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Fall-risk screening test: A prospective study on predictors for falls in community-dwelling elderly

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Abstract

This large prospective cohort study was undertaken to construct a fall-risk model for elderly. The emphasis of the study rests on easily measurable predictors for any falls and recurrent falls. The occurrence of falls among 1285 community-dwelling elderly aged 65 years and over was followed during 1 year by means of a "fall calendar." Physical, cognitive, emotional and social functioning preceding the registration of falls were studied as potential predictors of fall-risk. Previous falls, visual impairment, urinary incontinence and use of benzodiazepines were the strongest predictors identified in the risk profile model for any falls (area under the curve [AUC] = 0.65), whereas previous falls, visual impairment, urinary incontinence and functional limitations proved to be the strongest predictors in the model for recurrent falls (AUC = 0.71). The probability of recurrent falls for subsequent scores of the screening test ranged from 4.7% (95% Confidence Interval [CI]: 4.0–5.4%) to 46.8% (95% CI: 43.0–50.6%). Our study provides a fall-risk screening test based on four easily measurable predictors that can be used for fall-risk stratification in community-dwelling elderly.

Keywords: Fall-risk; Elderly; Screening test

1. Introduction

Falls leading to physical trauma and restriction of activity are among the principal causes of morbidity in the elderly [1]. Thirty percent of people over the age of 65 years who live in the community fall at least once per year and this proportion increases strongly with age [2–4]. About 40% of all serious fall injuries among elderly resulted in hospital admission and after hospitalization, 30–40% of these patients are transferred to a nursing home [5]. As a consequence, the health care costs associated with falls and fall-related injuries are high [6]. Serious injuries caused by a fall include fractures, joint dislocations, and head trauma. Psychological trauma such as fear of falling is another consequence of falls which may lead to self-imposed restrictions in activity and, consequently, loss of independence [3,7].

Falls are a multicausal phenomenon with a complex interaction between intrinsic (within-subject) factors and extrinsic or environmental factors [8,9]. About 50% of fallers in the community experience two or more falls per year [4]. Elderly with multiple falls need extra attention of health professionals because multiple fallers in general have a worse health status and significantly more intrinsic predictors than single fallers [4,10,11]. The most important intrinsic predictors for falls have been shown to be decreased mobility, cognitive impairment, use of medication, depression, urinary incontinence, stroke, postural hypotension, dizziness, fear of falling, impaired vision, and a history of previous falls [2,10,12,13]. Many, but not all, of these predictors are clues for prevention. A multiple predictor intervention strategy appears to be effective in reducing the risk of further falls and limiting functional impairment. Several studies among elderly living in the community have shown that the rate of falling in the group assigned to such an intervention was 9–20% lower than that in the control group [14–18].

However, because of feasibility, efficiency, and cost-effectiveness, intervention should preferably be focussed on people at high risk for falls. Selection of community-dwelling elderly with a high risk of falling is difficult. Several studies on the prediction of falls and recurrent falls in elderly people have been published [13,19], al-

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though mostly without evidence of feasibility. The aim of the present study, using data from a large prospective cohort of elderly, including similar numbers of men and women, is to develop a fall-risk screening test for community-dwelling older adults. The screening procedure in this study is based on simple predictors, which can be measured without much effort. The emphasis of this study, embedded in the multidisciplinary Longitudinal Aging Study Amsterdam (LASA), rests on identifying subgroups with highest risk and not on the identification of causal risk factors.

2. Methods

2.1. Subjects

The study was conducted within the framework of the Longitudinal Aging Study Amsterdam (LASA), a 10-year multidisciplinary cohort study on predictors and consequences of changes in autonomy and well-being in the aging population in the Netherlands [20]. A random sample of older men and women (aged 55–85 years) stratified by age, sex, and expected mortality, was drawn from the population registers of 11 municipalities, in three regions of the Netherlands. The sample represents the older Dutch population with respect to geographic region and degree of urbanization. The cohort was originally recruited for the study Living Arrangements and Social Networks of Older Adults (n = 3805; response rate, 62.3%). Nonresponse was higher ($P < 0.001$) among the oldest old persons because of physical or cognitive impairment [21]. Data collection procedures and nonresponse have been described in more detail elsewhere [22,23].

