The Development and Validation of a Brief Performance-Based Fall Risk Assessment Tool for Use in Primary Care

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Background. To report the development, external validity, reliability, and feasibility of a falls risk assessment tool for use in primary care.

Methods. Two prospective cohort studies, a test–retest reliability study, and a feasibility study were included. Seven hundred and sixty four older community-living people (mean age = 75.3 years, SD = 5.8) participated in the tool development study, 362 people (mean age = 80.25 years, SD = 4.5) participated in the external validation study, 30 older people took part in the test–retest reliability study, and 32 clinicians participated in the feasibility study.

Results. The fall risk assessment score (number of risk factors) displayed a good ability to discriminate between multiple fallers (those who experienced two or more falls) and non–multiple fallers in the external validation study (area under the receiver operating characteristic curve = 0.72, 95% confidence interval = 0.66–0.79). Each of the performance items; low contrast visual acuity, tactile sensitivity, sit to stand, alternate step, and near tandem stand ability; and measures of previous falls and medications could discriminate between prospectively categorized multiple fallers and non–multiple fallers with relative risk values ranging from 1.4 to 2.4 in the development study. The probability of future multiple falls increased from 7% with the identification of zero or one risk factor up to a probability of 49% with the identification of six or more risk factors. The assessment items exhibited moderate to excellent test–retest reliability and a high degree of acceptance by health professionals.

Conclusion. The assessment tool is an externally validated, reliable, and feasible falls risk assessment that can accurately predict multiple falls and assist with guiding interventions in community living older people.

Key Words: Accidental falls—Aged—Assessment—Screening.

Received June 3, 2009; Accepted April 15, 2010

Decision Editor: Luigi Ferrucci, MD, PhD

POPULATION ageing and the increased tendency to fall with age present a major challenge to health systems. There is now good evidence that multifactorial interventions can prevent falls (1). As health care resources are limited, widespread implementation of multiple interventions strategies is unlikely to be feasible. An individualized intervention approach based on an individual’s risk profile is likely to be an effective alternative. In addition, identification of people at high risk of falls enables health care providers to target appropriate interventions to those likely to gain the greatest benefit (1). Fall risk increases as a result of the cumulative effect of multiple impairments (2), making a multifactorial risk assessment important. However, few validated, multifactorial performance-based falls risk assessment tools have been developed for community-living older people.

A recent systematic review of the validity of published tools (3) illustrates the need for an evidence-based multidimensional tool that can accurately predict risk of falls in community-living older people that is feasible for clinicians to incorporate into their practice. Many existing tools do not meet necessary criteria to warrant recommendation for use in clinical practice as they have not been externally validated, and their development has relied on the retrospective reporting of falls (4,5). Many existing tools are too time consuming and/or equipment dependent to be practical for use in some clinical settings (6–9), and some tools have been validated only in frail populations (10,11), making their validity for use with general populations of older people uncertain. Finally, most simple tools have limited ability to guide fall prevention interventions.

Most published research in this area has focused on fall risk assessments that are able to discriminate between fallers and non-fallers. In this study, however, we focus on the identification of people at an increased risk of multiple falls, since multiple falls within a 1-year period are more predictable and are likely to indicate underlying physiological impairments and chronic conditions (12,13), making them more clinically important and likely to be amenable to intervention.
The primary aim of this study was to develop and validate a multifactorial falls risk assessment based on a medical and physiological theoretical framework that would help to guide fall prevention interventions and be feasible to use in clinical settings. We report on (a) the ability of the individual risk assessment items to discriminate between multiple fallers and non–multiple fallers, (b) the predictive accuracy of the assessment in an external sample, (c) the test–retest reliability of the assessment items, and (d) the acceptability of the assessment when used in clinical practice.

Methods

Selecting Assessment Measures

Initially, we selected a range of simple tests that covered five major physiological domains of falls risk as used in the Physiological Profile Assessment (8): vision, lower limb sensation, lower limb strength, reaction time, and standing balance. Test selection criteria were that each test was able to be administered quickly with the use of minimal equipment.

