4 points);
- Five timed chair stands (coordination and strength). Participants were asked to stand up and sit down five times as quickly as possible, with their hands folded across their chest. The time taken to complete the test, in seconds, was recorded and interpreted as follows: ≥16.7 sec (1 point), between 13.7 and 16.7 sec (2 points), between 13.7 and 11.2 (3 points), less than 11.2 sec (4 points);
- Tandem test (static balance ability). Participants were asked to maintain their balance in three different positions, *i.e*., a side-by-side position (SBS), a semi-tandem position (ST), and a full-tandem position (FT). The amount of time they succeeded in remaining in the various positions, in seconds, was recorded using the following criteria: Side-by-side 10 sec, <10 sec semi-tandem (1 point); semi-tandem 10 sec, tandem 0–2 sec (2 points); semi-tandem 10 sec, tandem 3–9 sec (3 points); tandem 10 sec (4 points).

Individuals received a score of 0 for each task they were unable to complete. Scores of 1–4 for each task were awarded on the basis of quartiles of performance for more than 5000 participants in the Established Populations for the Epidemiologic Study of the Elderly.[30,31] Adding together the three individual category scores gave a summary performance score for each participant (range, 0–12), with higher scores indicating a better lower body function. For our purposes, as in Guralnick et al.,[20] the SPPB scores were grouped into three classes: ≤6, from 7 to 9, and >9.

Statistical analyses

Participants' characteristics were summarized using means (±standard deviations [SD]) for continuous variables, and counts and percentages for categorical variables. Means and proportions were compared between study participants according to their SPPB score categories: Poor performers scoring 0–6, moderate performers scoring 7–9, and good performers scoring 10–12. For continuous variables, normal distributions were tested using the Shapiro–Wilk test. Age-adjusted p values for trends were calculated, checking the differences between the means of the covariates by SPPB score category using analysis of variance (ANOVA). Differences in category variables were examined using the chi-squared test. Given the gender-related differences in physical performance, all data analyses were stratified by sex.

Multivariate logistic regression models were run using SPPB score categories as independent variables, and the odds ratios (ORs) and 95% confidence intervals (95% CI) relating to the likelihood of being recurrent fallers were calculated for each SPPB score group, taking the better performance category as the reference group. In secondary analysis, the ORs and 95% CIs relating to the likelihood of being recurrent fallers were obtained for each SPPB item, taking the better performance levels as the reference group. Known factors associated with falls and/or physical functionality were examined for inclusion in the analyses as covariates, obtaining two multivariate models. A stepwise selection was performed to obtain the most effective set of variables in predicting the dependent variable. Model 1 included age, BMI (calculated as weight in kg/height in meters squared), physical activity (defined as ≥4 hr/week in the previous month of at least moderate physical activity, *e.g*., brisk walking, cycling, swimming, dancing, gardening or other physical exercise), visual impairment, cognitive impairment (Indexed MMSE score <0.8),[27] depression (defined as a score ≥11 on the Geriatric Depression Scale),[32] diagnoses of CVDs (coronary heart disease, congestive heart failure, cerebrovascular disease, peripheral artery disease, hypertension, stroke), diabetes, COPD, musculoskeletal diseases (including hand/knee/hip osteoarthritis and osteoporosis), cancer, orthostatic hypotension, alcohol drinking, number of drugs, and serum 25OHD levels added as confounders in the first model. Model 2 included all variables considered in model 1 plus disability in ADL and fear of falling. PTH serum levels were also initially considered for inclusion in the analysis, but they were subsequently removed from the models because of the high collinearity with the 25OHD levels, as quantified by the variance inflation factor (VIF).

All analyses were performed using the SPSS version 17.0 for Windows (SPPS Inc., Chicago, IL). All statistical tests were two-tailed, and statistical significance was assumed for a p value <0.05.

Results

The study sample consisted of 2710 community-dwelling elderly subjects, comprising 1594 women aged 75.1 years (±7.2; range 65–97 years) with a mean SPPB score of 7.79±3.22 (range, 1–12) and 1116 men aged 75.8 years (±7.6; range, 65–97) with a mean SPPB score of 9.03 (±3.12; range, 1–12). The proportion of these individuals reporting at least one fall over the previous year was 32.5% among women and 22.2% among men (chi-squared test, $p<0.001$).