The present study on predictors for falls in the elderly was performed within a subsample of the LASA population. The subsample comprises LASA participants who were born in 1930 and before (aged 65 years and older as of 1 January 1996). The data collection was performed in 1995/1996 and, after the data collection, a follow-up study on falls was undertaken. Community-dwelling subjects who participated in the data examination in 1995/1996 (N = 1420), were eligible for participation in the follow-up study on falls. The criteria for selection were age (65 years and over), living arrangements (community-dwelling elderly) and participation in the previous data collection cycle (which was prior to the fall follow-up). No further exclusion criteria were used. Of these, 1374 subjects agreed to be enrolled in the follow-up study. Of the 46 participants not included in this study, 31 died before the follow-up study started, 8 could not participate because of severe physical and/or mental health problems and 7 refused. Nonresponse of the follow-up study on falls (3.2%) was associated with gender ($P < 0.05$) and age ($P < 0.01$) but not with previous falls. The oldest and female subjects were less likely to respond.

2.2. Data collection

The determinants of functioning in older adults as measured in the LASA study were selected as potential predictor variables for falls [24]. Four components of functioning were distinguished: physical, cognitive, emotional and social.

Sociodemographic characteristics included age, gender, household composition (living alone or with other persons), education (ranging from 1 [elementary education not completed] to 9 [university education]), and urbanization (ranging from 1 [rural] to 4 [highly urban]). Anthropometry included body weight, body height and body mass index (BMI).

Self-reported data were obtained for several chronic diseases and included chronic obstructive pulmonary disease, cardiovascular disease, stroke, urinary incontinence, diabetes mellitus, joint disorders and malignant neoplasms [25,26]. Medication use was assessed by recording the medications of the participant directly from the containers regardless of whether or not prescribed. The anatomical-therapeutic-chemical coding and categorization system for medication was used to classify medication. Depressive symptoms were assessed using the Center for Epidemiologic Studies-Depression scale (CES-D) [27,28] (score range: 0–60). Cognitive status was estimated using the Mini Mental State Examination (MMSE) [29] (score range: 0–30). Participants were classified as having a cognitive impairment if their MMSE score was 24 or less [29], and were classified as depressed if their CES-D score was 16 or more [27].

Assessment of physical function included questions on any problems of the feet (e.g., sores, corns, skewed toes, amputation of toes or foot, insufficient muscle function), dizziness (lightheadedness, regular occurrence), perception impairments [25] and functional limitations [30,31]. Functional limitations were considered to be present when the participant reported difficulties with at least two of the following three activities: climbing stairs, using own or public transportation or cutting his or her own toenails. Poor distant vision and hearing impairment were ascertained by questioning the participant on whether he/she could recognize someone's face at a distance of 4 meters (with glasses or contact lenses if needed) and whether he/she could follow a conversation in a group of four persons (with a hearing aid if needed). Blood pressure and heart rate were measured in sitting position. Postural blood pressure change was measured after the participant was in a supine position for 5 minutes and subsequently stood for 1 minute [32]. A drop of $\geqslant 20$ mmHg in systolic blood pressure and/or a drop of $\geqslant 10$ mmHg in diastolic blood pressure were defined as orthostatic hypotension [32]. In the expiratory peak flow test [33], the participant was asked to expire three times as hard and fast as possible into the peak flow instrument. The best out of three maximal attempts was used as the definitive test. The test was used as a measurement, which gives information on physical fitness.

