

## RESEARCH PAPER

# Mobility screening for fall prediction in the Canadian Longitudinal Study on Aging (CLSA): implications for fall prevention in the decade of healthy ageing

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## Abstract

**Background:** Guidelines for fall prevention in older adults recommend mobility screening for fall risk assessment; however, there is no consensus on which test to use and at what cutoff. This study aimed to determine the accuracy and optimal cut-off values of commonly used mobility tests for predicting falls in the Canadian Longitudinal Study on Aging (CLSA).

**Methods:** Mobility tests at baseline included the Timed Up and Go (TUG), Single Leg Stance (SLS), chair-rise and gait speed. Inclusion criteria were: age  $\geq 65$  years and meeting first-level fall screening criteria (i.e. history of a fall or mobility problem) at baseline. Accuracy of fall prediction at 18-months for each test was measured by the area under the receiver operating curve (AUC).

**Results:** Of 1,121 participants that met inclusion criteria (mean age  $75.2 \pm 5.9$  years; 66.6% women), 218 (19.4%) reported  $\geq$  one fall at 18 months. None of the tests achieved acceptable accuracy for identifying individuals with  $\geq$  one fall at follow-up. Among women 65–74 and 75–85 years, the TUG identified recurrent fallers ( $\geq$  two falls) with optimal cut-off scores of 14.1 and 12.9 s (both AUCs 0.70), respectively. Among men 65–74 years, only the SLS showed acceptable accuracy (AUC 0.85) for identifying recurrent fallers with an optimal cutoff of 3.6 s.

**Conclusions:** Our findings indicate that commonly used mobility tests do not have sufficient discriminability to identify fallers in a population-based sample of community-dwelling older adults. The TUG and SLS can identify recurrent fallers; however, their accuracy and cut-off values vary by age and sex.

**Keywords:** accidental falls, CLSA, clinical practice guideline, cut-off values, physical performance measures, older people

## Key Points

- Performance-based tests of mobility and balance are recommended for fall risk assessment in community-dwelling older adults.
  - There is no consensus on which mobility test and cutoff to use to identify older adults at the highest risk of falling.
  - TUG, SLS, chair-rise and gait speed test lack predictive accuracy for identifying older adults at risk for 1 fall over 18 months.
  - Mobility screening, alongside other fall risk factors, may have a role in identifying older adults at risk for multiple falls.
  - The optimal mobility screening test for fall risk assessment varies by age and sex in community-dwelling older adults.
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## Introduction

Falls remain a costly problem in older adulthood. In Canada, the direct cost of falls in older adults is \$3.3 billion a year [1, 2], and in England, the estimated annual cost for the NHS is more than £2.3 billion per year [3]. Almost half of older adults who fall experience moderate to severe injuries, which increases their risk of disability, institutionalisation and death [2, 4]. Fall risk increases with age, and the risk of falls and fall-related injury is consistently higher among women than men [2, 5]. Given the devastating burden of falls, and that the number of adults over the age of 65 will double in the next 20 years, it is not surprising that the World Health Organization's Decade of Healthy Aging Report has highlighted fall prevention as an urgent global health priority [6, 7].

Clinical practice guidelines developed by international organisations aid in fall risk assessment and prevention in community-dwelling older adults [8–10]. Common to each guideline is a first-level screening process designed to determine if further assessment and intervention are warranted. The first step involves asking older adults if they have fallen in the previous year or feel unsteady with standing or walking. [8, 10] If an older adult answers yes to either question, the health provider must screen for mobility and balance problems using a performance-based test. If performance on the test is below a pre-specified cut-off value, the older adult is considered at high risk of falling and should be referred for multifactorial fall risk assessment and intervention.

One of the barriers to implementing routine mobility screening for fall risk assessment in older adults is a lack of consensus on which test to use and at what cut-off value an individual should be deemed at risk of falls. This issue was recently identified by a worldwide task force as a top ten priority for international fall prevention and management research [11]. Few prospective studies have examined the predictive accuracy of mobility tests for falls; results to date have been equivocal at best with many commonly used tests demonstrating sub-optimal accuracy [12–15]. These findings may be due, in part, to the lack of consideration of age and sex in existing research on mobility screening for fall risk assessment. The Canadian Longitudinal Study on Aging (CLSA) includes four of the most commonly used mobility tests for fall risk screening (Timed Up and Go, Single Leg Stance, Gait Speed and Chair-Rise) and has a sample large enough to accommodate age and sex-stratified analyses. Therefore, the objective of this study is to determine the accuracy and optimal cut-off values of commonly used mobility tests as part of the fall risk assessment process in different age and sex strata among community-dwelling older adults in the CLSA.