Participants' characteristics according to the SPPB score categories (poor performers scoring 0–6, moderate performers scoring 7–9, and good performers scoring 10–12) are shown in Tables 1a and 1b, for women and men, respectively. In both genders, participants in the lowest SPPB score category were significantly older than those in the group with the highest scores (p for trend <0.001). After adjusting for age, both male and female participants in the lowest SPPB score group were significantly more disabled and less active, and had more co-morbidities. Compared with participants with SPPB scores of 10–12, those with SPPB scores ≤6 were more likely to be recurrent fallers (23.9% vs. 5.1% in women, and 23.2% vs. 7.9% in men, $p<0.001$ in both groups).

Logistic regression analysis (Table 2) showed that both male and female participants scoring 0–6 in the SPPB were more likely to be recurrent fallers (OR=3.46, 95% CI 2.04–5.88, $p<0.001$ in women, and OR=3.82, 95% CI 1.77–8.52, $p<0.001$ in men) than the participants scoring from 10 to 12. In women, a SPPB score between 7 and 9 was associated to a higher presence of recurrent falling (OR=2.03, 95% CI

Table 1a. Participants' Baseline Characteristics by SPPB Score Categories in Females (the Pro.V.A. Study)

	SPPB score 0–6 (n = *453*)	*SPPB score 7–9* (n = *545*)	*SPPB score 10–12* (n = *596*)	*Age-adjusted* p *value*
Age (years)	80.12 (6.96)	75.03 (6.42)	71.29 (5.43)	< 0.001[a]
BMI (kg/m^2)	28.27 (5.53)	28.51 (4.77)	27.75 (4.53)	< 0.001
Medical conditions				
Cognitive impairment (%)	16.6	2.0	0.3	< 0.001
Diabetes (%)	21.6	19.1	11.1	< 0.001
CVD (%)	27.6	15.4	8.2	< 0.001
COPD (%)	5.1	6.1	3.7	0.38
Cancer (%)	6.6	8.4	5.5	0.52
Depression (%)	55.6	45.0	32.2	< 0.001
Musculoskeletal disease (%)	77.7	66.4	56.4	< 0.001
Orthostatic hypotension (%)	38.0	35.9	26.8	0.008
Visual impairment (%)	35.2	28.9	20.7	0.10
Regular physical activity (%)	5.1	19.3	24.8	< 0.001
Number of drugs taken	3.74 (2.26)	2.87 (1.96)	2.31 (1.86)	< 0.001
Alcohol drinking (%)	59.2	57.1	63.1	0.001
Current smokers (%)	1.8	4.4	6.5	0.43
25OHD (nmol/L)	49.97 (32.07)	67.13 (39.99)	77.39 (44.46)	< 0.001
PTH (ng/L)	53.19 (30.00)	41.45 (27.25)	39.20 (19.51)	0.47
ADL disability (%)	34.4	5.1	0.3	< 0.001
SPPB (0–12)	3.44 (2.13)	8.17 (0.80)	10.75 (0.74)	< 0.001
Gait speed (meters/sec)	0.52 (0.18)	0.72 (0.14)	0.84 (0.16)	< 0.001
Five timed chair stands (sec)	20.93 (10.91)	14.52 (6.00)	10.42 (1.85)	< 0.001
Full tandem test (sec)	5.66 (3.36)	7.79 (3.05)	9.51 (1.57)	< 0.001
Falls items				
Fear of falling (%)	36.6	35.0	28.4	< 0.001
Recurrent fallers (%)	23.9	8.3	5.1	< 0.001

Numbers are mean values (and standard deviations) or percentages (%), as appropriate.
[a]Not adjusted for age. Unless otherwise specified, p values are based on an age-adjusted general linear model or logistic regression, as appropriate.
Pro.V.A. Study, Progetto Veneto Anziani Study; SPPB, Short Physical Performance Battery; BMI, body mass index; CVD, cardiovascular diseases; COPD, chronic obstructive pulmonary disease; 25OHD, serum 25-hydroxyvitamin D; PTH, parathyroid hormone; ADL, activities of daily living.

1.28–3.22; $p = 0.002$) compared to women in the highest SPPB category.

When the motor performance tests were considered separately (Table 3), logistic regression analysis showed that women with a gait speed of less than 0.75 meter/sec were most likely to be recurrent fallers than women with higher gait speed, even after controlling for potential confounders (OR = 2.11, 95% CI 1.04–4.30, $p = 0.04$), whereas this association was not significant in men. Taking longer than 16.7 sec to complete the five timed chair stands test (*i.e.*, obtaining the worst score considered here for this test) was significantly associated with recurrent falls, in both genders (OR = 1.94, 95% CI 1.13–3.32, $p = 0.02$ in women; OR = 2.75, 95% CI 1.21–6.23, $p = 0.02$ in men). Finally, inability to maintain a semi-tandem position for more than 10 sec was associated with recurrent falls in women only (OR = 2.33; 95% CI 1.33–4.09, $p = 0.003$).