Level of activity and mobility included handgrip strength [34,35], three physical performance tests [36] and a questionnaire for the elderly which covered household activities, sports, and leisure activities during the previous 2 weeks [37,38]. Walking, bicycling, sport activities, light and heavy housekeeping activities were summed to a physical activity score (range: 0–5). Respondents not participating in any activity were given 0 points, whereas 5 points corresponded to participation in all five activities. The physical performance tests were adapted from validated tests used in the Established Populations for the Epidemiologic Study of the Elderly and in the US Third National Health and Nutrition Examination Survey. Physical performance tests included: time needed to walk 3 meters back and forth; time needed to stand up and sit down five times with arms folded (chair stands); and the ability to stand in tandem-stand (one foot placed behind the other on a straight line) for at least 10 seconds. The three items were summed to a physical performance score (range: 0–12) by giving for each physical performance test a score 1 to 4 points corresponding to the quartile of the distribution of time needed. Those subjects who did not complete the test were given the score 0. The more time was needed, the lower the physical performance scores. Handgrip strength was measured using a strain-gauged dynamometer. Handgrip strength is a reliable test (coefficient of variation 3–6% in older persons). Respondents were asked to perform two maximum force trials with each hand. The maximum values of the left- and right-hand grip measurements were summed for this analysis to remove consideration of hand dominance.

Other potential fall-related variables included questions on falls in the past year, alcohol consumption [25], smoking [25], and loneliness [39]. Fear of falling was ascertained using a modified version of the Falls Efficacy Scale (FES) developed by Tinetti et al. [40]. Each participant was asked to identify how confident he or she felt about carrying out each of 10 activities of daily living without falling (total score, 0–30). Instead of the original 10-point rating scale, the answers in this study were rated on a scale from 0 (no confidence) to 3 (completely confident).

To facilitate clinical interpretation, all categorical and continuous variables were dichotomized before they were entered into the analysis. Variables were dichotomized at the clinically acceptable cut-off point [27,29]. If there was no such cut-off point, the risk gradients within deciles and quartiles were considered [41]. Cut-off points were defined for handgrip strength (for women: < 30 kg and for men: < 50 kg), physical performance (< 5 points of the total score), physical activity (< 3 points of the total score), and fear of falling ($\geqslant 3$ points).

2.3. Outcome

A fall was defined as an unintentional change in position resulting in coming to rest on the ground or other lower level [42]. Fall events during 1 year of follow-up were ascertained with a “fall calendar.” Participants were instructed to complete the calendar weekly and to mail it to the institute at the end of every 3 months. They were contacted by telephone every 3 months if the procedure of the fall calendar was too complicated for them, if no calendar was returned even after a reminder, or if the calendar was completed incorrectly. Proxies were contacted if this procedure failed. Among the 1374 participants, 1285 (94%), 656 women and 629 men, completed all four periods of 3 months, whereas 89 completed three periods or less. Of these, 38 died during the follow-up, 49 were not able to complete one or more periods because of severe health problems, and two were lost to follow-up. In comparison with the 1285 participants, age, gender, and previous falls were not different in the 89 participants who were excluded from this study. For falls, two outcome variables were defined: any fallers ($\geqslant 1$ falls) were contrasted with “nonfallers,” and “recurrent fallers” ($\geqslant 2$ falls) were contrasted with participants who experienced no falls or only one fall ($\leqslant 1$ falls).

