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Physiological Factors and Medications as Predictors of Injurious Falls by Elderly People: A Prospective Population-based Study

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Summary

To determine the physiological factors and medications predicting injurious falls among the elderly population, the authors conducted a prospective study in a rural home-dwelling population aged 70 years or over, initially 979 persons (377 men and 602 women), from 1 January 1991 to 31 December 1992, in Northern Finland. The independent risk factors for all falling injuries, falls leading to minor injuries and ones leading to major injuries were determined. In men, the independent risk factors for all injuries were gait disturbances [odds ratio (OR) = 3.5] and the use of digitalis (OR = 2.2), those for minor injuries were gait disturbances (OR = 2.7) and the use of calcium blockers (OR = 3.0), and those for major injuries were the absence of a quadriceps reflex (OR = 4.8), gait disturbances (OR = 2.8) and the use of digitalis (OR = 2.9). In women, the corresponding independent risk factors were short step length (OR = 32.1), the use of calcium blockers (OR = 2.5) and the use of medications for improving peripheral circulation (OR = 3.7) for all injurious falls, path deviation (OR = 2.3), the use of calcium blockers (OR = 2.8) and the use of anti-inflammatory drugs (OR = 2.1) for minor injuries, and foot deformity (OR = 2.0), short step length (OR = 15.8), the use of long-acting benzodiazepines (OR = 4.0) and the use of calcium blockers (OR = 2.4) for major injuries. In order to prevent injurious falls, attention should be given to the prescription of tranquillizers, cardiovascular medications and anti-inflammatory drugs. The walking abilities of elderly people should be maintained and chronic diseases leading to peripheral neuropathy should be treated adequately.

Introduction

About 33% of people aged 65 years or over fall at least once each year [1–3], and 40–60% of the falls lead to injuries: 30–50% result in minor injuries, 5–6% in major ones other than fractures and 5% in fractures [2, 4–7].

Falls cause about 80% of the injuries in the aged [1–3, 8], and injuries caused by falls are more common among women than men [9, 10]. In the elderly population about 90% of fractures are caused by falls [5, 10–12]. The chance of sustaining a hip fracture in a fall varies from 0.3 to 1.0% [2, 7, 13] and the probability of some other fracture varies from 4 to 10% [2, 12–15].

Injuries due to falling are common causes of short-term institutional treatment and common predisposing factors for long-term institutional care of elderly people. Among home-dwelling elderly people, 21 injuries per 1000 person years result in hospital admissions [9]. The proportion of persons sustaining fractures leading to hospitalization varies from 8 to 40% of all injurious falls by elderly people [1]. Falling accidents and injuries are predisposing factors in 40% of the events leading to long-term institutional care of elderly people [16].

Injuries are the fifth commonest cause of death in the elderly population [1]. In Finland, the mortality from accidental falls among men aged 65–69 years is 0.27/1000 person years (PY) and that among women 0.10/1000 PY. The corresponding figures are 5.4 and 4.6/1000 PY among people aged 85 years or over [17]. In the USA the rates are somewhat lower: 0.11/1000 PY and 0.05/1000 PY in the younger group and 1.9 and 1.5/1000 PY among the older subjects [18].

High age, high alcohol consumption, the use of psychopharmacological agents, a low relative body weight, a high number of activity-limitation days, stroke, respiratory disorder, a slow hand reaction, decreased grip strength, lowered cognitive function and poor self-rated health are risk factors for injurious falls according to studies made on unselected elderly populations [2, 15, 19–21]. Age 80 years or over and lower extremity weakness are related to a decreased risk for minor injurious falls [20], and diversity of physical activities and the use of heart medication for all injurious falls [21].

The aim of this study was to describe physiological factors and medications as risk factors of all injurious falls, falls leading to minor injuries and ones leading to major injuries among community-dwelling persons aged 70 years or over.

Material and Methods

This study is part of a prospective community-based research project on the incidence and risk factors of falls and injurious falls conducted in Northern Finland around the city of Oulu from the beginning of 1991 onwards. The study population consisted of all persons born in 1920 or earlier and living in five rural municipalities (Hailuoto, Kempele, Kiiminki, Oulunsalo and Ylikiiminki, n = 1159) on 31 December 1990. The recording of falls was started on 1 January 1991, and continued until 31 December 1992. A further recording period is still going on. The recording was made by diaries posted to the participants with an information letter and by regular telephone calls made once every 3 months. The material and the recording have been described in detail in a previous report [22].

