Risk factors for serious fall related injury in elderly women living at home

A Bergland, T B Wyller

Objectives: To study whether balance, function, and other health status indicators can predict serious fall related injury in elderly women living at home.

Methods: In this prospective study, the authors took a random sample of 307 women aged 75 years and over (mean 80.8 years, response rate 74.5%), living in the community. Serious fall injuries which occurred over a period of during one year were recorded, together with baseline registrations of health, function, and tests of walking and balance.

Results: In all, 155 women (50.5%) fell one or more times. One hundred and fifty six (51%) of the 308 falls resulted in a fall related injury, 74 (24%) in a serious fall related injury, and 40 falls (13%) resulted in fractures. The presence of rheumatic disorders, inability to rise from the floor, arthrosis of the hip, having had more than one fall during the one year follow up period, and an increased tendency to sway in the frontal plane when doing a calculation task were independent and significant predictors for serious fall related injury (fractures included). The independent predictors of fall induced fractures were experiencing more than one fall in the follow up period, cognitive impairment, and receiving care from professional or other.

Conclusion: The study suggests that rheumatic disorders and the inability to get up from lying on the floor were the strongest independent risk factors for serious fall related injury. Experiencing more than one fall in the follow up period and cognitive impairment are the strongest independent predictors for fall induced fractures. Age was not a significant predictor of serious fall related injury. Assessment of these markers is feasible in a clinical setting and is a useful way of identifying those who are at risk of serious fall related injuries.

ORIGINAL ARTICLE

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alls are common in old age and frequently result in fall related injury and delayed recovery. This represents a huge burden on the individual and the community. Injuries are the sixth leading cause of death in adults of 65 years of age or more and falls are the leading cause of such injuries. Although many studies have identified risk factors for falls among the elderly in the general population, few have focused on risk factors for fall related injury.

Depending on the population under study, between 20% and 60% of the elderly suffer injuries from falls in any one year. Among elderly people living at home, almost half of the falls lead to a fall related injury. About one tenth lead to a major soft tissue injury, and about one in 20 to a fall induced fracture, but the estimates vary widely. Falling is a condition that meets all the criteria for prevention: high frequency, evidence of preventability, and a high rate of morbidity. Despite this, there is little information from prospective studies regarding the possible reasons why some falls result in injuries and others do not. Vellas et al. and Davis et al. suggested that risk factors for falls resulting in injuries may differ substantially from those for falls that do not. However, Grasso et al. state that predictors of fall related injuries, including fall induced fractures, are, to a large extent, the same as those of falls without injury.

In a previous study, we found that approximately 50% of the elderly living at home fall during the period of a year. Risk factors for falling were previous falls, osteoporosis, feeling depressed, impaired vision, a slow comfortable walking speed, not managing steps higher than 30 cm, and hypertension. The aim of this work was to study the impact of balance, function, and other health status indicators (including medication and illnesses) upon the risk of serious fall related injury or fall induced fracture in elderly women living at home. To our knowledge, no earlier studies have addressed both fall related serious injury and fall induced fracture as the main outcome of the study. Moreover, no study has addressed so many potentially relevant intrinsic predictors for serious fall related injuries and fall induced fractures.

SUBJECTS AND METHODS

A random sample of 650 women aged 75 years and above was drawn from the census files of one of the 25 local authorities in Oslo. We decided in advance that subjects should be referred to the hospital's geriatric outpatient clinic if health problems were discovered that they could not reasonably handle on their own, and for practical reasons the local authority area surrounding our hospital was chosen.

By the time of the survey, 130 individuals of those sampled were dead, had moved, or were living in an institution, and 133 refused to participate, giving a response rate of 74.5%. Those who had to be excluded were 36 women unable to reach the research office alone (by taxi if necessary), eight unable to stand for at least 60 seconds, and 15 with major cognitive impairment (score ≤8 on a short version of the Mini-Mental State Examination (MMSE)). Six (2%) died or moved to an institution during the follow up year, and data from 15 subjects could not be further analysed because of technical problems with recordings of the data, leaving data from 307 subjects available for analysis. The mean age of the participants was 80.8 years (range 75–93 years). Attendance for testing was not related to age. The study was approved by

Abbreviations: ADL, activities of daily living; CI, confidence interval; MMSE, Mini-Mental State Examination; OR, odds ratio

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the Regional Committee for Ethics in Medical Research, but the committee did not allow us to contact non-attendants.