## Methods

### Study sample

The CLSA is a population-based prospective cohort study of over 50,000 community-dwelling men and women aged 45–85 years from across Canada; details of the CLSA are provided elsewhere [16, 17]. Briefly, of the 51,338 participants, 30,097 provided core information through in-home interviews (CLSA Comprehensive). Within 2–3 weeks of their home visit, participants in the CLSA Comprehensive also underwent detailed physical assessments at one of 11 data collection sites. Approximately 18 months after the baseline assessment, a maintaining contact questionnaire (MCQ) was implemented via telephone to collect additional data. In this analysis, we used baseline physical assessment data of individuals  $\geq 65$  years ( $n = 12,646$ ) from the CLSA Comprehensive, and data on falls from the MCQ at 18 months for participants who had at least 12 months between the baseline visit and the MCQ. In line with current fall prevention guidelines, we included participants who reported an injury from a fall in the previous 12 months at baseline or reported difficulty with mobility during activities of daily living (i.e. required assistance with walking, transferring, community mobility, shopping or housework).

### Performance-based mobility tests

Mobility tests were collected in the baseline data collection visit using standard operating procedures (<https://www.clsa-elcv.ca/researchers/physical-assessments>). Each test had pre-specified contraindications to ensure participant safety (e.g. walking tests were not performed if a participant required assistance to stand/walk); therefore, the total number of participants who completed each test varied.

- 1) The *Single Leg Stance Test (SLS)* requires participants to: place their hands on their hips, lift one foot off the floor, and hold the position up to a maximum of 60 s. Higher times indicate better balance [18]. The SLS has excellent reliability in older adults [19–21]; however, studies on predictive validity are limited.
- 2) The *Timed Up and Go (TUG)* [22] is a widely used measure of balance and functional mobility in older adults [23, 24], and the most commonly suggested tool in fall risk guidelines [8, 10]. Participants are timed while they: stand up from a chair, walk 3 m, turn 180°, walk back to the chair and sit down. The TUG has excellent reliability in community-dwelling older adults.<sup>14,38</sup> Evidence on the predictive validity of the TUG in community-dwelling older adults has been mixed [12].
- 3) The *5-repetition chair-rise test* is the most commonly used chair-stand test for measuring fall risk and is considered a measure of both balance and lower body function [25, 26]. Participants are asked to stand up and sit down from a chair five times as quickly as possible. It has some evidence of predictive validity for falls; however,

no cut-off scores have been established [13–15].

- 4) The *4-m gait speed* test measures walking speed over 4 m at participants' usual pace. Although it has excellent predictive validity for other health outcomes, gait speed has shown inconsistent results for predicting falls [27, 28].

### Falls assessment

Participants were asked at follow-up to recall falls in the previous year that resulted in limitations to their normal activities using the question: 'In the past 12-months did you have any falls?' The response options were yes or no. If they responded yes, participants were also asked 'How many times have you fallen in the past 12-months?' Individuals who reported one or more falls were classified as a faller. A subgroup of fallers with  $\geq 2$  falls were considered recurrent fallers.

### Covariates

To enable meaningful comparison with previous work, we considered other fall risk factors based on their inclusion in fall prevention guidelines or if they were consistently cited as a fall risk factor in the literature [2, 29–31]. The following measures were included as covariates in our adjusted analysis: age, sex, depression (score  $\geq 10$  on the Center for Epidemiologic Studies Short Depression Scale (CES-D)), cognitive impairment (mental alteration test (MAT) score of  $< 35$ ), fair or poor self-rated vision, secondary or less education, moderate or severe self-rated pain, urinary incontinence and use of psychotropic medication.

### Statistical analysis

Descriptive analysis was presented as frequencies, percentages, means and standard deviations (SD) stratified by age and sex. We examined the accuracy of each mobility test for predicting fallers and recurrent fallers by employing the proc logistic procedure for calculating the area under the curve (AUC) of the receiver operating characteristic (ROC) curve along with the 95% confidence interval (95%CI). We calculated sensitivity, specificity, positive predictive values and negative predictive values for each mobility test and considered the optimum cut-off values as the maximum value of sensitivity plus specificity. The accuracy of fall prediction (i.e. identifying fallers and recurrent fallers) for each screening test was measured by the AUC for the entire sample and disaggregated by age (65–74 and 75–85 years) and sex. Statistical significance was set at  $P < 0.05$  and, by convention, an AUC of  $\geq 0.70$  was deemed acceptable [32]. We also examined AUC values for ROC curves with the mobility test and other fall risk factors included in the model. The adjusted models used the optimum cut-off values for the mobility tests we observed from the original ROC analysis to explore any improvements in the model with the inclusion of other risk factors. Due to a high proportion of missing

data (because of contraindications), we created an imputed dataset using PROC MI and performed the analysis as above; however, we did not observe any substantive improvements in the models. All analyses were conducted in SAS version 9.4.