Discussion

The results of the present study support an association between performance levels as assessed by the SPPB and falls in old people, underscoring this tool's potential for identifying recurrent fallers. The prevalence of fallers in our population was 28.3%, whereas in reports in the literature it ranges between 35% and 40%.[3,33] The difference probably stems from our exclusion of individuals with severe physical impairments, precluding their completion of the SPPB and giving rise to a lower falls rates than might be expected in the general elderly population. This impression is supported by the higher mean difference in SPPB scores between fallers and non-fallers (7.39 ± 3.41 vs. 8.66 ± 3.10, $p < 0.001$) by comparison with a previous study involving a group of older people (5.9 ± 3.1 vs. 7 ± 2.3, $p = 0.167$).[34]

The SPPB score once again was found to provide a good indication of global frailty in old people and seems to be a simple and reliable method for identifying people of both genders who fall frequently. To our knowledge, there is little in the literature on the association between falls and SPPB scores, but our findings are consistent with another two studies involving smaller groups of old people.[23,24]

In our logistic regression analysis, both male and female participants with a SPPB score under 6 were three-fold at greater likelihood of being recurrent fallers, compared to subjects scoring from 10 to 12 with the SPPB tool. Among women, even lower SPPB scores (from 7 to 9) were associated with a higher probability of being a recurrent faller. A possible reason why women fall more frequently than men,

Table 1b. Participants' Baseline Characteristics by SPPB Score Categories in Males (the Pro.V.A. Study)

	SPPB score 0–6 (n = 197)	*SPPB score 7–9 (n = 254)*	*SPPB score 10–12 (n = 665)*	*Age-adjusted p value*
Age (years)	82.43 (7.46)	78.61 (7.10)	72.80 (6.04)	< 0.001[a]
BMI (kg/m^2)	26.61 (4.17)	26.69 (4.16)	26.95 (3.60)	0.02
Medical conditions				
Cognitive impairment (%)	15.2	4.3	0.9	< 0.001
Diabetes (%)	14.2	16.1	14.4	0.56
CVD (%)	38.1	34.3	21.2	< 0.001
COPD (%)	24.4	21.7	10.1	< 0.001
Cancer (%)	13.7	7.5	7.5	0.10
Depression (%)	48.7	33.1	18.2	< 0.001
Musculoskeletal disease (%)	53.8	39.0	27.1	< 0.001
Orthostatic hypotension (%)	41.4	31.0	23.7	< 0.001
Visual impairment (%)	36.6	26.0	23.6	0.05
Regular physical activity (%)	18.3	38.6	38.8	< 0.001
Number of drugs taken	3.45 (2.20)	2.89 (2.25)	1.97 (1.88)	< 0.001
Alcohol drinking (%)	78.2	82.7	87.2	0.004
Current smokers (%)	9.6	18.9	18.2	0.44
25OHD (nmol/L)	79.01 (52.20)	91.15 (60.48)	115.07 (62.79)	< 0.001
PTH (ng/L)	42.13 (22.03)	42.57 (30.78)	35.11 (18.02)	0.48
ADL disability (%)	34.5	3.5	0.3	< 0.001
SPPB (0–12)	3.32 (2.18)	8.09 (0.81)	11.07 (0.74)	< 0.001
Gait speed (meters/sec)	0.54 (0.17)	0.76 (0.15)	0.92 (0.16)	< 0.001
5 timed chair stands (sec)	21.47 (19.29)	14.19 (3.51)	10.16 (7.88)	< 0.001
Full tandem test (sec)	5.68 (3.66)	8.01 (3.10)	9.78 (1.08)	< 0.001
Falls items				
Fear of falling (%)	37.3	29.6	33	< 0.001
Recurrent fallers (%)	23.2	13.6	7.9	< 0.001

Numbers are mean values (and standard deviations) or percentages (%), as appropriate.

[a]Not adjusted for age. Unless otherwise specified, *p* values are based on an age-adjusted general linear model or logistic regression, as appropriate.