**Power calculation**

Suppose that the true rate of serious fall related injury in the population studied is 15% among subjects with one legged stance less than median, and 30% among those with one legged stance above median. It may then be shown that a sample size of 300 implies a probability of 88% to detect a statistically significant difference in serious fall related injury prevalence between these two groups.

**Tests**

Clinical tests of balance and walking were carried out in the research laboratory. The research leader instructed the subjects and demonstrated how the tests should be performed. The subjects were allowed to practise each test once, and only one try was allowed. This limitation was set up in order not to tire the participants and also to make the test situation clinically relevant. All the participants managed sufficiently well after one trial. The tests were always performed in the same order.

**Standing on one leg, eyes open**
The subject was asked to stand on the preferred foot, to flex the opposite knee to allow the foot to rise from the floor, and to stand as long as possible with the arms hanging down. The foot being used was not allowed to move from the base position, but compensatory movements of the arms and of the lifted leg were allowed. The time (in seconds) before the subject touched the floor with the other foot was recorded. The validity and reliability of this test have been demonstrated.18 20

**Tandem stance, eyes open**
The heel of one foot was placed in front of and touching the toes of the other, the arms hanging down. The subject was not allowed to move the feet from the base position, but compensatory movements of the arms and were allowed. Whether the subject could maintain this position for at least 30 seconds was recorded. This test is also found to be reliable and valid.19 20

**Ability to climb stairs**
This was a test of ability to mount boxes of increasing heights (10, 20, 30, 40, 50, 60, and 70 cm) without using a handrail.18 The test has been evaluated for validity, though not for reliability.19 20 The height of the highest box mounted was recorded. The results were dichotomised at the median; 30 cm or less versus 40 cm or higher.

**Getting up from lying on the floor**
This was scored according to whether the subject managed without assistance or not and is a validated measurement.20

**Functional reach**
Functional reach is the maximum distance (cm) one can reach forward in the standing position while maintaining a fixed base of support. This measure is reliable, valid, and sensitive to change.19 21

**Timed up and go**
The subject was instructed to rise from a chair, walk 3 m as fast as possible, turn around, return, and sit down again, wearing regular footwear and using customary walking aids if necessary. No assistance was given.22 The outcome was the time from when the subject’s back left the back of the chair until the buttock touched the seat again. The test is a reliable, sensitive, and specific indicator of increased risk of falling.23 24

**Maximum and comfortable walking speed**
The subject was asked to walk at a comfortable speed for 29 m along a corridor, and then to walk the same distance as fast as possible.20 The test has been evaluated for validity and reliability.20 22

**Force plate tests**
A calibrated Kistler (Switzerland) force plate (40 × 60 cm) was used to measure displacement of centre of pressure with gain set at 1000. The vertical forces were recorded on a computer and expressed as position and movements in the sagittal and frontal planes. The force plate signals were sampled for one second, for a total of 15 times, with a sampling frequency of 1000 Hz. Software from PEAK (Englewood, CO, USA) was used to calculate the position and the movement of the centre of pressure, called “sway”. Before testing, the test position was demonstrated for the subjects who stood barefoot on the force plate with their feet in a fixed position (heels together, each foot toeing out at a 30° angle from the sagittal plane).

For further analyses, the force plate test data were exported to a computer program (M Guttormsen, Norwegian University of Sports and Physical Education, University of Oslo) and filtered with a second order Butterworth filter at 20 Hz, and the length (mm) of the sway path in the anterior-posterior and the mediolateral directions were then calculated. Analyses of variance showed that the variance over time was small compared with the between-subject variance, and we therefore decided to use the accumulated data from the full 15 second registration period for further analyses.