## Results

### Participant characteristics

Of the 12,646 participants over age 65 in the CLSA Comprehensive at baseline, 8,594 had at least 12 months between the baseline assessment and follow-up. A total of 1,121 participants met inclusion criteria; 419 participants reported a previous fall, 646 reported a mobility limitation, and 56 reported a fall and mobility problem. The mean age of our sample was  $75.2 \pm 5.9$  years (66.6% women), and participants had an average of three chronic conditions. There was a higher proportion of chronic disease, depression, less than secondary school education, self-reported pain and psychotropic drug use among women than men (see Table 1). The number of participants with missing data for TUG, gait speed, SLS and chair-rise were 62 (5.8%, 41 contraindicated), 55 (5.2%, 38 contraindicated), 309 (27.7%, 185 contraindicated) and 253 (23.3%, 190 contraindicated), respectively. Baseline performance by age and sex is also provided in Table 1.

At follow-up, 218 (19.4%) participants reported one or more falls. Among women, 147 (19.8%) were classified as fallers ( $\geq 1$  fall) and 58 (7.8%) as recurrent fallers ( $\geq 2$  falls). Among men, 71 (19%) were classified as fallers and 26 (7.0%) as recurrent fallers.

Among those aged 65–74 years, 98 (21.4%) were classified as fallers ( $\geq 1$  fall) and 36 (7.9%) as recurrent fallers ( $\geq 2$  falls), whereas for ages 75+, 120 (18.2%) were classified as fallers and 48 (7.3%) as recurrent fallers.

### Performance of mobility screening tests in adults $\geq 65$ years old

Table 2 shows the findings for men and women 65 and over combined and by sex. None of the mobility tests had adequate predictive accuracy for identifying fallers (AUC values 0.52 for chair-rise to 0.60 for TUG) or recurrent fallers (AUC values 0.60 for chair-rise to 0.68 for TUG). Among the mobility tests, TUG had the consistently highest predictive accuracy, reaching an AUC of 0.68 (95% CI 0.62–0.75) for identifying recurrent fallers with an optimal cut-off value of 13.7 s or slower (sensitivity 56%, specificity 78%). In the models with all other fall risk factors included, adequate predictive accuracy was observed only for identifying recurrent fallers (AUC 0.70–0.74; see Appendix Table 1).

A post-hoc analysis was conducted to explore any differences in the predictive value of the tests between participants who reported an injurious fall at baseline and those who reported a mobility problem. Results can be found in the Appendix Table 2a and b.