2.4. Statistical analyses

The relationship between falls and potential predictors was examined by means of logistic regression analysis, which was first performed for each predictor separately. In the bivariate logistic regression analysis, we identified predictors for any falls and recurrent falls. We did not adjust for age, gender or other variables since the emphasis in this study was centered on identifying subgroups with highest risk and not on the identification of causal risk factors. Risk profile models for falls were obtained by multiple logistic regression (forward stepwise selection, $P < 0.05$). Initially all variables that were associated with any falls or recurrent falls ($P < 0.10$) were entered into the regression model for any falls and recurrent falls. The sequence of potential predictors, which were entered into the regression model, was based on the simplicity of the study variables. Questionnaires had priority over tests. The predictive power of the risk profile model was determined using the area under the Receiver-Operating Characteristics (ROC) curve (AUC). To enable computation of the risk for falls and recurrent falls of future respondents, the regression coefficients associated with the identified predictors in the final logistic regression model were transformed (multiplied by 5 and rounded off to the nearest integer) into simple scores that can be added up to obtain an aggregate score. The individual risk for falls and recurrent falls can be computed by substituting 0.2 multiplied by the aggregate score instead of $b_1x_1 + b_2x_2 + \ldots$ in the formula $P = 1/\{1 + e^{-(a+b1 \times 1+b2 \times 2+\ldots)}\}$. In addition, sensitivity, specificity, positive predictive value (PV+) and negative predictive value (PV−) per score were calculated.

3. Results

The mean age was 75.2 (6.5 years, range 64.8–88.6 years). The cumulative incidences of any falls and recurrent

Table 1
Cumulative incidences of any falls (⩾1 fall) and recurrent falls (⩾2 falls) in 1 year of follow-up for women and men (n = 1285)

Age (years)	n	Cumulative incidence of any falls (%)	Cumulative incidence of recurrent falls (%)
Women			
65–70	172	36.6	11.6
70–75	175	38.3	8.0
75–80	138	41.3	14.5
⩾80	171	33.3	9.9
Total	656	37.2	10.8
Men			
65–70	178	25.3	6.7
70–75	138	26.1	13.0
75–80	129	31.0	11.6
⩾80	184	34.2	16.8
Total	629	29.3	12.1

falls in 1-year of follow-up for women and men are shown in Table 1. At least one fall occurred in 33.3% (95% CI: 30.7–35.9%) of the participants. Single falls were reported by 21.9% (95% CI: 19.6–24.2%) and recurrent falls by 11.4% (95% CI: 9.7–13.1%) of the participants. The difference of the cumulative incidence of recurrent falls between women and men was not significant, whereas the percentage of single falls was significantly higher in women than in men ($P < 0.01$). Older age was associated with recurrent falls in men, but not in women ($P < 0.01$ and $P = 0.86$, respectively). In 1 year of follow-up, 28 fractures were recorded, including 6 hip fractures, 3 wrist fractures, 1 fracture of the humerus and 18 other fractures. In the "no-falls" group, 5 subjects (0.6%) suffered from a fracture, in the "single fall" group 11 subjects (3.9%) and in the "recurrent falls" group 9 subjects (6.1%).

Table 2 shows the predictors measured in relation to any falls and recurrent falls. Household composition, several chronic diseases, cognitive impairment, heart rate, expiratory peak flow test, BMI, alcohol consumption, smoking, and loneliness were not significantly related to any falls or recurrent falls. The systolic criterion for orthostatic hypotension (a decrease of ⩾ 20 mmHg) was met by 10% of the participants, while 6% of the participants met the diastolic criterion (decrease of ⩾ 10 mmHg). Orthostatic hypotension was not associated with any falls or recurrent falls. Use of medication was not related to any falls or recurrent falls, except for use of four or more drugs, use of benzodiazepines, and use of antiepileptic drugs. Nine percent of the participants used nitrates, 7% anti-arrhythmic drugs, 22% antihypertensives, 2% vasodilators, 16% diuretics, 16% β-blockers, 14% benzodiazepines, 8% analgetics, 3% antidepressants, and 1% antiepileptics. Elevated risks for any falls as well as recurrent falls were observed for the following predictors: urinary incontinence, joint disorders, visual impairment, hearing impairment, functional limitations, dizziness, feet problems, chair stands, handgrip strength in men, previous falls, and fear of falling.