Of the 1159 persons, 979 (377 men and 602 women) lived at home on 31 December 1990 and participated in the recording of falls. Nineteen men and 18 women refused to participate, 18 men and 22 women moved into long-term institutional care during the 2-year follow-up and six (five men and one woman) moved away from the area. Of the home-dwelling subjects, 90 (44 men and 46 women) died during the 2 follow-up years. On 31 December 1992, there were 843 (310 men and 533 women) home-dwelling participants alive.

A fall was defined according to the ninth revision of the International Classification of Diseases (ICD 9)[23](E880A-E889A, exp E882A) as an unexpected event where a person falls to the ground from an upper level or the same level. The fallers were classified as recurrent (two or more falls within 6 months) or non-recurrent. The classification of fall injuries was similar to that used by Nevitt *et al.* [20]. Minor injuries included lacerations without sutures, bruises, abrasions, sprains and other minor soft-tissue injuries causing a mark of violence on the body. Fractures, joint dislocations, lacerations requiring sutures and other high-energy soft-tissue injuries were defined as major injuries. Falls resulting in both minor and major injuries were classified as falls leading to major injuries [9].

In order to measure the possible risk factors for falls and injurious falls, participants were interviewed and clinically examined by two teams consisting of three general practitioners, an opthalmologist, four nurses, two physiotherapists and a trained research assistant in five health centres between 1 September 1991, and 29 February 1992. Some participants were examined in their homes. Eighty-nine persons refused examination and the final number of participants was 828 (87.5%) (311, 85%, of the men, and 517, 89%, of the women) [24].

Altogether 3% of the men and 3% of the women refused to record falls. According to the medical records of health centres and hospitals only one non-participating woman had been treated in a hospital because of an injurious fall during the follow-up. The mean age of the male non-participants was 75 years and that of the female 77 years; the age difference between the participants and the non-participants was nonsignificant. A comparison of the structured questionnaires and the medical records of the health centres showed no differences in the occurrence of chronic diseases between the participants and the non-participants [22].

The falls were classified as syncopal or non-syncopal by asking whether the fall had been associated with loss of consciousness. Consciousness had been lost in 30 falls by 11 persons (three men and eight women). The syncopal falls of men had been non-injurious, whereas the falls of women had caused two minor and five major injuries, of which three were fractures. The falls defined as being syncopal were excluded from the material in the statistical analyses [24].

The variables used in analysing risk factors have been described previously: weight (kg), height (m), body mass index (kg/m^2) (BMI), right mid-arm circumference, skin-fold thickness over the right back, mid-arm and lower scapula, blood pressure, heart rate, orthostatic reaction [25], peak expiratory flow (PEF, l/min) [26], best corrected near and distant visual acuities, field of vision, Achilles and quadriceps reflexes, pain sense on the patella and the sternum, vibration sense by a 250 Hz tuning fork on the same points, co-ordination, muscle strengths of the upper and lower extremities, grip strength of the better hand, balance (with a test consisting of six measures), gait without or with walking devices, walking speed (m/s on 10 m), step length, motion ranges of the knee and the hip and the medications in use [24]. In addition, reaction time was measured as a response of the upper extremity to a light flash with or without co-ordination by a modified Digitest 1000 system (Digitest Oy, 40950 Muurame, Finland; Digitest 1000).

Statistical methods: The significances of the differences between recurrent and non-recurrent fallers were tested by χ^2. The significances of the differences between fallers who had sustained injury and fallers who had not were tested by calculating relative risks (RR) with their 95% confidence intervals (95% CI) if the variable had been measured with a nominal or an ordinal scale. The *t* test or the Kruskal–Wallis test was used for the continuous variables. To analyse the simultaneous dependence of the risk factors for injurious falls, stepwise logistic regression analyses were used [27]. The variables including fewer events than 10 per independent variable and showing a statistical significance of at least $p < 0.1$, or the lower level of 95% CI for RR exceeding 0.95 or the upper level of 95% CI for RR being less than 1.05 in bivariate analyses, were included [28]. Regression coefficients and their standard errors (SE) and odds ratios (OR) and their 95% CI were determined. The possible interactions between the variables emerging in the model were also studied. Finally, the efficiencies of the analyses were determined as percentages of individuals correctly classified.