Tests of visual acuity, contrast sensitivity, depth perception, and visual field were considered for assessing vision. Of these, a test of low (10%) contrast visual acuity (Figure 1A) (8) measured at a distance of 3 m was selected because it had acceptable predictive value (notably, superior predictive ability to the standard test of high contrast visual acuity (14)) and was feasible for use in clinical settings. Tests of tactile sensitivity, vibration sense, and proprioception were considered as tests of peripheral sensation. A tactile sensitivity test at the ankle (Figure 1B) using a single Semmes–Weinstein-type pressure monofilament was selected as it required only one small equipment item and had good inter-rater reliability and acceptable predictive value with respect to multiple falls (15). The monofilament was applied three times to the lateral malleolus of the ankle while the participant kept their eyes closed (13).

Three performance tests were included to provide measures of balance (near tandem stand test), composite lower limb strength (sit-to-stand test), and coordinated stepping (alternate step test)—complementary measures for guiding physiotherapy interventions.
The near tandem stand test was selected as poor performance in this test is associated with an increased risk of falls in older people (16) and because it provides a measure of lateral stability—a crucial factor for maintaining balance and preventing sideways falls (17). The near tandem stand test is a modification of the tandem stand test, which has previously been too difficult for many older people to complete (16). For this test, the participant stands with their eyes closed and their bare feet in a near tandem position; feet parallel and separated laterally by 2.5 cm, and the heel of the front foot 2.5 cm anterior to the great toe of the back foot (Figure 1C).

The sit-to-stand test with five repetitions (Figure 1E) was selected as a functional measure that is underpinned to a large degree by lower limb strength (18) but also requires speed and balance (19). Previous studies have also reported that the sit-to-stand test is a significant predictor of falls in older community-living people (12,20). For this test, participants were asked to rise from a standard height (43 cm) chair, five times as fast as possible with their arms folded. Participants undertook the test barefoot, and performance was measured in seconds, as the time from the initial seated position to the final seated position after completing five stands.

The alternate step test is a modified version of the stool stepping task—one of the 14 components of the Berg Balance Scale, which can predict falls risk in older people in several settings (4,21). The alternate step test requires speed, strength, and balance as it involves placing the whole foot (shoes removed) onto a step, which is 18-cm high and 40-cm deep and alternating with the right and left feet, for a total of eight repetitions as quickly as possible (Figure 1D). The time taken to complete the task is the score.

In a previous study, we have found that while loading on a common mobility factor, poor performances in both the alternate step and sit-to-stand tests provide significant additional value in predicting multiple falls than a poor performance in either test alone (20). Other performance measures were also considered for inclusion in the falls risk assessment (20); however, these items were omitted after consideration of their validity, reliability, and feasibility for use in clinical settings.

Three additional items were added to the assessment (see Figure 2). These included a question about previous falls: “Has the patient had one or more falls in the previous 12 months?” and two questions regarding medication usage: “Does the patient currently take 4 or more medications (excluding vitamins and minerals) per day?” and “Does the patient currently take any psychoactive medications?”. These measures have been shown to be independent risk factors for falls in many previous studies (12,22–24), so were included in this assessment to address these important domains.

Tool Development

Data from 764 community-living participants who took part in three falls risk factor studies (13,14,25) were pooled for the assessment tool development study. These participants resided in Sydney, Australia, and were aged 63–95 years (mean = 75.31 years, \(SD = 5.76\); 163 [21%] men). The prevalence of self-reported medical conditions and limitations in activities of daily living in the pooled study sample are shown in Table 1. Exclusion criteria were similar for each study and included blindness, minimal English language skills, and cognitive impairment (defined as a short portable mental status questionnaire [SPMSQ] score of \(\leq 7\) (26) or a Mini-Mental State Examination score <24 (27)).

The aim of the tool development study was to determine performance cut-points for the assessment measures and to determine the ability of the individual assessment items to discriminate between multiple fallers (two or more falls) and non–multiple fallers (one or no falls) prospectively determined over 1 year. Falls were defined as “events that resulted in a person coming to rest unintentionally on the ground or other lower level, not as the result of a major intrinsic event or an overwhelming hazard” (28). Falls were monitored for 1 year with monthly fall calendars, and if calendars were not returned, further contact was made by telephone.

