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SYSTEMATIC REVIEW

Multifactorial and functional mobility assessment tools for fall risk among older adults in community, home-support, long-term and acute care settings

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Abstract

Objective: to conduct a systematic review of published studies that test the validity and reliability of fall-risk assessment tools for use among older adults in community, home-support, long-term and acute care settings.
Methods: searches were conducted in EbscoHost and MEDLINE for published studies in the English language between January 1980 and July 2004, where the primary or secondary purpose was to test the predictive value of one or more fall assessment tools on a population primarily 65 years and older. The tool must have had as its primary outcome falls, fall-related injury or gait/balance. Only studies that used prospective validation were considered.
Findings: thirty-four articles testing 38 different tools met the inclusion criteria. The community setting represents the largest number of studies (14) and tools (23) tested, followed by acute (12 studies and 8 tools), long-term care (LTC) (6 studies and 10 tools) and home-support (4 studies and 4 tools). Eleven of the 38 tools are multifactorial assessment tools (MAT) that cover a wide range of fall-risk factors, and 27 are functional mobility assessment tools (FMA) that involve measures of physical activity related to gait, strength or balance.
Conclusion: fall-risk assessment tools exist that show moderate to good validity and reliability in most health service delivery areas. However, few tools were tested more than once or in more than one setting. Therefore, no single tool can be recommended for implementation in all settings or for all subpopulations within each setting.

Keywords: *fall-risk assessment, older adults, systematic review, predictive value, elderly, systematic review*

Introduction

As the population aged 65 years and over grows, the number of falls and subsequent injuries is increasing. In the absence of evidence to support a population-based approach to prevention and the imperative to deliver cost-effective and efficient services, health care providers need risk assessment tools that reliably identify at-risk populations and guide intervention by highlighting remediable risk factors for falls and fall-related injuries. Such tools typically consist of a rating or scoring system designed to reflect the cumulative effect of known risk factors for the purpose of identifying those at greatest risk for sustaining a fall or fall-related injury. Fall-risk profiles and evidence-based approaches to intervention differ considerably among well, active seniors who live in the community; those who are frail and need support to live at home in the community; those who require long-term care (LTC); and those who are hospitalised for acute health problems.

Among the general population of seniors, the factors strongly associated with risk of falling include a history of prior falls, muscle weakness, poor gait or balance, visual impairment, arthritis, functional limitation, depression and use of psychotropic medications [1]. Furthermore, having multiple risk factors increases the risk exponentially [2]. However, risk profiles are not the same for all seniors. Among active seniors living in the community, fall risk tends to be mostly related to mobility status, exposure to hazardous environments and risk-taking behaviours, such as climbing ladders [2, 3]. Seniors who require support to live in the community tend to be more susceptible to falls owing to the direct effects of health problems such as arthritis, depression, use of psychotropics and the functional consequences of a chronic disease [3, 4]. Among older adults who are hospitalised, the risk of falling is greatly influenced by acute illness that often has a marked, albeit temporary, impact on physical and cognitive function. This is compounded by care being provided in unfamiliar surroundings such that intrinsic and extrinsic risk factors combine to produce a period of heightened risk for an older person [4]. Among residents of LTC facilities, risk factors are influenced by impaired cognition, wandering or impulsive behaviour, use of psychotropic medications, incontinence and urgency, lack of exercise, unsafe environments and low staffing levels [5, 6].

Assessment of fall risk typically involves either the use of multifactorial assessment tools (MAT) that cover a wide range of fall-risk factors, or functional mobility assessments (FMA) that typically focus on the physiological and functional domains of postural stability including strength, balance, gait and reaction times. Some tools exist purely as a mechanism to screen for high-risk populations, while others allow for tailoring of intervention based on assessment.