Results

Injuries by recurrence of falling: Factors showing significant differences between recurrent and non-recurrent fallers included sex, age and severity of injury due to falling. Nonrecurrent male fallers were significantly more prone to major injuries than recurrent male fallers ($p = 0.018$) and tended to be more prone to injuries ($p = 0.079$), whereas recurrent male fallers tended to be more prone to minor injuries ($p = 0.066$). Among women, recurrent fallers experienced more minor injuries than nonrecurrent ones ($p = 0.018$).

In the younger (70–79 years) male group there were no significant differences in the severity of injuries between recurrent and nonrecurrent fallers, but the female recurrent fallers experienced more minor

injuries ($p = 0.015$) and the nonrecurrent female fallers tended to be more prone to major injuries ($p = 0.057$). Analysis of the older group showed no significant difference between the faller groups in women, but the nonrecurrent male fallers were significantly more prone to major injuries than were the recurrent fallers ($p = 0.002$).

Risk factors for injurious falls: Among men there were positive associations between injurious falls and older age, absence of the Achilles reflex, absence of the quadriceps reflex, muscle weakness in the inferior extremities (iliopsoas, tibialis anterior, tibialis posterior and peroneal muscles), gait disturbances and the use of long-acting benzodiazepines, digitalis glycosides, calcium blockers and anti-inflammatory drugs (Table I).

In women, significant associations were found between injurious falls and reduced iliopsoas muscle strength, impaired gait, a small mid-arm circumference, impaired orthostatic reaction, short step length, the use of more than four medications and the use of long-acting benzodiazepines, calcium blockers (and also separately: the use of verapamil, nifedipine or diltiazem), drugs for improving peripheral circulation, anti-inflammatory and antidiabetic drugs.

Table I. Significant associations (RR and their 95% CI or p values) in bivariate analyses between physiological test measures, tests for balance and gait, medications and injurious falls in home-dwelling elderly people

	RR (95% CI)		
	Men	Women	Total population
No. of subjects	67	183	250
Female sex			1.2 (1.00–1.45)
Age 80 or over	1.4 (1.00–1.90)		
Bunion			1.1 (0.97–1.33)
Absence of reflex:			
Achilles	1.5 (1.06–2.05)		1.1 (0.96–1.32)
Quadriceps	1.4 (0.96–2.00)		
Reduced sternal pain sense			1.3 (1.00–1.65)
Reduced muscle strength:			
Iliopsoas	1.7 (1.22–2.25)	1.1 (0.96–1.37)	1.3 (1.08–1.48)
Tibialis anterior	1.6 (1.14–2.31)		1.2 (0.97–1.42)
Tibialis posterior	1.5 (1.05–2.13)		1.2 (0.97–1.37)
Peroneal muscles	1.5 (1.10–2.16)		
Impaired balance:			
Dizzy on turning neck			1.2 (0.96–1.39)
Impaired gait:			
Difficulty in initiation			1.3 (1.05–1.61)
Step asymmetry	1.5 (1.09–2.13)		1.2 (1.03–1.45)
Path deviation	1.4 (0.98–2.08)	1.2 (1.00–1.42)	1.3 (1.08–1.43)
Swaying in gait	1.4 (0.99–1.92)		1.2 (0.98–1.36)
Incomplete step continuity	1.4 (1.01–1.95)	1.1 (0.96–1.38)	1.2 (1.04–1.43)
Disturbed gait (Tinetti score)	1.7 (1.19–2.37)	1.2 (0.98–1.38)	1.3 (1.09–1.48)
Small mid-arm circumference		1.1 (0.95–1.37)	1.1 (0.96–1.35)
Impaired orthostatic reaction		1.2 (0.97–1.39)	
The use of medications:			
More than 4 drugs in use		1.2 (1.01–1.45)	1.3 (1.07–1.46)
Tranquillizers			1.1 (0.97–1.33)
Long-acting benzodiazepines	1.6 (1.10–2.25)	1.3 (1.03–1.56)	1.4 (1.13–1.62)
Anti-epileptics			1.5 (1.20–1.87)
Digitalis glycosides	1.4 (1.03–1.94)		1.2 (1.00–1.37)
Calcium blockers	1.4 (1.01–1.96)	1.3 (1.14–1.58)	1.4 (1.17–1.59)
Verapamil		1.4 (1.17–1.77)	1.5 (1.24–1.86)
Nifedipine		1.3 (1.04–1.72)	1.4 (1.08–1.69)
Diltiazem		1.2 (0.96–1.49)	1.2 (1.02–1.50)
Drugs improving peripheral circulation		1.4 (1.08–1.71)	1.3 (1.01–1.64)
Anti-inflammatory drugs	1.6 (0.97–2.75)	1.2 (0.98–1.40)	1.2 (1.06–1.45)
Antidiabetic drugs		1.5 (1.06–2.12)	1.3 (1.10–1.57)
Vitamins			1.2 (0.99–1.53)
Reduced peak expiratory flow			$p = 0.0181$
Short step		$p = 0.0443$	$p = 0.0033$
Slow gait			$p = 0.0109$