All variables that were associated with any falls or recurrent falls were entered into the regression model. Table 3 shows the final risk profile models including the strongest predictors for any falls and recurrent falls. Previous falls, visual impairment, urinary incontinence and use of benzodiazepines proved to be the strongest predictors for any falls and previous falls, visual impairment, urinary incontinence and functional limitations for recurrent falls. The AUC of the final risk model of recurrent falls is 0.71, which is clearly more predictive than the simplest risk model of recurrent falls including only gender and age (AUC = 0.55). The regression coefficients of the identified predictors in the final risk profile models were transformed (multiplied by 5 and rounded off to the nearest integer) into simple scores, previous falls having the highest score in each risk model. The predicted probability of recurrent falls per score (range: 0–15 points) and the prevalence of these scores are displayed in Figure 1. The prevalence of the subsequent scores varied from 1.3% (95% CI: 1.1–1.5%) to 38.3% (95% CI: 34.7–43.4%). The probability of recurrent falls ranged from 4.7% (0 points, 95% CI: 4.0–5.4%) to 46.8% (15 points, 95% CI: 43.0–50.6%). How Figure 1 is to be read can be demonstrated by the following example: 7% of the subjects scored 8 points at the final risk profile model, which was associated with a predicted probability of recurrent falls of 19%. A score of 8 points corresponded with those subjects who have a history of falls and are incontinent for urine or those subjects who have a history of falls and have functional limitations.

Table 4 shows the diagnostic and predictive values of the risk profile model for recurrent falls per score. The table demonstrates that the maximum sum of sensitivity and specificity is reached at 7 points. The positive predictive value (PV+) at this score is 24.9% (95% CI: 22.5–27.3%) and the negative predictive value (PV−) is 93.0% (95% CI: 91.6–94.4%).

When different risk profile models of any falls were constructed for women and men, previous falls and use of benzodiazepines were identified as the strongest predictors for women (AUC = 0.64) and previous falls, visual impair-

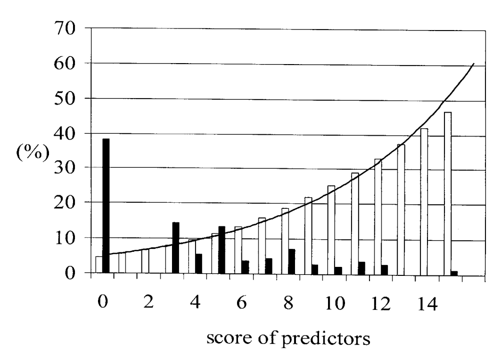

Fig. 1. The predicted probability of recurrent falls per score (clear bars, predicted probability of recurrent falls; solid bars, prevalence per score of predictors).

Table 2
Prevalence or mean ± SD, ORs and 95% CI for predictors for any falls (⩾ 1 falls) (33%) and recurrent falls (⩾ 2 falls) (11%) in 1 year of follow-up (n = 1285)