The subjects had to stand as still and as symmetrically as possible, with their hands clasped behind their backs. Spontaneous sway was measured under four different conditions with at least one minute’s rest in between: (1) with eyes open and looking at a target 4 m straight ahead; (2) blindfolded in the same position; (3) as in (1) while checking whether simple calculations presented by the research leader were correct or not; (4) with a version of Stroop’s test, where 25 coloured words representing the names of colours are shown on a white screen, but where the name of the colour does not correspond to the colour in which the word is written, and where the subject is asked to name the colour.25 Best subset regression showed that the test situation where subjects performed calculations gave the best prediction of falling, and the data from this test situation were therefore used in the further analyses.

**Indicators of health status and function**
Activities of daily living (ADL) were scored according to whether or not the subject needed assistance with indoor mobility, outdoor mobility, grooming, dressing, eating, shopping, preparing meals, heavy housework, light housework, and medication. The participants were asked to bring all current medications for verification. The drugs were coded according to the ATC coding system,27 and the number of drugs taken on a regular basis was used as a global indicator of use of medication. Factor analyses of the ADL data gave two factors with Eigenvalues over 1.0, named “personal ADL” (PADL) and “instrumental ADL” (IADL), respectively. The factor PADL contained the items grooming, dressing, toileting, and eating, and the factor IADL contained the items shopping, preparing one’s own meal, doing heavy housework, and doing light housework. Disability in PADL and IADL was defined as a dependency on at least one item within the respective factor.2 Cognitive disability was defined as less than a full score on the MMSE short version.17 Body mass index (weight (kg)/height (m)²)28 was also calculated.

The participants were asked if they had ever had any of the following diseases: stroke, Parkinson’s disease, heart disease,
Logistic regression analyses were applied to test associations between falls resulting in serious fall-related injuries and the baseline characteristics. The dependent variable, serious fall related injury or fracture, was coded 0 = experiencing one serious fall related injury or more and 1 = experiencing no fall related injury or 0 = experiencing one fracture or more and 1 = experiencing no fracture, respectively. Explanatory variables showing statistically significant associations with the outcome in bivariate analyses were finally included in a multivariate logistic regression model in order to identify independent risk factors for serious falls. A value of $p<0.05$ on the $\chi^2$ goodness of fit test was used as an indicator of a poor fit of the model to the data.

RESULTS

Eighty seven women experienced only one fall, and 68 women had two or more falls (range 2–11). More than half of the falls occurred outdoors (57.5%, 95% confidence interval (CI) 51.9 to 63.0). The number of indoor falls ranged between one and six, and for outdoors between one and eight. Most of the indoor falls occurred at home except for two falls in a theatre and one at a holiday home. In all, 308 falls were reported, of which 156 (50.6%, 95% CI 45.1 to 56.2) resulted in a fall related injury. In 74 cases (24.0%) the injury was categorised as serious. Forty falls (13.0%) resulted in fractures; 15 of the upper and 13 of the lower extremities, categorised as serious. Forty falls (13.0%) resulted in fractures; 15 of the upper and 13 of the lower extremities, categorised as serious. Forty falls (13.0%) resulted in fractures; 15 of the upper and 13 of the lower extremities, categorised as serious. Forty falls (13.0%) resulted in fractures; 15 of the upper and 13 of the lower extremities, categorised as serious.

Explanatory variables for serious fall related injury and fractures, reaching statistical significance in bivariate analyses, are shown in table 1. The occurrence of falls resulting in injury was not related to age (grouped 75–79, 80+, odds ratio (OR) 1.9, 95% CI 0.9 to 3.9) or whether the person lived alone (OR 1.4, 95% CI 0.6 to 3.1). The corresponding odds ratios for fractures were 1.5 (95% CI 0.67 to 3.3) for age and 0.85 (95% CI 0.4 to 2.0) for living alone.