Pro.V.A. Study, Progetto Veneto Anziani Study; SPPB, Short Physical Performance Battery; BMI, body mass index; CVD, cardiovascular diseases; COPD, chronic obstructive pulmonary disease; 25OHD, serum 25-hydroxyvitamin D; PTH, parathyroid hormone; ADL, activities of daily living.

even when the former's physical performance is better than the latter's, probably relates to the well-known differences in body composition and physical structure between the two genders. Women have a higher fat mass ratio than men, and less muscle mass, and their different fat distribution and consequently different center of gravity also make it easier for women to fall.[35–37]

Analyzing our data for each SPPB item, lower gait speed, however modest, seemed to be the most sensitive factor for pinpointing recurrent fallers among women, followed by the

Table 2. Odds Ratios and 95% Confidence Intervals for Falls by Gender and SPPB Score Categories in Pro.V.A Study Participants

	Females				*Males*			
	Model 1		*Model 2*		*Model 1*		*Model 2*	
	OR (95%CI)	p *value*	*OR (95% CI)*	p *value*	*OR (95% CI)*	p *value*	*OR (95% CI)*	p *value*
SPPB score 10–12	- (reference)		- (reference)		- (reference)		- (reference)	
SPPB score 7–9	2.11 (1.34–3.33)	0.001	2.03 (1.28–3.22)	0.002	1.87 (0.93–3.75)	0.08	1.64 (0.81–3.35)	0.17
SPPB score 0–6	4.19 (2.52–6.40)	< 0.001	3.46 (2.04–5.88)	< 0.001	5.61 (2.78–11.29)	< 0.001	3.82 (1.77–8.52)	< 0.001

Model 1 was adjusted for age, BMI, regular physical activity, medical conditions (visual or cognitive impairments, diabetes, CVD, COPD, cancer, depression, musculoskeletal diseases, orthostatic hypotension), alcohol drinking, number of drugs taken, serum 25OHD levels. Model 2 was adjusted for variables in Model 1 plus disability in ADL and fear of falling.

Pro.V.A. Study, Progetto Venbeto Anziani Study; SPPB, Short Physical Performance Test; OR, odds ratio; CI, confidence interval; BMI, body mass index; CVD, cardiovascular disease; COPD, chronic obstructive pulmonary disorder; 25OHD, serum 25-hydroxyvitamin D; ADL, activities of daily living.

Table 3. Odds Ratio and 95% Confidence Intervals for Falls by Gender and Performance Levels for Each Item in the SPPB in Pro.V.A Study Participants

	Females				*Males*			
	Model 1		*Model 2*		*Model 1*		*Model 2*	
	OR (95% CI)	p *value*	*OR (95% CI)*	p *value*	*OR (95% CI)*	p *value*	*OR (95% CI)*	p *value*
Gait speed								
> 0.75 meters/sec	- (reference)		- (reference)		- (reference)		- (reference)	
> 0.58 and ≤ 0.75 meters/sec	2.19 (1.08–4.44)	0.03	2.11 (1.04–4.30)	0.04	0.95 (0.44–2.03)	0.89	0.95 (0.44–2.04)	0.89
> 0.42 and ≤ 0.58 meters/sec	3.30 (1.61–6.73)	0.001	2.99 (1.45–6.13)	0.003	2.15 (0.94–4.91)	0.07	1.79 (0.76–4.19)	0.18
≤ 0.42 meters/sec	6.12 (2.78–13.48)	< 0.001	4.67 (2.08–10.52)	< 0.001	3.49 (1.31–9.35)	0.01	2.13 (0.74–6.14)	0.16
Five timed chair stands								
< 11.2 sec	- (reference)		- (reference)		- (reference)		- (reference)	
≥ 11.2 and < 13.7 sec	1.35 (0.82–2.22)	0.25	1.31 (0.79–2.16)	0.30	0.96 (0.42–2.18)	0.92	0.96 (0.42–2.19)	0.92
≥ 13.7 and < 16.7 sec	1.63 (0.94–2.83)	0.08	1.52 (0.87–2.64)	0.14	1.51 (0.66–3.44)	0.33	1.44 (0.63–3.30)	0.39
≥ 16.7 sec	2.33 (1.38–3.93)	0.001	1.94 (1.13–3.32)	0.02	3.33 (1.51–7.38)	0.003	2.75 (1.21–6.23)	0.02
Tandem test								
FT ≥ 10 sec	- (reference)		- (reference)		- (reference)		- (reference)	
FT > 2 sec and < 10 sec	1.28 (0.80–2.05)	0.30	1.27 (0.79–2.03)	0.33	1.25 (0.48–3.22)	0.65	1.12 (0.43–2.95)	0.81
ST ≥ 10 sec and FT ≤ 2 sec	1.05 (0.63–1.76)	0.85	0.95 (0.56–1.61)	0.85	3.15 (1.54–6.43)	0.002	2.63 (0.94–5.43)	0.14
SBS ≥ 10 sec and ST < 10 sec	2.73 (1.58–4.73)	< 0.001	2.33 (1.33–4.09)	0.003	3.00 (1.18–7.63)	0.02	2.06 (0.77–5.47)	0.15