**Table 1.** Sample characteristics at baseline ( $N = 1,121$ )

Characteristic	Women ( $N = 747$ ) Mean (Std) or $N$ (%)	Men ( $N = 374$ ) Mean (Std) or $N$ (%)	Both ( $N = 1,121$ ) Mean (Std) or $N$ (%)
Mean age	75.5 (5.84)	74.8 (6.01)	75.2 (5.91)
# of chronic diseases			
0–3	91 (14.9)	71 (23.3)	162 (17.7)
4–6	231 (37.9)	118 (38.7)	349 (38.2)
7+	287 (47.1)	116 (38.0)	403 (44.1)
Average # of chronic condition	6.64 (3.06)	5.92 (2.90)	6.40 (3.03)
CES-D ( $\geq 10$ )	196 (27.1)	74 (20.7)	270 (25.0)
Mental alteration test ( $< 35$ )	60 (8.7)	32 (9.2)	92 (8.9)
Self-rated vision (fair or poor)	126 (16.9)	59 (15.8)	185 (16.5)
Education level (secondary school or less)	176 (23.6)	54 (14.5)	230 (20.6)
Household income ( $\leq \$50,000$ )	383 (58.5)	115 (33.1)	498 (49.7)
Urinary incontinence	137 (18.4)	26 (7.0)	163 (14.6)
Self-rated pain or discomfort (moderate or severe)	356 (48.4)	114 (30.8)	470 (42.5)
Psychotropic drug use (yes)	131 (18.3)	50 (13.7)	181 (16.8)
Timed Up and Go (TUG) (s)			
Overall	12.1 (3.60)	12.0 (3.72)	12.1 (3.64)
Age 65–74	11.1 (3.26)	11.3 (3.61)	11.2 (3.39)
Age 75–85	12.8 (3.66)	12.5 (3.73)	12.7 (3.68)
Gait speed (m/s)			
Overall	0.80 (0.21)	0.84 (0.22)	0.81 (0.22)
Age 65–74	0.86 (0.22)	0.88 (0.23)	0.87 (0.22)
Age 75–85	0.75 (0.20)	0.81 (0.21)	0.77 (0.20)
Single Leg Stance (SLS) (s)			
Overall	15.6 (18.4)	21.5 (22.5)	17.6 (20.0)
Age 65–74	24.1 (22.2)	28.2 (24.4)	25.6 (23.1)
Age 75–85	9.0 (10.8)	14.9 (18.2)	10.8 (13.8)
Chair-rise (sec)			
Overall	16.0 (4.70)	15.2 (4.21)	15.7 (4.56)
Age 65–74	15.4 (4.70)	14.8 (4.19)	15.2 (4.53)
Age 75–85	16.4 (4.65)	15.6 (4.20)	16.2 (4.53)

$N$ , Number; SD, standard deviation; CES-D: Center for Epidemiologic Studies Short Depression Scale.

### Performance of mobility screening tests stratified by age and sex

Age- and sex-stratified findings for the mobility screening tests are shown in Table 3. Similar to the combined analysis, in both women and men, none of the mobility tests achieved an adequate AUC for identifying fallers (AUC 0.51–0.60 for women and 0.50–0.63 for men). In women aged 65–74 years, the TUG had an AUC of 0.70 (95%CI 0.58–0.82) for identifying recurrent fallers with an optimal cut-off score of 14.1 s (sensitivity 52%, specificity 88%; Figure 1). Similarly, in women aged 75–85 years, the TUG had an AUC of 0.70 (95%CI 0.61–0.79) for identifying recurrent fallers with an optimal cut-off score of 12.9 s (sensitivity 70%, specificity 64%; Figure 1). None of the other tests achieved an AUC of 0.70 or higher in women. When other risk factors were included (see Appendix Table 1), among women, the models with TUG and gait speed showed adequate accuracy for identifying fallers in those aged 65–74 (AUC 0.70 for both), and most of the mobility tests had AUC values above 0.70 for those aged 75–85 for both fallers and recurrent fallers.

In men aged 65–74 years, the SLS had an AUC value of 0.85 (95%CI 0.69–1.0) for identifying recurrent fallers with an optimal cut-off score of 3.6 s or less (sensitivity 88%,

specificity 83%; Figure 2). None of the other mobility tests showed adequate accuracy in identifying fallers or recurrent fallers in men of any age group. In men aged 65–74, the AUC values for identifying fallers improved by including other risk factors for most of the models, with the chair-stand model achieving the highest AUC of 0.70 (Appendix Table 1). For identifying recurrent fallers, the multivariable models achieved very high AUC values, even in those aged 75–85 (AUC 0.75–1.0; Appendix Table 1).

### Discussion

To our knowledge, this is one of the only population-based studies to examine the predictive accuracy of commonly used mobility screening tests for fall risk assessment in community-dwelling older adults, and the first to consider stratification by age and sex. Our study makes several important contributions: (i) commonly used mobility tests do not appear to have sufficient accuracy for identifying community-living older adults at risk for just one fall; (ii) mobility screening, alongside other fall risk factors, may have a role in identifying older adults at risk for multiple falls; and (iii) the predictive accuracy and optimal cut-off values

**Table 2.** Accuracy of mobility tests for predicting falls in men and women  $\geq 65$  years old combined and gender specific