The risk for serious fall related injury and fracture was significantly associated with number of falls during the follow up period, OR = 2.2 (95% CI 1.2 to 4.3) for injury and OR = 13.6 (95% CI 1.2 to 30.7) for fracture. But the experience of one or more falls during the six months before the study was a significant risk factor neither for serious fall related injury nor for fracture. Regarding the balance platform measurements, the travel distance of the centre of pressure was dichotomised between the first and the second quartile. A value in the second quartile or higher was significantly associated with number of falls during the follow up period, OR = 2.2 (95% CI 1.2 to 4.3) for injury and OR = 13.6 (95% CI 1.2 to 30.7) for fracture. But the experience of one or more falls during the six months before the study was a significant risk factor neither for serious fall related injury nor for fracture. Regarding the balance platform measurements, the travel distance of the centre of pressure was dichotomised between the first and the second quartile. A value in the second quartile or higher was associated with a threefold increase in the probability of a

### Table 1
Bivariate relations between baseline characteristics and one year occurrence of serious fall injury (fractures included) and fractures*

<table>
<thead>
<tr>
<th></th>
<th>Percentage with poor score</th>
<th>Injurious falls OR 95% CI</th>
<th>Fracture OR 95% CI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inability to get up from lying on the floor</td>
<td>21.8</td>
<td>3.7</td>
<td>1.6 to 8.5</td>
</tr>
<tr>
<td>Rheumatic disorders†</td>
<td>9.8</td>
<td>3.6</td>
<td>1.3 to 10.3</td>
</tr>
<tr>
<td>Centre of pressure travel path in the frontal plane (cutpoint between 1st and 2nd quartile) when doing a calculation task</td>
<td>2.6</td>
<td>1.2 to 5.4</td>
<td>2.0</td>
</tr>
<tr>
<td>Anthrohisis of the hipt</td>
<td>30.9</td>
<td>2.6</td>
<td>1.3 to 5.3</td>
</tr>
<tr>
<td>Inability to climb steps higher than 30 cm (cutpoint = median)</td>
<td>2.6</td>
<td>1.2 to 5.4</td>
<td>2.9</td>
</tr>
<tr>
<td>Suffering from more than three diseases (cutpoint = median†)</td>
<td>2.5</td>
<td>1.3 to 5.0</td>
<td>2.9</td>
</tr>
<tr>
<td>Use of antihypertensive drugs†</td>
<td>13</td>
<td>2.4</td>
<td>1.1 to 6.5</td>
</tr>
<tr>
<td>One legged stance (cutpoint = median)</td>
<td>2.4</td>
<td>1.1 to 5.2</td>
<td>2.4</td>
</tr>
<tr>
<td>Needs care from health professional or somebody else†</td>
<td>43.3</td>
<td>2.3</td>
<td>1.2 to 4.5</td>
</tr>
<tr>
<td>Osteoporosis†</td>
<td>22.1</td>
<td>1.9</td>
<td>0.9 to 3.8</td>
</tr>
<tr>
<td>Cognitive impairment</td>
<td>56.1</td>
<td>2.1</td>
<td>1.0 to 4.0</td>
</tr>
<tr>
<td>Impaired vision†</td>
<td>23.0</td>
<td>1.8</td>
<td>0.9 to 3.6</td>
</tr>
<tr>
<td>Maximum walking speed (cutpoint = median)</td>
<td>2.0</td>
<td>1.0 to 3.8</td>
<td>0.8</td>
</tr>
<tr>
<td>Disability in instrumental activity of daily living†</td>
<td>46.4</td>
<td>2.0</td>
<td>1.0 to 3.9</td>
</tr>
</tbody>
</table>

OR, odds ratio; CI, confidence interval.
*Dependent variable serious injury (fracture included): one serious fall injury or more = 0, no serious injury = 1 or dependent variable fracture: one fracture or more = 0, no fracture = 1.
†Self reported measure.

Logistic regression analyses (n = 307).
serious fall related injury during the follow up period. Four of the clinical tests were significant predictors of a serious fall related injury, namely: inability to rise from the floor, to climb steps and to stand on one leg, and the maximum walking speed. The strongest predictor was inability to rise from the floor. Women suffering from rheumatic disorders demonstrated an almost fourfold greater risk of serious fall related injury, and those suffering from arthrosis of the hip had a threefold greater risk (table 1).