Since 2000, three reviews have been published that detail a cross-section of fall-risk assessment tools [7–9]. However, the focus has been on institutional settings with little attention to tools tested in community settings. Other reviews have included community-dwelling seniors in their testing sites but have focused on tools limited to the assessment of balance with little consideration of other risk factors [10–12]. In an attempt to fill the gaps in the literature and to provide an update on published studies, this paper presents the findings of a systematic review of published studies that test the reliability and validity of fall-risk assessment tools for use in detecting a variety of fall-related risk factors among persons aged 65 years and older in community, supportive housing, long-term and acute care settings. The purpose of this review is to assist health professionals in selecting the most appropriate fall-risk assessment tool(s) for the risk profile of the intended population.

Methods

Search strategy and selection criteria

The methodology was consistent with the Cochrane collaborative standards [13]. A search strategy and filter was developed, tested and conducted in collaboration with a health science librarian. The search engines used were MEDLINE and EbscoHost Academic Search Premier, Psychology and Behavioural Sciences Collection, Nursing and Allied Health Collection, Health Business Elite, Biomedical Reference Collection, Cochrane Database of Systematic Reviews (CDSR), Database of Abstracts of Reviews of Effectiveness, and Cochrane Controlled Trials Register with restrictions to published articles in the English language between January 1980 and July 2004. As shown in Appendix 1, the key search terms used were: accidental, falls, age, risk assessment, assessment tool, balance, gait and validation studies. A hand search of bibliographic references of relevant articles and existing reviews was also conducted to identify studies not captured in the electronic database search. One member of the research team (KV) screened abstracts from the initial search and obtained articles deemed potentially relevant based on keywords and indications that the study purpose was to evaluate one or more fall-risk assessment tools. Two members of the research team (AS and KV) examined each article independently to determine if it met the inclusion criteria. A third reviewer (VS) was consulted where there was a disagreement or question regarding relevance. An article was considered relevant when reviewers agreed that it met the following criteria: (i) its primary or secondary purpose was testing/evaluating a fall-risk assessment tool; (ii) it dealt with a primary outcome measure of falls, fall-related injury or gait/balance; (iii) the majority of persons assessed were aged 65 years and older; and (iv) it contained a prospective research methodology.

Data extraction

Data extraction forms were developed with consideration for the criteria established by Wyatt and Altman (1995) [14] and Oliver *et al.* (2004) [9] as below:

'Gold Standard Criteria' for Quality of Risk Assessment Tools*

- Validated in a prospective study
- Used specificity and sensitivity analyses
- Tested in more than one population
- Demonstrates good face validity
- Demonstrates good inter-rater reliability
- Good adherence from staff
- Clear and easy to calculate score

*Oliver *et al.*, 2004 [9]; Wyatt and Altman, 1995 [14].

To assist in judging the clinical relevance and application of the tool and the research quality of the validation study, the data presented in this review include: the number of items, time to complete the tool, recommended cut-off scores, sample size and the mean age of the sample. Also presented are findings from reviewed studies in which the authors have provided predictive values for the entire tool using sensitivity, specificity or inter-rater reliability (IRR) measures. Where studies used other validation measures, findings are presented in table footnotes, provided the results are for the entire tool and not limited to subcomponents of the tool. Few studies provided the statistical significance of their results. Unless otherwise noted, results are for fallers versus non-fallers. To facilitate selection of tools for the appropriate population and intended use, data are presented by the type of risk assessment tool and the setting in which each tool was tested.

Findings

Two hundred and fourteen abstracts were identified as potentially relevant on the basis of the subject-related keyword search and hand-search of relevant articles. A total of 38 tools were examined across 4 settings in 34 articles (Table 1). Of the articles that were included in the final analysis, some presented studies of more than one tool and some tools were examined in a number of different studies. Table 1 presents each tool by setting and type of tool, with the number of references indicating the number of studies conducted for each tool. Twenty-seven of the 38 fall-risk assessment tools are FMA tools and 11 are MAT. No tools were found that represent comprehensive medical assessments.