		N	Cut-off	Mobility only				
				AUC (CI)	Sens	Spec	PPV	NPV
.....								
Both women and men								
FALLER	TUG	1,056	14.21	0.60 (0.55,0.64)	0.36	0.82	0.32	0.84
	Gait speed	1,063	0.73	0.57 (0.53,0.62)	0.47	0.66	0.25	0.83
	Single Leg Stance	810	4.47	0.52 (0.47,0.58)	0.43	0.66	0.20	0.85
	Chair-rise	860	15.90	0.52 (0.47,0.57)	0.46	0.59	0.19	0.84
RECURRENT	TUG	1,056	13.71	0.68 (0.62,0.75)	0.56	0.78	0.17	0.96
FALLER	Gait speed	1,063	0.73	0.65 (0.59,0.72)	0.63	0.65	0.13	0.96
	Single Leg Stance	810	5.24	0.62 (0.53,0.71)	0.68	0.63	0.09	0.97
	Chair-rise	860	15.75	0.60 (0.51,0.69)	0.65	0.58	0.08	0.97
Women								
FALLER	TUG	706	12.22	0.59 (0.54,0.65)	0.52	0.64	0.26	0.84
	Gait speed	709	0.77	0.57 (0.51,0.62)	0.58	0.55	0.24	0.84
	Single Leg Stance	540	6.16	0.51 (0.45,0.58)	0.54	0.56	0.20	0.85
	Chair-rise	584	18.25	0.53 (0.47,0.59)	0.31	0.76	0.21	0.83
RECURRENT	TUG	706	12.91	0.69 (0.62,0.77)	0.63	0.71	0.16	0.96
FALLER	Gait speed	709	0.73	0.66 (0.58,0.74)	0.68	0.63	0.14	0.96
	Single Leg Stance	540	5.24	0.57 (0.47,0.68)	0.66	0.60	0.08	0.97
	Chair-rise	584	16.21	0.64 (0.55,0.73)	0.67	0.60	0.09	0.97
Men								
FALLER	TUG	350	14.91	0.60 (0.51,0.68)	0.37	0.87	0.40	0.85
	Gait speed	354	0.66	0.58 (0.50,0.66)	0.35	0.82	0.32	0.84
	Single Leg Stance	270	3.63	0.53 (0.43,0.63)	0.37	0.79	0.23	0.87
	Chair-rise	276	19.28	0.52 (0.43,0.61)	0.95	0.18	0.17	0.95
RECURRENT	TUG	350	13.91	0.65 (0.51,0.78)	0.57	0.80	0.16	0.96
FALLER	Gait speed	354	0.66	0.63 (0.51,0.75)	0.42	0.80	0.13	0.95
	Single Leg Stance	270	4.18	0.71 (0.54,0.89)	0.75	0.73	0.12	0.98
	Chair-rise	276	19.03	0.58 (0.37,0.78)	1.00	0.18	0.04	1.00

N, number of participants; AUC, area under the curve; CI, 95% confidence interval; Sens, sensitivity; Spec, specificity; PPV, positive predictive values; NPV, negative predictive values; TUG, Timed Up and Go.

of mobility screening tests for identifying fallers vary by age and sex. These findings have valuable implications for best practices in fall prevention among community-dwelling older adults.

An abundance of evidence has shown that falls can be prevented by 25%–40%, amounting to billions of dollars in potential savings [1, 33, 34]. Given that most falls result from a loss of balance while walking and that poor balance is a leading risk factor for falls, mobility testing is consistently recommended to identify older persons at risk of falls who require further assessment and intervention [8, 9, 35, 36]. Our findings suggest that existing mobility screening tests used for this purpose may lack sufficient predictive accuracy to identify older adults at risk for one or more falls, even when applied to individuals that meet first-level screening criteria (i.e. those with a history of a fall or self-reported mobility problem). A previous systematic review of fall risk tools in older people [12] found only eight prospective studies examining the predictive validity of mobility tests for falls in a community setting, with most of the short mobility screening tests having insufficient accuracy. Our results using the CLSA extend this work and highlight the