External Validation

The external validation study was undertaken to determine the ability of the combined risk assessment measures to discriminate between multiple fallers and non–multiple fallers, prospectively measured over a 1-year period, in an external sample of older people (29). A further aim was to determine the absolute risk of future falls predicted by the identification of multiple risk factors. Three hundred and sixty two community-living people were drawn from a study investigating falls prevention interventions in Sydney, Australia (control participants only were included here) (29). Participants were aged 74–98 years (mean = 80.25 years, \(SD = 4.5\)) and 128 (35%) were men. The prevalence of self-reported medical conditions and limitations in activities of daily living in this sample are shown in Table 1. Exclusion criteria, method of falls surveillance, and falls definition were in the same as those included in the development study.

Test–Retest Reliability

A subgroup of 30 people (10 men and 20 women) from the external validation study (29) took part in the reliability study. These participants were aged 75–90 years (mean = 80.1, \(SD = 4.0\)) and underwent the physical assessments (sit-to-stand test, alternate step test, near tandem stand test, visual acuity test, and tactile sensitivity test) on two occasions, 2 weeks apart, with the same assessor administering the tests on both occasions.

Feasibility in Clinical Settings

To assess the clinical acceptability of the tool, fall risk assessment kits were provided to 32 clinicians (18 general...
The kits included a test administration manual, testing equipment, patient information sheets pertaining to specific risk factors, and assessment forms, and training was provided by one of the authors (A.T.) to all clinicians. They trialled the assessment with their older patients for a 3- to 4-month period and then completed an evaluation regarding its utility.

**Statistical Analysis**

In the development study, cut-points for maximizing the sensitivity and specificity for each continuously scaled test

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**Figure 2.** The (QuickScreen) falls risk assessment form.
with regard to falls were determined using the Youden Index (30). Relative risk values were also calculated to determine the relative strength of different predictors. In the validation study, the risk assessment tool’s discrimination (ie, ability to distinguish high-risk participants from low-risk participants) was assessed using the area under the receiver operating characteristic curve (AUC) (31). To ascertain the likely performance of our model in other samples, a bootstrap-adjusted AUC was obtained by averaging the difference between the AUC on the original data set and each of 1,000 bootstrapped samples (32). Observed and predicted probabilities of multiple falls, stratified by the total number of risk factors identified by the falls risk assessment, were calculated, and the agreement between the observed and predicted probabilities, or calibration, was then tested with the Hosmer–Lemeshow statistic.

Results

Tool Development

Of the tool development sample, 450 people (59%) reported no falls, 164 people (21%) reported one fall, and 150 people (20%) reported two or more falls during the 12-month follow-up period. The results of the receiver operating characteristic curve inspections are shown in Table 2. For the prediction of multiple falls, the sensitivity values ranged from 18% to 64%, and the specificity values ranged from 50% to 88%. The AUCs for the individual assessment measures were only fair at discriminating between multiple fallers and non–multiple fallers (range 0.53–0.66); however, the relative risk (RR) values ranged from 1.42 to 2.35, indicating that poor performance in the assessment measures was associated with a significantly increased risk of future multiple falls.

External Validation Study

Of the 362 people in the external validation study, 183 people (51%) had no falls, 99 people (27%) had one fall, and 80 people (22%) reported two or more falls during the 12-month follow-up period. The AUC of the combined risk assessment measures was 0.72 (95% confidence interval [CI] = 0.66–0.79), and the bootstrap-adjusted AUC was also 0.72, which indicates a good overall ability of the tool’s combined risk factors score to discriminate between the 80 multiple fallers and 282 non–multiple fallers.