The MAT typically consist of a checklist comprising questions used to screen the level and nature of risk based on a combined score of multiple factors known to be associated with fall-related risk. These include factors such as psychological status, mobility dysfunction, elimination patterns, acute/chronic illnesses, sensory deficits, medication use and a history of falling. In addition to questions that rely on self-report, the tools may or may not include physical assessments of health status (e.g. blood pressure) or mobility function. Most tools are administered in person and some are conducted by telephone or a postal survey. Some take

Table 1. Fall-risk assessment tools by type and number of validation and reliability studies conducted in each setting

Tool	Community	Supportive housing	Long-term care	Acute
FMA				
Activity-based balance and gait		[15]		
Area ellipse of postural sway			[16]	
Berg balance scale	[17–19]	[20]		[21]
CTSIB	[18]			
Dynamic gait index	[18]			
Elderly mobility scale				[22]
Floor transfer	[23]			
5 min walk	[23]			
Five-step test	[23]			
Functional reach test	[19, 23–25]		[16, 25]	[26]
Lateral reach test	[19]			
Maximal step length	[27]			
Mean velocity of postural sway			[16]	
Mobility interaction fall chart			[28, 29]	
100% Limit of stability	[18]			
POAM-B	[23]			
Postural balance		[30]		
Postural stability tests	[19]			
Quantitative gait assessment	[31]			
Rapid step test	[27]			
Step up test	[19]			
Tandem stance	[23]			
Timed chair stands			[16]	
Timed up and go	[18, 25]		[25]	
Timed walk			[16]	
Tinetti balance scale	[32]			
Tinetti balance subscale			[16]	
MAT				
Balance self efficacy test	[33]			
Conley scale				[34]
Downton index			[35]	[36]
Elderly fall screening	[37]			
Fall-risk assessment				[38, 39]
Fall-risk screening test	[40]			
Geriatric postal screen	[33]			
Home assessment profile	[41]			
Morse fall scale			[42]	[26, 42, 43]
Physiological and clinical predictors		[44]		
STRATIFY				[45–47]

FMA, functional mobility assessment; CTSIB, clinical test sensory interaction for balance; POAM-B, performance-oriented mobility assessment for balance; MAT, multifactorial assessment tools.

as little as 1 min to complete and others can take over 1 h. They are typically administered by a nurse or therapist on admission to hospital or a nursing home and are usually updated regularly or when there is a change in health status.

FMA focus on functional limitations in gait, strength and balance and are often completed by physical therapists or physicians in outpatient or acute care settings. In most cases, the subject is required to perform a physical demonstration of ability while the assessor monitors limitations in function compared to a pre-established standard. MAT and FMA may be designed as a quick screen for determining high risk or to target specific factors for risk reduction—either may trigger referral for further investigation and testing.

Single or recurrent falls were the primary outcome for all but three studies. Two studies reported balance as a primary outcome measure [25, 30], and for one study, injury due to a fall was the intended primary outcome [18]. Sample size varied widely among the studies (from 17 to 1,939 participants), with five studies validating tools with fewer than 70 subjects: two from the community [17,31] and two from acute [21, 22]. The following section provides a summary of reported results for each tool by the setting in which the tests