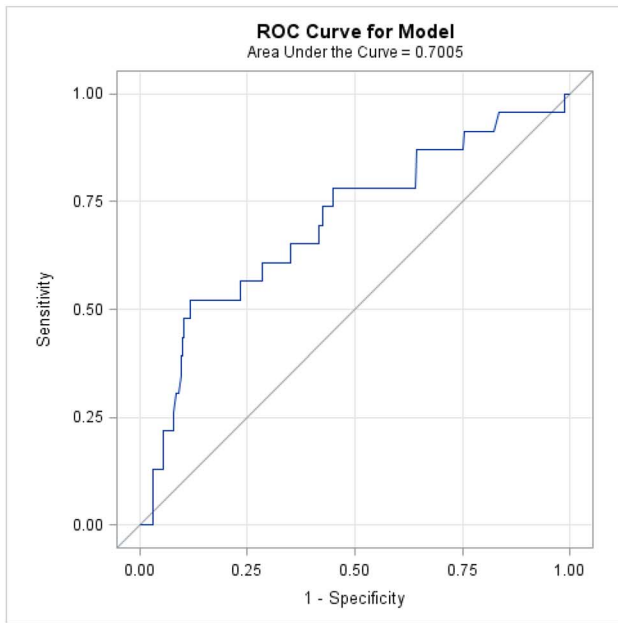
complexity of risk of falling; fall risk aetiology can involve interactions between health conditions, an accumulation of age-related impairments in multiple systems [37], as well as the environment. In general, we found higher accuracy for identifying older adults at risk for one or more falls when models incorporated other fall risk factors (e.g. depression and vision), suggesting that perhaps a fall risk index may increase the sensitivity of fall risk screening in community settings. It is also possible that mobility tests that involve a higher challenge to balance are needed to identify fallers in this population. Nonetheless, our findings do suggest that quick to administer mobility tests such as the TUG (for women) and SLS (for men) could be used to identify older adults at risk of repeat falls.

Our age and sex-stratified falls data from the CLSA are in line with previous work showing that fall risk increases with age and that the prevalence of falls and risk of fall-related injury are higher among women than men [2, 5]. Interestingly, although the TUG had the highest predictive accuracy in women, the SLS had better accuracy in men. Both the TUG (12 s cut-off) and SLS (10 s cut-off) are suggested as fall risk screening tools within the Centre for

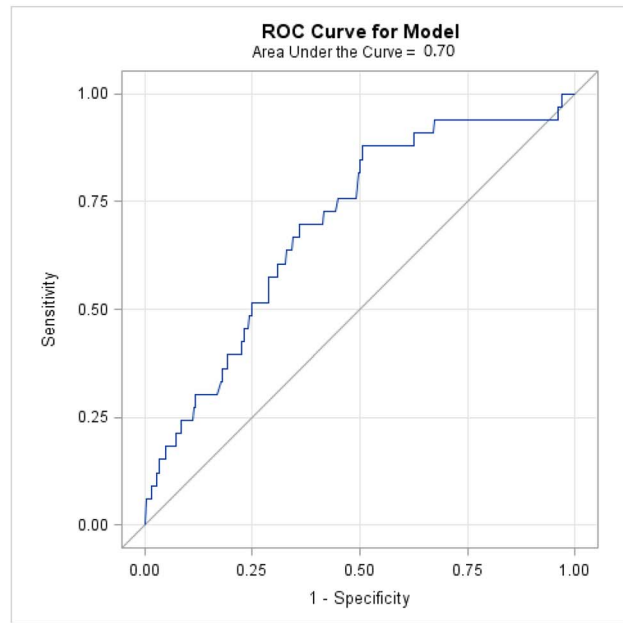
**Table 3.** Accuracy of mobility tests for predicting falls in women and men by age–sex strata