The use of antihypertensive drugs was significantly related to serious fall related injury, but not the use of any other classes of drugs. A significant relation was observed between a submaximal score on the MMSE and a serious fall related injury. Needing care or suffering from a disability on primary or instrumental activities of daily living also predicted future falls resulting in injury (table 1).

The final models of the multivariate analyses regarding serious fall related injury are shown in table 2. The presence of rheumatic disorders or arthrosis of the hip, inability to rise from the floor, and a long centre of pressure travel path when standing still were significant and independent predictors of serious fall injuries. Having more than one fall during the follow up period, needing care, and cognitive impairment were all significant predictors of fracture (table 3).

**DISCUSSION**

This study confirms that falls may have serious consequences even for relative healthy and mobile elderly Norwegian women aged 75 years or older. The primary purpose of the work was to explore the relation between health, function, and balance on the one hand, and a serious fall related injury (including fractures) on the other. Our observation that 24% of falls resulted in serious fall related injury fits in with the finding of falls resulting in serious fall related injury. In our population, this clinical marker could identify those who had a greater risk of serious fall related injury and who were possibly more likely to benefit from intervention. Inability to rise from the floor may serve as a simple proxy measure for some of the balance, function, and health variables used in this study, and also as a marker of frailty. Cognitive impairment, the presence of at least two chronic conditions, and impaired balance and gait are associated with serious fall injury. Inability to rise from the floor appears to be a promising predictive marker for falls resulting in injury. In our population, this clinical marker could identify those who had a greater risk of serious fall related injury and who were possibly more likely to benefit from intervention. Inability to rise from the floor may serve as a simple proxy measure for some of the balance, function, and health variables used in this study, and also as a marker of frailty. Cognitive impairment, the presence of at least two chronic conditions, and impaired balance and gait are associated with serious fall injury. Inability to rise from the floor appears to be a promising predictive marker for falls resulting in injury. In our population, this clinical marker could identify those who had a greater risk of serious fall related injury and who were possibly more likely to benefit from intervention. Inability to rise from the floor may serve as a simple proxy measure for some of the balance, function, and health variables used in this study, and also as a marker of frailty. Cognitive impairment, the presence of at least two chronic conditions, and impaired balance and gait are associated with serious fall injury. Inability to rise from the floor appears to be a promising predictive marker for falls resulting in injury. In our population, this clinical marker could identify those who had a greater risk of serious fall related injury and who were possibly more likely to benefit from intervention. **Table 3 Independent risk factors for fracture:**

<table>
<thead>
<tr>
<th>Risk Factor</th>
<th>OR 95% CI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rheumatic disorders*</td>
<td>3.8 1.2 to 11.7</td>
</tr>
<tr>
<td>Inability to get up from lying on the floor</td>
<td>3.0 1.3 to 7.2</td>
</tr>
<tr>
<td>Centre of pressure travel in the frontal plane (outpoint between 1st and 2nd quartile) when doing a calculation task</td>
<td>2.4 1.1 to 5.3</td>
</tr>
<tr>
<td>Arthrosis of the hip*</td>
<td></td>
</tr>
<tr>
<td>Serious fall during the follow up period*</td>
<td>2.4 1.1 to 6.5</td>
</tr>
<tr>
<td>In none of these analyses did the $\chi^2$ goodness of fit test indicate a poor model fit.</td>
<td></td>
</tr>
</tbody>
</table>

In our study, falls that had occurred before inclusion did not predict fall related serious injury or fracture.