Predictors	Prevalence (%) or mean ± SD	Falls (⩾ 1 fall)[a] OR	Falls (⩾ 1 fall)[a] 95% CI[c]	Recurrent falls (⩾ 2 falls)[b] OR	Recurrent falls (⩾ 2 falls)[b] 95% CI[c]
Sociodemographics					
Age (per 10 years)	75.2 ± 6.5	1.1	(0.9–1.3)	1.4	(1.0–1.8)
Female gender	51	1.4	(1.1–1.8)	0.9	(0.6–1.3)
High education level[d]	12	1.5	(1.0–2.0)	1.9	(1.2–2.9)
High/moderate urbanization level[d]	76	1.4	(1.0–1.8)	1.7	(1.1–2.7)
Chronic diseases					
Urinary incontinence	24	1.8	(1.4–2.4)	2.3	(1.6–3.2)
Joint disorders[d]	47	1.5	(1.2–1.8)	1.4	(1.0–2.0)
Chronic disease (⩾ 1 disease)	73	1.3	(1.0–1.7)	1.1	(0.8–1.7)
Medication use (⩾ 4 drugs)	25	1.3	(1.0–1.7)	1.5	(1.0–2.3)
Use of benzodiazepines	14	1.6	(1.2–2.3)	1.4	(0.9–2.2)
Use of antiepileptic drugs	1	1.7	(0.6–5.2)	3.5	(1.1–11.5)
Depression (n = 1262)[d]	13	1.4	(1.0–2.0)	1.6	(1.0–2.5)
Physical function					
Visual impairment[d]	19	1.7	(1.3–2.3)	2.6	(1.8–3.8)
Hearing impairment[d]	36	1.4	(1.1–1.8)	1.8	(1.3–2.5)
Functional limitations (n = 1270)[c]	27	1.6	(1.2–2.0)	2.3	(1.6–3.3)
Dizziness	14	1.5	(1.1–2.0)	1.7	(1.1–2.6)
Feet problems[d]	28	1.4	(1.1–1.8)	1.5	(1.1–2.2)
Low level of activity and mobility					
Physical activity (n = 1280)[d]					
(total score: 0–5; per point)[e]	3.4 ± 1.3	1.1	(1.0–1.2)	1.3	(1.1–1.5)
No walking	16	1.2	(0.8–1.6)	1.3	(0.9–2.1)
No cycling	43	1.2	(1.0–1.5)	1.7	(1.2–2.4)
No sports	63	0.9	(0.7–1.2)	1.2	(0.8–1.7)
No light household tasks	8	1.3	(0.9–2.0)	2.8	(1.7–4.5)
No heavy household tasks	35	1.3	(1.0–1.7)	1.9	(1.3–2.6)
Physical performance (n = 1259)[d]					
(total score: 0–12; per point)[f]	7.2 ± 3.2	1.1	(1.0–1.1)	1.1	(1.1–1.2)
Walking test (score: 0–4; per point)[f]	2.3 ± 1.4	1.0	(1.0–1.1)	1.1	(1.0–1.3)
Chair stands (score: 0–4; per point)[f]	2.0 ± 1.2	1.2	(1.1–1.4)	1.4	(1.2–1.6)
Tandem stand (score: 0–4; per point)[f]	2.9 ± 1.6	1.1	(1.0–1.2)	1.2	(1.1–1.3)
Handgrip strength (per 10 kg decrease)[d]					
Women (n = 642)	42.3 ± 9.8kg	1.1	(1.0–1.3)	1.3	(1.0–1.7)
Men (n = 622)	71.4 ± 16.3kg	1.2	(1.1–1.3)	1.4	(1.2–1.6)
Other fall-related variables					
Previous falls	31	2.6	(2.0–3.3)	3.1	(2.2–4.4)
Fear of falling (n = 1260)[d]					
(total score: 0–30; per point)[g]	2.4 ± 4.1	1.8	(1.3–2.3)	2.0	(1.4–2.8)

n is mentioned when missing values ⩾ 1.
[a]"Fallers" (⩾ 1 fall) versus "nonfallers."
[b]"Recurrent fallers" (⩾ 2 falls) versus participants who experienced no falls or only one fall (⩽1 fall).
[c]OR, odds ratio; CI, confidence interval.
[d]See Methods for definition.
[e]Low score = inactive; high score = active. OR per point decrease.
[f]Low score = poor performance; high score = good performance. OR per point decrease.
[g]Low score = no fear of falling; high score = fear of falling.

ment, urinary incontinence, and dizziness were the identified predictors for men (AUC = 0.67). In the risk profile models of recurrent falls, previous falls and visual impairment proved to be the strongest predictors for women (AUC = 0.66), whereas previous falls, visual impairment, urinary incontinence, functional limitations, and low level of physical activity were the strongest predictors for men (AUC = 0.74).