	65–74 YEARS										75–85 YEARS									
	N	Cut-off	AUC (CI)	Sen	Spec	PPV	NPV	N	Cut-off	AUC (CI)	Sen	Spec	PPV	NPV						
	Both men and women																			
FALLER	434	11.97	0.59 (0.52,0.66)	0.39	0.77	0.32	0.82	622	14.21	0.62 (0.56,0.68)	0.44	0.77	0.30	0.86						
Gait speed	433	0.79	0.57 (0.50,0.63)	0.47	0.67	0.28	0.82	630	0.69	0.59 (0.53,0.65)	0.50	0.67	0.25	0.86						
Single Leg Stance	371	4.47	0.56 (0.49,0.64)	0.37	0.78	0.30	0.83	439	6.16	0.52 (0.45,0.60)	0.66	0.48	0.16	0.90						
Chair-rise	374	15.32	0.54 (0.47,0.61)	0.52	0.61	0.25	0.84	486	21.69	0.50 (0.43,0.58)	0.17	0.90	0.22	0.86						
TUG	434	14.09	0.69 (0.60,0.79)	0.48	0.87	0.23	0.95	622	12.91	0.68 (0.60,0.77)	0.70	0.65	0.14	0.96						
Gait speed	433	0.74	0.66 (0.56,0.76)	0.58	0.74	0.15	0.95	630	0.66	0.66 (0.58,0.75)	0.57	0.71	0.14	0.95						
Single Leg Stance	371	4.47	0.66 (0.51,0.80)	0.62	0.77	0.14	0.97	439	5.24	0.58 (0.48,0.69)	0.75	0.54	0.07	0.98						
Chair-rise	374	16.47	0.61 (0.48,0.74)	0.57	0.69	0.10	0.96	486	16.21	0.59 (0.46,0.71)	0.64	0.57	0.07	0.97						
	Women																			
FALLER	276	11.12	0.60 (0.51,0.68)	0.53	0.64	0.30	0.83	430	15.81	0.62 (0.55,0.69)	0.33	0.84	0.31	0.85						
Gait speed	276	0.78	0.56 (0.48,0.65)	0.48	0.68	0.30	0.82	433	0.73	0.59 (0.52,0.66)	0.61	0.56	0.23	0.86						
Single Leg Stance	236	4.47	0.52 (0.43,0.62)	0.35	0.77	0.28	0.82	304	6.16	0.54 (0.46,0.62)	0.73	0.45	0.18	0.91						
Chair-rise	243	15.53	0.57 (0.48,0.65)	0.56	0.61	0.27	0.84	341	22.35	0.51 (0.42,0.60)	0.19	0.91	0.28	0.86						
TUG	276	14.09	0.70 (0.58,0.82)	0.52	0.88	0.29	0.95	430	12.91	0.70 (0.61,0.79)	0.70	0.64	0.14	0.96						
Gait speed	276	0.74	0.65 (0.52,0.78)	0.61	0.74	0.18	0.95	433	0.70	0.68 (0.59,0.77)	0.70	0.62	0.13	0.96						
Single Leg Stance	236	4.47	0.53 (0.34,0.72)	0.46	0.76	0.10	0.96	304	6.16	0.60 (0.50,0.70)	0.88	0.44	0.08	0.98						
Chair-rise	243	16.47	0.66 (0.52,0.81)	0.67	0.69	0.13	0.97	341	16.60	0.63 (0.50,0.75)	0.61	0.59	0.08	0.96						
	Men																			
FALLER	158	15.25	0.58 (0.46,0.71)	0.28	0.91	0.45	0.83	192	13.91	0.63 (0.51,0.75)	0.54	0.80	0.37	0.89						
Gait speed	157	0.85	0.57 (0.45,0.68)	0.56	0.58	0.26	0.84	197	0.66	0.60 (0.49,0.72)	0.44	0.80	0.33	0.86						
Single Leg Stance	135	24.34	0.63 (0.51,0.75)	0.73	0.50	0.26	0.89	135	14.16	0.57 (0.39,0.74)	0.47	0.73	0.18	0.92						
Chair-rise	131	20.15	0.50 (0.37,0.63)	1.00	0.10	0.21	1.00	145	18.58	0.52 (0.39,0.66)	0.94	0.23	0.14	0.97						
TUG	158	11.66	0.68 (0.51,0.86)	0.60	0.71	0.12	0.96	192	13.91	0.64 (0.44,0.85)	0.69	0.77	0.18	0.97						
Gait speed	157	0.85	0.67 (0.53,0.82)	0.70	0.57	0.10	0.97	197	0.66	0.61 (0.43,0.80)	0.50	0.77	0.14	0.95						
Single Leg Stance	135	3.63	0.85 (0.69,1.00)	0.88	0.83	0.24	0.99	135	14.16	0.56 (0.21,0.91)	0.50	0.72	0.05	0.98						
Chair-rise	131	19.03	0.53 (0.26,0.81)	1.00	0.15	0.05	1.00	145	18.53	0.61 (0.25,0.98)	1.00	0.23	0.04	1.00						

N, number of participants; AUC, area under the curve; CI, 95% confidence interval; Sens, sensitivity; Spec, specificity; PPV, positive predictive values; NPV, negative predictive values; TUG, Timed Up and Go.