Table 2. Review findings for fall-risk assessment in community settings

Tool	Author	No. of Items	Time to complete	Cut-off score	Sample size	Mean Age	Sensitivity	Specificity	IRR
Balance self efficacy	Gunter [33]	18	NS	NS	142	80	83	38	NS
Berg balance	Thorbahn [17]	14	15–20 min	<45	66	79	53	96	.88
Berg balance	Boulgarides [18][a]	14	15–20 min	NS	99	74	NS	NS	.80
Berg balance	Brauer [19][b]	14	15–20 min	NS	100	71	NS	NS	NS
CTSIB	Boulgarides [18][a]	4	<3 min	NS	99	74	NS	NS	NS
Dynamic gait index	Boulgarides [18][a]	8	NS	NS	99	74	NS	NS	.80
Elderly fall screening	Cwikel [37]	5	NS	2+	283	71	83	69	NS
Fall-risk screen test	Tromp [40][c]	NS	NS	7	1,285	75	54	79	NS
5 min walk	Murphy [23][d]	—	5 min	1,000 ft.	45	73	82	79	NS
Five-step test	Murphy [23][d]	—	NS	21 s	45	73	82	82	NS
Floor transfer	Murphy [23][d]	—	NS	unable/able	45	73	64	100	NS
Functional reach	Duncan [24][e]	1	NS	<7.4″	217	70–104[f]	NS	NS	NS
Functional reach	Brauer [19][b]	1	NS	NS	100	71	NS	NS	NS
Functional reach	Murphy [23][d]	1	NS	8 in	45	73	73	88	NS
Functional reach	Rockwood [25]	1	NS	NS	1,161	78	NS	NS	.92
GPSS	Alessi [48][g]	10	NS	4+	147	74	94	51	.88
Home assessment	Chandler [41]	NS	NS	NS	159	75	NS	NS	.92
Lateral reach	Brauer [19][b]	1	NS	NS	100	71	NS	NS	.99
Maximum step length	Cho [27][h]	1	<10 min.	NS	167	78	NS	NS	.86
POAM-B	Murphy [23][d]	—	NS	12	45	73	55	97	NS
Postural stability	Brauer [19][b]	NS	NS	NS	100	71	14	94	NS
Quantitative gait	Feltner [31][i]	1	NS	NS	17	73	NS	NS	NS
Rapid step	Cho [27][h]	1	<10 min.	NS	167	78	NS	NS	.42
Step up test	Brauer [19][b]	1	15 s	NS	100	71	NS	NS	NS
Tandem stance	Murphy [23][d]	—	10 s	unable/able	45	73	55	94	NS
Timed up and go	Boulgarides [18][a]	1	<1 min	10–12	99	74	NS	NS	.99
Timed up and go	Rockwood [25]	1	<1 min	10–12	1,115	78	NS	NS	.56
Tinetti balance	Raiche [32]	24	NS	36	225	80	70	52	NS
100% limit of stability	Boulgarides [18][a]	1	NS	NS	99	74	NS	NS	NS

NS, Not Specified; CTSIB, clinical test sensory interaction for balance; GPSS, geriatric postal screening survey.

[a]Boulgarides [18] tests five tools but only reports validity measures for the CTSIB. Using logistic regression analysis, only the 'standing on a firm surface with eyes closed' (FEC) portion correctly classified 80.8% (OR 12.9; 95% CI: 1.0–159.8) of non-recurrent and recurrent fallers.

[b]Brauer [19] tests the predictive validity of seven clinical balance tests and reports a combined score in predicting fallers and non-fallers of 12% sensitivity and 95% specificity. Only postural stability was tested independently—results presented above.

[c]Tromp [40] findings are for recurrent fallers (2 or more falls) versus non-recurrent fallers.

[d]Murphy [23] validated the combined effect of single risk factors and tools representing multiple factors. Eleven tools were tested, only six reported on full tools (see table above) and three reported on variables within tools. Discriminant analysis of mixed variables revealed that 'floor transfer' and '50 ft walk' combined successfully predicted fallers from non-fallers with an overall predictive value of 96% (82% sensitivity and 100% specificity).

[e]Duncan [24] uses adjusted odds ratio, controlling for age, mental status and depression to predict the validity of the functional reach test in identifying older male veterans at risk of falling. The odds of being a recurrent faller (two or more falls) and being unable to reach is 8.07.

[f]Average age not provided. Age range is between 70 and 104 years.

[g]Alessi [48] validated the diagnostic accuracy of the GPSS using a high-risk subsample ($n = 147$) who were referred to a geriatric assessment clinic within 6 months of completing the GPSS. IRR was tested on a larger sample ($n = 314$).

[h]Cho [27] reported that the maximum step length was a significant predictor of recurrent fallers (OR = 0.52). The Rapid Step Test was found to be a poor predictor of recurrent fallers (OR = 0.98) with poor reliability measures.