4. Discussion

In this large prospective cohort study of 1285 participants, subgroups with the highest risk for falls were identified. In contrast to most other studies, the population sample in this study includes similar numbers of women and men and, moreover, this study considers a multidisciplinary set of easily measurable study variables as possible predictors of falls. Multiple regression analyses identified four predic-

Table 3
Scores, ORs and 95% CI for each predictor included in the risk profile model, obtained by multiple logistic regression (forward selection, $P < 0.05$) for any falls and recurrent falls ($n = 1285$)

	Falls[a] ($n = 1280$)					Recurrent falls[a] ($n = 1266$)			
Predictors	β	Score[b]	OR[c]	95% CI[c]	Predictors	β	Score[b]	OR[c]	95% CI[c]
Previous falls	0.90	5	2.5	(1.9–3.2)	Previous falls	0.99	5	2.7	(1.9–3.9)
Urinary incontinence	0.46	2	1.6	(1.2–2.1)	Urinary incontinence	0.53	3	1.7	(1.2–2.5)
Visual impairment	0.44	2	1.6	(1.2–2.1)	Visual impairment	0.82	4	2.3	(1.5–3.4)
Use of benzodiazepines	0.44	2	1.6	(1.1–2.2)	Functional limitations	0.54	3	1.7	(1.2–2.5)
AUC[d] = 0.65					AUC[d] = 0.71				

[a]"Fallers" (⩾ 1 falls) versus "nonfallers." "Recurrent fallers" (⩾ 2 falls) versus participants who experienced no falls or only one fall (⩽ 1 fall).
[b]The score is the regression coefficient multiplied by 5 and rounded off to the nearest integer.
[c]OR, odds ratio; CI, confidence interval.
[d]Area Under the Receiver Operator Characteristics (ROC) Curve.

tors that were significantly associated with recurrent falls: previous falls, urinary incontinence, visual impairment and functional limitations. Findings from other studies among community-dwelling elderly [2,43–49] confirm the validity of these predictors.

While the relationship of recurrent falls with previous falls, visual impairment, and functional limitations appears clear, the specific relationship of falls with urinary incontinence may not be causal and needs further research. It is suggested that urinary incontinence is caused, on the one hand, by a diminished neuromuscular functioning of the area around the bladder and, on the other hand, is associated with a decreased neuromuscular control of locomotion, which subsequently provokes falls. While most studies assessed corrected visual function with the Snellen card or equivalent, our study shows that a simple question about visual impairment ("can you recognize someone's face at a distance of 4 meters") is also predictive for falls. Self-report on functional limitations, obtained on the following items: using own or public transportation, going up and down a staircase, and cutting one's toenails, is another easily measurable predictor for recurrent falls in this study.

The predictors identified in the risk profile model for falls do not appear to be different from those of recurrent falls, except that functional limitations are identified as predictor for recurrent falls, whereas use of benzodiazepines is a predictor for any falls. Use of benzodiazepines as a predictor for any falls is also found in other studies [3,11,50,51]. In this study, the association of use of benzodiazepines with falls especially applies to women. The prevalence of use of benzodiazepines is 20% in women and 7% in men. Based upon the AUC, recurrent falls may be easier to predict than any falls. A single fall can occur once, for example in a traffic accident. However, a repetitive pattern of falling exceeds pure coincidence and, as this study shows, is linked to more intrinsic factors like urinary incontinence, vision problems and/or functional limitations. This seems to confirm the expectation that recurrent falls are caused by intrinsic factors rather than by accidental or extrinsic factors, which are difficult to predict.

The identified predictors of the risk profile models for recurrent falls were transformed into an aggregate score (range: 0–15 points). The maximum sum of sensitivity and specificity was reached with a cut-off at 7 points. Higher scores imply a probability of recurrent falls of 25% whereas participants with a score below 7 points have a probability of only 7%. The risk of recurrent falls in the whole study population is 11%. At the score of 7 or more points, the positive predictive value is 25% and the negative predictive value is 93%. Thus, 25% of the participants with a score of 7 or more points is correctly diagnosed as recurrent faller, whereas 93% of the participants with a score below 7 points is correctly diagnosed as non-recurrent faller. However, the choice of the "best" cut-off in this screening test is not merely a statistical decision. The "best" cut-off must be chosen according to the relative costs (not necessarily financial) of the screening test, which is related to the false positives and false negatives, and to the prevention strategy that will follow after a positive test [52].