Table 2. Test Performance Criteria for Predicting Multiple Fallers in Tool Development Sample

<table>
<thead>
<tr>
<th>Variable</th>
<th>n</th>
<th>Cut-Point</th>
<th>Number of multiple fallers (%)</th>
<th>Sensitivity, % (95% CI)</th>
<th>Specificity, % (95% CI)</th>
<th>AUC</th>
<th>RR (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Falls in past year</td>
<td>764</td>
<td>≥1</td>
<td>150 (20)</td>
<td>57 (49–65)</td>
<td>66 (65–72)</td>
<td>0.66</td>
<td>2.35 (1.76–3.13)</td>
</tr>
<tr>
<td>Total medications</td>
<td>764</td>
<td>≥4</td>
<td>150 (20)</td>
<td>64 (56–72)</td>
<td>55 (51–59)</td>
<td>0.60</td>
<td>1.88 (1.39–2.55)</td>
</tr>
<tr>
<td>Psychoactive meds</td>
<td>764</td>
<td>≥1</td>
<td>150 (20)</td>
<td>18 (12–25)</td>
<td>88 (85–90)</td>
<td>0.53</td>
<td>1.43 (0.99–2.04)</td>
</tr>
<tr>
<td>Visual acuity test (MAR)</td>
<td>764</td>
<td>≥2.3</td>
<td>150 (20)</td>
<td>64 (56–72)</td>
<td>51 (47–55)</td>
<td>0.61</td>
<td>1.64 (1.21–2.21)</td>
</tr>
<tr>
<td>Touch sensation test</td>
<td>328</td>
<td>&gt;4.29</td>
<td>65 (20)</td>
<td>45 (32–57)</td>
<td>66 (60–71)</td>
<td>0.57</td>
<td>1.42 (0.92–2.18)</td>
</tr>
<tr>
<td>(lg10 mg pressure)*</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Alternate step test (s)†</td>
<td>287</td>
<td>≥10</td>
<td>52 (18)</td>
<td>50 (36–64)</td>
<td>66 (59–72)</td>
<td>0.58</td>
<td>1.68 (1.03–2.74)</td>
</tr>
<tr>
<td>Sit-to-stand test (s)†</td>
<td>287</td>
<td>≥12</td>
<td>52 (18)</td>
<td>64 (49–76)</td>
<td>50 (44–57)</td>
<td>0.57</td>
<td>1.59 (0.95–2.65)</td>
</tr>
<tr>
<td>Tandem stand test (s)†</td>
<td>287</td>
<td>&lt;10</td>
<td>52 (18)</td>
<td>46 (32–60)</td>
<td>69 (62–74)</td>
<td>0.57</td>
<td>1.65 (1.02–2.69)</td>
</tr>
</tbody>
</table>

Notes: AUC = area under receiver operating characteristic curve, CI = confidence interval, MAR = minimum angle resolvable, RR = relative risk.

* Data from one study sample (13).
† Data from one study sample (25).
The proportion of people predicted and observed to fall based on the number of risk factors identified and the associated likelihood ratios are shown in Table 3. These results indicate that the predicted probability of future multiple falls increases from 7% with the identification of zero or one risk factor up to a probability of 49% with the identification of six or more risk factors. The predicted and observed proportions are closely related as demonstrated by the Homer–Lemeshow test result \( p = .35 \). This result confirms the validity of the tool items and shows that the performance cut-points selected in the initial development study can be generalized to a second external sample.

The accuracy of the individual fall risk assessment measures in discriminating between the non–multiple fallers and multiple fallers in the external validation sample is indicated by the sensitivity, specificity, AUC, and RR values included in Table 4. The sensitivity values are slightly higher than those achieved in the tool development sample (range 26%–70%), and the specificity, AUC, and RR values are similar. These results confirm the findings of the development study that there is an association between performance in the individual assessment items and risk of future falls.

**Feasibility of the Falls Risk Assessment**

The 32 clinicians in the feasibility study assessed an average of nine patients each \( (SD = 5.7) \). The evaluation showed that most clinicians \( (72\%) \) found that the assessment took less than 10 minutes to administer, making it feasible for use in a normal consultation time. When the clinicians rated the individual measures on a 4-point scale, from “not at all useful” to “very useful”, 88% of the responses rated the assessment measures as “useful” or “very useful”. Ninety-four percent of respondents also stated that they would continue to use the assessment in their routine patient care.