[i]Feltner [31] reported that the Quantitative Gait Assessment was not significantly predictive of falling (statistics not provided).

were conducted—community, supportive housing, LTC or acute. Clinicians are encouraged to refer to the article directly for more detailed information on subpopulations and tool efficiency.

Community

The community setting includes studies conducted with subjects living independently in their own homes or retirement communities. This is the most common setting for risk assessment testing, with 23 tools tested in 14 studies (Table 2). Of the 14 studies, 7 report measures other than sensitivity and specificity values ([18, 19, 24, 25, 27, 31, 41]; refer Table 2 footnotes). Six studies report IRR scores for one or more tools. All reported strong IRR measures of 80% or more, with the exception of the Timed Up and Go (TUG) test by Rockwood [19] (IRR 56%).

Sensitivity results ranged from 14 to 94% and specificity results ranged from 38 to 100%. The Elderly Fall Screening Test [37] demonstrated discrimination between fallers and non-fallers of 83% sensitivity and 69% specificity. In the Murphy [23] study, the 5 min walk, the five-step test and the Functional Reach all reached sensitivity and specificity values greater than 70. The Functional Reach tool was also tested in other studies with different populations, including recurrent fallers (two or more falls) versus non-recurrent fallers [19, 24] and cognitively impaired versus non-cognitively impaired [25]. However, because of the differences in the study populations, the predictive value cannot be compared to those of Murphy [23], who studied fallers versus non-fallers among the general population in the community setting.

Supportive housing

Supportive housing describes settings in which fall-risk assessment tools are tested among community-dwelling seniors living in private or congregate housing with ‘on-demand’ services rather than on-site nursing and/or home-support services. In the supportive housing setting four studies examined four tools (Table 3). Two [20, 44] do not report the sensitivity and specificity values but use regression analyses to indicate the relative risk of falling. None of the studies reported reliability scores.

Sensitivity results ranged from 72 to 80%, with specificity results from 43 to 57%. None of the studies in this setting reported both sensitivity and specificity values greater than 70. Lord [44] used discriminant analysis to demonstrate that 86% of fallers and non-fallers were correctly classified using the Physiological and Clinical Predictors tool.

Long-term care

LTC settings, also known as residential care or nursing homes, include institutional facilities for residents that require on-site staff for routine care, owing to chronic illnesses, disabilities and/or cognitive impairments. As shown in Table 4, six studies examined ten different tools in this setting. Among the six studies, three reported sensitivity and specificity values [28, 29, 35], one only reported reliability scores [25], and one [16] used other measures to assess predictive value.

Sensitivity scores ranged from 43 to 91% and specificity scores from 39 to 82%. The Mobility Fall Chart showed 85% sensitivity and 82% specificity in a developmental study [29] but only 43% sensitivity and 69% specificity in a follow-up study [28]. The Downton index [35] demonstrated high sensitivity yet failed to produce acceptable specificity. Reliability scores of tools tested in the LTC setting range from 56 to 98% agreement among raters, with the TUG test in Rockwood’s study [25], at the lowest end of the range. However, this study was conducted among a population of mixed community and LTC with 63% of participants assessed with cognitive impairment and, therefore, likely reflects the challenges of administering the TUG to those who are cognitively impaired.

Acute care

Acute care settings include acute care hospitals, emergency departments, or geriatric inpatient or outpatient rehabilitation services. As shown in Table 5, 12 studies examined eight different tools in the acute setting.

Sensitivity results ranged from 66 to 93% and specificity results from 25 to 88%. Two studies reported predictive values above 70% for both sensitivity and specificity. Schmid [38] correctly predicted 93% of fallers and 78% of

Table 3. Review findings for fall-risk assessment tools in supportive housing settings

Tool	Author	No. of Items	Time to complete	Cut-off	Sample size	Mean age	Sensitivity	Specificity	IRR
Activity-based balance and gait	Topper [15]	NS	40–55 min	NS	100	83	72	57	NS
Berg balance	Berg [20][a]	45	10–15 min	<45	113	72	NS	NS	NS
Physiological and clinical predictors	Lord [44][b]	NS	NS	NS	66	86	NS	NS	NS
Postural balance testing	Maki [30]	6	45–60 min	NS	96	83	80	43	NS

NS, Not Specified.