Model 1 was adjusted for age, BMI, regular physical activity, medical conditions (visual or cognitive impairments, diabetes, CVD, COPD, cancer, depression, musculoskeletal diseases, orthostatic hypotension), alcohol drinking, number of drugs taken, serum 25OHD levels. Model 2 was adjusted for variables in model 1 plus disability in ADL and fear of falling.

Pro.V.A. Study, Progetto Veneto Anziani Study; SPPB, Short Physical Performance Battery; OR, odds ratio; CI, confidence interval; SBS, side-by-side stance; ST, semi-tandem stance; FT, full tandem test; BMI, body mass index; CVD, cardiovascular diseases; COPD, chronic obstructive pulmonary disease; 25OHD, serum 25-hydroxyvitamin D; PTH, parathyroid hormone; ADL, activities of daily living.

tandem test and the five timed chair stands. Our findings are supported by other work reporting a significant difference in gait speed between fallers and non-fallers. A gait speed of less than 1 meter/sec had already been associated with an increased risk of falls.[38] For women, but not for men, a slower gait speed seems to be the strongest indicator of those who are more likely to fall, even if their global SPPB scores are in the medium to high range. Women probably have a higher incidence of arthritis and foot disorders, such as hammer toe, that affect gait and balance, predisposing them to falls.[39,40] Older men's declining gait speed is probably compensated by their better balance control than in women, so the influence of a loss of muscle strength is predominant in the association with falls. This assumption is supported by the finding, here again in women, but not in men, that inability to maintain a semi-tandem position for more than 10 sec, or a full tandem position for more than 2 sec, related to more frequent falls. The full tandem position is considered a key factor in older adult falls because it tests lateral postural stability by narrowing the base of support.[41–43]

In men, gait speed was not associated *per se* with falls. Among the tests included in the SPPB tool, the five timed chair stands test seems to be most strongly related to a higher presence of being recurrent faller. This test is highly associated to the gradual age-related decline in muscle mass and sarcopenia, which in turn correlate with both loss of muscle coordination and impaired postural balance, and a consequently increasing risk of falls.[44] Loss of muscle strength and power is a normal aspect with aging, and up to 50% of the overall decline in muscle strength from 30 to 80 years of age involves the lower limbs.[45] According to previous investigations, fall rates have been found associated with chair standing performance in both genders.[46–48] In active elderly men, on the other hand, only a severely impaired performance in the three motor tests in the SPPB seems to be associated with recurrent falls.

The present study has limitations that need to be mentioned. First, the use of a self-reported recall of falling might lead to an under-reporting of milder events. Nevertheless, bearing in mind that recording of falls was accurate, because we derived it from a cross-check between the medical documents with self-reported falls (by patients and caregivers), we can assume that this bias would be limited.

Second, the cross-sectional design of the study prevents us from establishing the causality between poor physical performance and falling rates. In other words, recurrent fallers might be expected to have a worse physical performance in the SPPB than non-fallers due to their fear of falling. On the other hand, our analyses were all controlled for a large number of adjudicated diseases and confounders, including regular physical activity and the fear of falling. Another strength of our study lies in its population-based design and large sample size, comprising men and women representative of the general community-dwelling older population.

In conclusion, our findings show that very low SPPB scores are associated with a higher rate of falls among community-dwelling old people of either gender, and for women a SPPB score between 7 and 9 identifies recurrent fallers subjects. Among the single items in the SPPB, those most strongly related to recurrent falls are gait speed in women and the five timed chair stands in men.

SPPB has been shown to be a reliable tool in the assessment of falls in older subjects. Thus, the use of this test should be implemented in the clinical setting because it is easy to use, short, and standardized. Interventional trials on subjects with low SPPB scores might clarify whether physical training focusing on general physical performance or on the single SPPB items might reduce the risk of falling.

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