**Discussion**

This article reports the development, external validation, test–retest reliability, and clinical acceptability of a falls risk assessment tool for use in primary care with community-living older people.

The risk assessment discriminated between multiple fallers and non–multiple fallers with an accuracy of 72%, which compares well with other similar assessments for identifying multiple fallers in this setting \( (33–35) \) and exceeds the predictive ability of the Timed Up and Go test, functional reach, and the Falls Risk for Older People in the Community \( (9) \). The tool also demonstrated good calibration, with the observed and predicted absolute risk values for different predictor scores being well matched.

Multiple fallers performed significantly worse than non–multiple fallers in all of the assessment measures, with RR values ranging from 1.4 to 2.4 in the development study. These results were confirmed in the external validation study, where RR values ranged from 1.2 to 2.8. Consistent with previous studies \( (3) \), each individual measure had only moderate predictive ability, which reflects the multiple...
causes of falls and the limitations of single item screens (20). However, when used in combination, the assessment measures are useful in discriminating between multiple and non–multiple fallers. Furthermore, a major benefit of this assessment is that it allows for the summing of predictors to calculate an individual’s prognosis for future falls (2). Our analyses showed that the identification of zero or one fall risk factors resulted in a 7% probability of future multiple falls. The probability of multiple falling approximately doubled with the presence of two or three risk factors and increased with the addition of further risk factors up to 49% in those with six or more risk factors.

Clinical trials have shown that individually designed multifactorial intervention strategies can prevent falls (1). Strategies used in these trials have included visual assessment and correction, medication management and specific balance, and strength training. We suggest that this falls risk assessment could assist with guiding the implementation of multifactorial intervention approaches.

It is acknowledged that the study has certain limitations. First, it is acknowledged that the assessment cannot be considered a comprehensive geriatric assessment for falls as could be provided in a falls clinic or secondary care setting. The assessment, however, can be used to assist in guiding evidence-based interventions for important risk factors and thus provide a valuable assessment for primary health care settings, in particular, rural and remote settings where alternative services are not available. This approach of targeting important risk factors has proved to be effective in related work on the management and prevention of cardiovascular disease (36). Second, the falls risk assessment was devised to provide a simple “pencil and paper” assessment of risk factors for falls. “Predictive value—feasibility trade-offs” were necessary since it was not possible to use the most direct measures of certain risk domains, such as lower limb strength, due to equipment requirements. Furthermore, the inclusion of past falls as a predictor of future risk may be subject to recall bias. The use of cut-points rather than continuous data also inevitably leads to loss of information (37), as might the simple summing of risk factors (instead of computing and summing weighted loadings for independent predictors). However, the results of the external validation study demonstrated good generalizability of the tool to another sample despite these possible limitations. Further analyses could also be undertaken to directly compare the predictive ability of this falls risk assessment with other risk assessments used in this setting.

The prevalence of chronic medical conditions in our study participants was comparable with that identified in the general Australian population of older people (38); however, we excluded people with a cognitive impairment. As fall rates are high in older people with cognitive impairment, a validated measure of cognition such as the SPMSQ (26) would compliment the fall risk assessment.

In summary, this falls risk assessment is a multifactorial, reliable, and externally validated assessment tool. It has advantages over other risk factor assessments since it can predict future fall risk, gives a meaningful score of probability of future falls, and can help to guide the implementation of interventions found to be effective in clinical trials. Clinicians who have used the assessment report that it is a practical assessment, which can be incorporated into clinical practice.

Funding

This work was supported by National Health and Medical Research Council (Population Health Capacity Building Grant in Injury Prevention, Trauma, and Rehabilitation and Health Research Partnership Grant: Prevention of Older People’s Injuries). The sponsors played no role in the design or execution of the study, analysis and interpretation of data, or writing of the manuscript.

Conflict of Interest

The falls risk assessment “QuickScreen” is commercially available from the Prince of Wales Medical Research Institute.

References