[a]Berg [20] scores were significant predictors, with scores <45 indicating a relative risk of 2.7 (CI 1.5–4.9) for multiple falls over the next 12 months.

[b]Lord [44] reported that discriminant analysis identified reaction time, body sway, quadriceps strength, tactile sensitivity, gait impairment, cognitive impairment, psychoactive drug use and age as variables that significantly discriminated between fallers and non-fallers with 86% accuracy. Predictive values of overall scores of the tool were not reported.

Table 4. Review findings for fall-risk assessment tools in long-term care settings

Tool	Author	No. of Items	Time to complete	Cut-off	Sample size	Mean age	Sensitivity	Specificity	IRR
Area ellipse of postural sway[a]	Thapa [16][b]	NS	10 s	NS	118	81	NS	NS	.72
Downton index	Rosendahl [35][c]	11	NS	3+	78	81	91	39	NS
Functional reach	Rockwood [25][d]	1	NS	NS	323	78	NS	NS	.92
Functional reach	Thapa [16][b]	1	NS	NS	118	81	NS	NS	.57
Mean velocity of postural sway[a]	Thapa [16][b]	NS	10 s	NS	118	81	NS	NS	NS
Mobility fall chart	Lundin-Olsson [29][e]	NS	5–15 min	NS	78	82	85	82	.80
Mobility fall chart	Lundin-Olsson [28]	NS	5–15 min	NS	208	82	43	69	NS
Morse fall scale	Morse [42]	6	1–3 min	45	124	NS	NS	NS	.96
Timed chair stands	Thapa [16][b]	1	30 s	NS	118	81	NS	NS	.63
Timed up and go	Rockwood [25][d]	1	<1 min	NS	323	79	NS	NS	.56
Timed walk	Thapa [16][b]	1	10 ft	NS	118	81	NS	NS	.88
Tinetti balance subscale	Thapa [16][b]	6	NS	NS	118	81	NS	NS	.98

NS, Not Specified.
[a]Postural sway is often measured using a biomechanic force platform to reflect the body's effort at maintaining balance during quiet standing.
[b]Thapa [16] used incidence density ratio (IDR) to test 6 balance measures. After controlling for demographic measures, anthropometric measures and significant fall-risk factors, 'area ellipse of postural sway' (IDR = 1.16, 95% CI: 1.02–1.36) and the 'Tinetti Balance Subscale' (IDR = 1.17, 95% CI: 1.01–1–34) were the only tools that independently predicted future recurrent fallers.
[c]Rosendahl [35] tested the Downton index at 3, 6 and 12 months. Six-month results are presented here.
[d]Rockwood [25] states that these tools have good construct validity but does not report predictive validity.
[e]Lundin-Olsson [29] reports a positive predictive value of 78% (95% CI: 67–87%) and a negative predictive value of 88% (95% CI: 79–95%). Sensitivity and specificity values were not reported but calculated from data provided in order to compare sensitivity and specificity values reported for this tool in a subsequent study by the same authors [28].