One reason for the high frequency of fall and fall related injury in our study may be the careful recording of falls, where the participants were encouraged to phone the research leader whenever a fall had occurred. This may to some extent have counteracted the effect of forgetting the occurrence of falls, a phenomenon believed to have a definite impact on this kind of research. 41

"Inability to rise from the floor", "rheumatic disorders", "centre of pressure travel path in the frontal plane", "arthrosis of the hip", and "inability to climb steps higher than 30 cm" were the variables that increased the risk of serious fall injury (table 1) with a factor of 2.5 or more. This corresponds well with the findings of others.29 13 14 42 43 44 45

Schwartz et al found that a history of arthritis or rheumatism was associated with a higher risk of falling, 46 but an association with serious fall injury has, to our knowledge, not been reported. Corticosteroid therapy is widely used in the treatment of rheumatic disorders 47 and corticosteroid induced osteoporosis could explain the association between rheumatic disorders and falls resulting in injury.7 Considering the wide confidence intervals in tables 2 and 3, the estimates should be interpreted cautiously.

Performance based measurements of physical capacity, particularly measurements of balance and gait impairments, are strong predictors of the risk of falling among elderly people.2 7 8 Our results and those of Cummings et al 48 show that such measurements are also important for prediction of the most damaging falls—that is, those that lead to hip fractures and other serious injuries. Inability to rise from the floor appears to be a promising predictive marker for falls resulting in injury. In our population, this clinical marker could identify those who had a greater risk of serious fall related injury and who were possibly more likely to benefit from intervention. Inability to rise from the floor may serve as a simple proxy measure for some of the balance, function, and health variables used in this study, and also as a marker of frailty. Cognitive impairment, the presence of at least two chronic conditions, and impaired balance and gait are associated with serious fall injury. 49 This fits in with our results both regarding serious fall injury, including fracture, and when looking at predictors of fracture separately. 49 In the present study, approximately 15% had to be excluded owing to poor general function and major cognitive impairment, and presumably these subjects had a higher risk of fall related injury. 50 There was also some attrition to the study in the sense that 2% died or moved to an institution. This may have been related to injuries resulting from falls. Thus, our incidence estimates may be too low.

The significance of the centre of pressure travel path is supported by a case-control study identifying the degree of displacement of the body at waist level as a risk factor for...
injuries falls. The association between abnormal balance registered by the travel path in the frontal plane and fall injuries may be explained by an increased tendency of people with balance problems to fall to the side, and falls to the side are more likely to result in fall related injury than falls in other directions. There is accumulating evidence that the effects of aging on balance is more accentuated in the medially-lateral direction. Lord et al., Maki et al., and Bergland et al found that the amplitude of movement of the centre of pressure in the medially-lateral direction is an independent and significant predictor of falls.

Physiotherapists often treat people with impaired balance in order to improve overall function and prevent further falls and fall related injury, and they use simple clinical tests to evaluate and predict function. Typical examples of performance based tests used in clinical practice are the one legged stance, stair climbing, functional reach, the timed up and go, and the ability to get up from lying on the floor. The force plate balance test is, however, not often used. According to our results, tests of the ability to get up from lying on the floor, stair climbing, the one legged stance, and walking speed could be useful in a clinical setting.

A limitation of this study is the use of self reports for some of the clinical variables. Registrations based upon self reported functioning and actual performances are assumed to complement each other. In self reports, recall bias can be a problem when respondents have been asked to remember past events, especially if they are of a sensitive nature or have had severe consequences for the individual. However, self reported measures are generally considered reliable and valid, in the elderly as well as the general population.

During the tests, the surroundings were fixed and the motor activities were carried out at the person’s preferred speed. The walking tests were performed in an empty corridor. If the corridor demand would have increased markedly, Unless a test can incorporate open and challenging environments, clinicians should be aware that the balance assessments currently in use have definite limitations for predicting falls. A clinical balance test where attention demanding or situational factors are also included might, at least theoretically, give a better prediction of fall related serious injury or fall induced fracture.

Key points
- 50.5% of the women fell one or more times.
- 24% of the falls resulted in fall related injuries.
- 13% of the falls resulted in fall induced fractures.
- Rhythmic disorders, inability to rise from the floor, arthritis of the hip, having had more than one fall during the one year follow up period (fractures included).
- Increased tendency to sway in the frontal plane when doing a calculation task were independent and significant predictors for serious fall related injury (fractures included).

REFERENCES