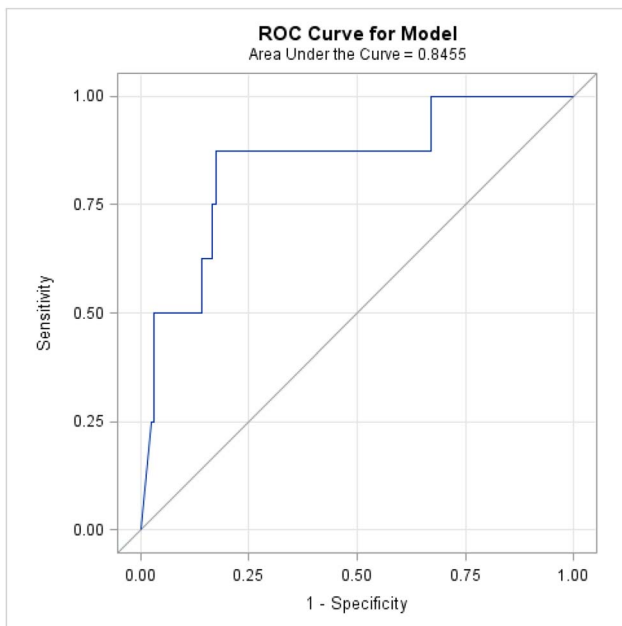


TUG, 65-74 years, AUC=0.70, cut-off 14.1 seconds



TUG, 75-85 years, AUC=0.70, cut-off 12.9 seconds

**Figure 1.** Timed Up and Go (TUG) identifies multiple fallers in women aged 65–74 years and 75–85 years.



Balance, 65-74 years, AUC=0.85, cut-off 3.6 seconds

**Figure 2.** Single Leg Stance test identifies multiple fallers in men aged 65–74 years.

Disease Control and Prevention’s (CDC) fall prevention algorithm without consideration of age or sex [8]. Although the CDC recommends a cutoff of 12 s for predicting falls on the TUG, the endorsed cutoff is based on data from a single study among primary care patients in which the AUC for falls ranged from 0.6 (in older adults with no fall history) to 0.72 (in those with a fall history at baseline) [38]. Our

results suggest that for the TUG, a higher cut-off score may be needed to identify women at risk for multiple falls (14.1 s for women aged 65–74 and 12.9 s for women aged 75+). Whereas in men, the optimal cut-off score for identifying recurrent fallers on the TUG was 11.7 s in those aged 65–74 (AUC 0.68) and 13.9 s in those 75 and older (AUC 0.64). Similarly, for the SLS, the commonly used 10 s threshold has not been validated against falls. Our results suggest a lower optimal threshold of 3.6 s for identifying men aged 65–74 who may be at risk for repeat falls (AUC 0.85). Our findings suggest that both age and sex should be considered when interpreting the results of mobility testing for fall risk assessment among community-dwelling older adults.

**Limitations of the study**

Our study should be interpreted considering several limitations. Firstly, the specific wording of the questions on fall history in the CLSA differs from suggested phrasing in current clinical practice guidelines. In the CLSA, participants are asked about falls that impacted their usual routines and activities, whereas in most fall prevention algorithms patients are first asked about any falls regardless of their significance. In addition, the CLSA did not include monthly fall diary postcards or a definition of a fall which has been recommended by international guidelines for measuring falls. Taken together, these modifications likely resulted in under reporting and a more restrictive classification of fallers in this study (i.e. falls had to impact daily life). Furthermore, we did not have specific questions on steadiness with standing or walking, and instead used responses to CLSA questions on activities of daily living; those who indicated difficulty

with walking, transferring, community mobility, shopping or housework were considered to have mobility limitations. The CLSA does not include a question on whether a person is concerned about falling, typical in fall risk screening, so we could not assess this subgroup. A second key limitation is our small sample size in men aged 75 and over. Our results in this age group may not be generalizable to other populations of community-living men, as the baseline performance and few fall events in this group suggest that men in this age category may have been high functioning. Finally, we did not have mobility scores for individuals with contraindications to performing the CLSA battery of performance-based tests, decreasing the sample's generalizability; in a healthcare setting, a healthcare professional may be able to administer such tests even on lower functioning patients. Future studies will also be needed to validate our findings in a separate cohort.

## Conclusion

In summary, our results indicate that for a population-based sample of community-dwelling older adults, simple and commonly used mobility and balance tests do not have sufficient predictive accuracy for identifying individuals at risk of falls. Although the TUG and SLS can be used to identify older adults at risk for recurrent falls, it is important to note that their accuracy and optimal cut-off values vary by age and sex. Future work should evaluate other, perhaps more challenging mobility screening tests or fall risk indices that incorporate other risk factors in community-living older people.

## Authors' contributors

MKB and AK conceived the study. NS performed the analysis. MKB, AK, AM, CD, LEG and PR contributed to the analysis and interpretation of findings. MKB drafted the article with critical revision by MKB, AK, AM, CD, LEG, PR. All authors approved the final manuscript. MKB is the guarantor. The corresponding author attests that all listed authors meet authorship criteria and that no others meeting the criteria have been omitted.

The lead author, MKB (the manuscript's guarantor), affirms that the manuscript is an honest, accurate, and transparent account of the resource and analyses being described and that no important aspects have been omitted.

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