Table 5. Review findings for fall-risk assessment tools in acute care settings

Tool	Author	No. of Items	Time to complete	Cut-off	Sample size	Mean age	Sensitivity	Specificity	IRR
Berg balance	Wood-Dauphinee [21]	14	10–15 min	<45	60	71	NS	NS	.98
Conley scale	Conley [34]	6	1–2 min	2	1,168	74	71	59	.80
Downton index	Nyberg [36]	NS	NS	3	135	NS	91	27	NS
Elderly mobility scale	Prosser [22]	4	NS	NS	66	82	NS	NS	.88
Fall-risk assessment	Schmid [38]	17	NS	3	334	60–69[a]	93	78	.88
Fall-risk assessment	Myers [39]	17	NS	3	226	85	91	25	NS
Functional reach	Eagle [26]	1	NS	6.0″	98	69	76	34	NS
Morse fall scale	Morse [42]	6	1–3 min	45	1,939	NS	NS	NS	.96
Morse fall scale	McCollum [43]	6	1–3 min	55	458	NS	83	68	.98
Morse fall scale	Eagle [26]	6	1–3 min	NS	98	69	72	51	NS
STRATIFY	Coker [45]	5	1 min	2	432	81	66	47	.74
STRATIFY	Papaionnou [46]	5	1 min	9	620	81	91	60	.78
STRATIFY	Oliver [47][b]	5	1 min	2	C1: 217 C2: 331	C1: 80 C2: 83	C1: 93 C2: 92	C1: 88 C2: 68	NS

NS, Not Specified.
[a]Average age not provided.
[b]Oliver [47] tested the STRATIFY tool with two cohorts (C1 and C2) from different hospitals.

non-fallers for the fall-risk assessment tool and Oliver [47] correctly predicted 93% of fallers and 88% of non-fallers in one cohort, of a two cohort study, using the STRATIFY tool. Eight of the 12 studies reported reliability measures [21, 22, 34, 38, 42, 43, 45, 46]. Generally, IRR measures were high, ranging between 74 and 99% agreement between raters.

Discussion

The findings of this review demonstrate that there are a number of fall-risk assessment tools available with some evidence to support their use in predicting risk of falls. The choice of a tool in a clinical context needs to reflect the purpose for which the tool is to be applied. If the purpose is to screen for high-risk populations, a tool is needed that is quick and easy to apply, yet has good sensitivity and specificity. If the purpose is to reduce risk, the tool needs to reliably identify remediable risk factors on which interventions can be focussed.

Selecting an appropriate tool is complicated by the lack of consistency in methods of reporting and interpreting the comparative properties of fall-risk assessment tools in the published literature. For example, criteria for establishing 'high' predictive values for fall-risk assessment tools are recommended by Perell *et al.* (2001) [7] as those that have sensitivity measures above 80% and specificity above 75%.

However, Oliver and colleagues (2004) [9] imply that a 70% cut-off for sensitivity and specificity indicates a 'high' predictive value.

On the basis of predictive values of 70% or higher for both sensitivity and specificity [7, 9], there are six tools tested in four studies [23, 29, 38, 47] found in this review to have strong predictive validity. Three tools—the 5 min walk, the five-step test and the Functional Reach—were tested in a community setting [23]. The Mobility Fall Chart was tested in an LTC setting [29] and the fall-risk assessment and STRATIFY tools were tested in acute care settings [38, 47].

Seven studies reported values other than sensitivity and specificity that showed strong predictive values. Four of these studies [18, 23, 24, 27] were conducted in community settings on the following five tools: the CTSIB, Floor Transfer, 5 min walk, Functional Reach and maximum step length. Two studies in the supportive housing setting [20, 44] found good predictive validity for the BERG and Physiological and Clinical Predictors tools, and one study conducted in a LTC setting [16] showed strong values for the Area Ellipse of Postural Sway and Tinetti Balance Subscale tools. However, some of these studies only report on components of the tool and not on the predictive values of the entire tool [18, 44], and one study reported only on the combined predictive value of two combined tools [23].

The lack of studies on the predictive validity of comprehensive medical assessments likely reflects the fact that such assessments are not undertaken to predict risk but to identify areas where medical intervention is required [7]. What constitutes a comprehensive medical assessment for a faller has yet to be clearly defined—this work is currently a focus of the Prevention of Falls Network Europe Group (profane.org.eu). Aspects of comprehensive medical examinations are included in a number of MAT and FMA, such as the assessment of cognition, sensory impairments, pain, weight loss, incontinence, effects of medication use and mobility impairment.