Table 4
Diagnostic and predictive values of the risk profile model for recurrent falls[a] per score ($n = 1266$)

Score[b]	Sensitivity (%)	Specificity (%)	PV[+c]	PV[−c]
0	100	0	11.4	0
3	83	41	15.4	95.1
4	74	56	17.8	94.3
5	67	62	18.4	93.6
6	57	76	23.0	93.2
7	54	79	24.9	93.0
8	47	84	27.0	92.5
9	33	90	29.0	91.2
10	28	92	31.5	90.9
11	24	94	35.0	90.7
12	15	97	39.6	89.9
15	4	99	37.5	89.0

[a]"Recurrent fallers" (⩾2 falls) versus participants who experienced no falls or only one fall (⩽1 fall).
[b]The score is the regression coefficient multiplied by 5 and rounded off to the nearest integer.
[c]Positive predictive value, negative predictive value.

The predictive value of our test for recurrent falls is rather low and therefore implementation of the fall-risk screening test is not yet recommended. To achieve "successful" implementation of the test, two important but rather incompatible criteria should be fulfilled: simple predictors, which can be used in practice without much effort, and a high predictive value of the screening test. In our study, more sophisticated measurements may improve the predictive value of the test but may at the same time increase the difficulty of implementation. Implementation of the models in general practice is only meaningful when the predictive value is raised and when the validity of the test has been replicated in other elderly populations. When validated, the screening test can facilitate intervention studies to prevent falls and can help health professionals in the prevention of further falls. Currently, health professionals seem to be predominantly focused on the injury caused by falls, whereas the underlying cause, the functional consequences, and the possibilities for future prevention are often neglected. However, as other studies have shown, treatment of the risk factors may reduce the risk of falls by 9–20% [14–18]. If the same percentage reduction applies to the consequences of falls, this may lead to a substantial reduction of morbidity and health care costs.

The screening test is not applicable to other populations such as institutionalized elderly since the risk profile model is specifically based on this population sample of community-dwelling elderly. The risk profile for older, institutionalized elderly, constructed for recurrent falls in a previous study [10], included the predictors: mobility impairment, history of stroke, cognitive impairment, dizziness, and postural hypotension. The differences in risk profile models may be explained by differences in age (mean age 75 vs. 83 years) and residence (independent vs. institutionalized elderly). In a previous retrospective study on falls and fractures among community-dwelling participants of LASA [2], urinary incontinence, impaired mobility, use of analgetics, and use of antiepileptic drugs proved to be the predictors most strongly associated with recurrent falls. However, in that study, specific fall-related predictors, such as previous falls, were not assessed. Impaired mobility or inactivity were not identified as predictors for recurrent falls in the present study, but when functional limitations are replaced by physical activity in the final risk profile model, the same AUC (i.e., AUC = 0.71) is found.

A limitation of our study is that the outcome "injurious falls" was not determined. The number of hip fractures, observed in a 1-year follow-up, was too limited for statistical analyses and other severe traumas, as a consequence of falling, were not recorded. Furthermore, general practitioners were not involved in this study and therefore it is unknown how many participants visited their general practitioner after a fall accident.

In conclusion, the results in our study show that in community-dwelling elderly, recurrent falls can be predicted by four predictors: previous falls, visual impairment, functional limitations and urinary incontinence. When compared to the predictors for recurrent falls which are most frequently used by health professionals, namely age and gender, the final risk profile of recurrent falls has an important added value (AUC = 0.55 vs. AUC = 0.71, respectively). An additional advantage is that the screening test is easy to perform and is not time-consuming as it consists of a few simple questions. Before implementing our test in practice a higher predictive value and a replication of its validity in other community-dwelling populations are desirable. When validated, the screening test can facilitate intervention studies to prevent falls.

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