A number of studies claim to demonstrate evidence to support the use of fall-risk assessment tools but fail to provide the validity or reliability measures to support these recommendations. Furthermore, there are no tools that show consistently strong predictive values across two or more settings, and only two tools show good predictive validity in repeated studies within one setting: the Functional Reach test in two studies in community settings [23, 24] and the STRATIFY tool tested among different acute setting cohorts in a single study [47]. Generalisation of findings is further limited by validation studies that target subpopulations within a given setting, such as those with cognitive impairments, studies limited to recurrent fallers (rather than fallers versus non-fallers) and studies that are specific to one gender or that test the tool on small samples.

Future research on the validation of fall-risk assessment tools would benefit from an agreed taxonomy for reporting to facilitate direct comparison across studies. Most studies reviewed provide validation measures based on cut points for sensitivity and specificity without consideration of positive and negative predictive values, which give results that more accurately reflect the numbers and proportions of those tested with correct and incorrect outcomes [49]. The use of the receiver operating curve (ROC) is beneficial, as it provides a continuous curve of cut points, thereby providing a range of choices for selecting a score that separates those at 'high' or 'low' risk. An ROC displays the relationship between sensitivity and specificity and provides the opportunity to select the point that best represents the trade-off between failing to detect the positives (sensitivity) against the failure to detect the negatives (specificity) [50]. ROCs provide a graphic representation of the usefulness of the tool through the display of the area under the curve—the larger area, the greater overall predictive value.

To facilitate clinician selection of appropriate fall-risk assessment tools, authors of validation studies must report their predictive validity and reliability in a manner that is accessible to a lay audience. Furthermore, if authors find that only subcomponents of the tool are found to be predictive, the tool should not be recommended for use until it is revised, re-tested and demonstrated to be valid and reliable. Tool selection should also be dependent upon knowing the time required to complete the tool, recommended cut-off scores (including the cut-off score which the predictive validity was tested against) and the necessary equipment and training. It is also important that the target population be described, including sample size, mean age, sample criteria and where the sample resides (i.e. community, supportive housing, long-term or acute care settings).

The use of fall-risk assessment as part of a multifactorial approach for the prevention of falls is supported by evidence of strong associations between a multiple risk factors and falls, as well as from experimental studies demonstrating significant fall reductions where assessment is combined with tailored interventions (Gillespie *et al.* 2003 [13]). At present no tool exists that can be applied reliably across different settings to accurately predict risk of falling, and of the tools that do exist, few have actually been validated in more than one setting. One might argue that development of screening tools to predict falls in high-risk populations such as residents of nursing homes is of limited use and that all residents should be considered high risk and therefore receive an assessment linked to evidence-based interventions. The same is not true of community-dwelling populations, where valid, reliable and quick to administer tools are required to aid health care workers identify populations likely to benefit from intervention.

As the evidence for strategies to prevent falls continues to expand, so does the need to ensure that interventions are applied to appropriate populations. Further research is needed to strengthen the evidence for the use of multifactorial tools and FMA within and across settings, and new tools may be required if no evidence exists to support the use of an existing tool in a specific setting. Active partnerships between clinicians and researchers should be encouraged to ensure that any future tool developed is reliable and valid as well as feasible and acceptable in everyday practice in all health care settings.

Key points

- This is the first systematic review of fall-risk assessment tools for older adults presented by the setting in which the tool was tested; community, supportive housing, LTC and acute care.
- Thirty-four articles met the criteria for inclusion and reported on the validity and reliability results of 38 risk assessment tools.
- Few tools were found that were tested more than once or in more than one setting, therefore, no single tool can be recommended for use in all settings or for all subpopulations within each setting.

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Conflicts of interests

The authors have no commercial interests in, or travel expenses received from, organisations whose product is reviewed in this study or referred to in the article, nor any financial interests in competing companies.

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Appendix 1. Literature search: inclusion and exclusion criteria