The analyses made in the total population showed more variables were associated with injurious falls than in the analyses made separately for men and women. Injurious falls were more common in women than in men.

Risk factors for falls leading to minor injuries: In men, there were positive associations between falls leading to minor injuries and older age, reduced muscle strength (iliopsoas, tibialis anterior and posterior), falling tendency in the Romberg test, gait disturbances, and the use of long-acting benzodiazepines and diltiazem (Table II).

Among women, there were positive relations between minor injurious falls and younger age (70–79 years), non-occurrence of nystagmus, gait disturbances, impaired orthostatic reaction, multipharmacy and the use of calcium blockers (and also separately: the use of verapamil and nifedipine), drugs improving peripheral circulation and anti-inflammatory and antidiabetic drugs.

More risk factors for falls leading to minor injuries were also identified in the total population than among either men or women. The risk ratio of women compared with men was 1.4.

Risk factors for falls leading to major injuries: The risk factors for falls leading to major injuries in men were an absence of the quadriceps and Achilles reflexes, reduced sternal pain sense, reduced muscle strength of tibialis anterior and peroneal muscles, impaired balance and gait, a small mid-arm circumference and the use of long-acting benzodiazepines and digitalis glycosides (Table III).

In women, there were positive relations between falls leading to major injuries and foot deformity (bunions), reduced sternal pain sense, reduced strength of iliopsoas muscle, impaired gait, small lower scapular

Table II. Significant associations (RR and their 95% CI or p values) in bivariate analyses between physiological test measures, tests for balance and gait, medications and minor injuries in the home-dwelling elderly people

	RR (95% CI)		
	Men	Women	Total population
No. of subjects	34	104	138
Female sex			1.4 (1.02–1.86)
Age 70–79 years		1.3 (1.01–1.75)	
Age 80 or over	1.7 (0.99–2.80)		
Non-occurrence of nystagmus		1.8 (1.23–2.70)	1.7 (1.27–2.23)
Reduced muscle strength:			
Iliopsoas	2.4 (1.54–3.84)		1.4 (1.10–1.79)
Tibialis anterior	2.0 (1.08–3.85)		
Tibialis posterior	1.9 (1.11–3.42)		
Peroneal muscles	1.5 (1.10–2.16)		
Impaired balance:			
In one-foot standing			1.2 (0.97–1.59)
Positive Romberg test	2.2 (1.31–3.78)		
Impaired gait:			
Difficulty in initiation			1.5 (1.02–2.07)
Step asymmetry	1.9 (1.08–3.31)		1.3 (1.03–1.76)
Path deviation		1.4 (1.05–1.78)	1.4 (1.14–1.84)
Swaying in gait	1.9 (1.14–3.20)		1.3 (1.04–1.70)
Disturbed gait (Tinetti score)	1.9 (1.10–3.21)	1.3 (0.98–1.66)	1.4 (1.10–1.78)
Impaired orthostatic reaction		1.3 (0.97–1.68)	
The use of medications:			
More than 4 drugs in use		1.3 (0.96–1.66)	1.4 (1.06–1.73)
Long-acting benzodiazepines	1.9 (1.02–3.65)		1.4 (1.01–2.00)
Digitalis glycosides			1.3 (1.01–1.63)
Calcium blockers		1.6 (1.19–2.01)	1.6 (1.30–2.09)
Verapamil		1.7 (1.15–2.47)	1.8 (1.26–2.68)
Nifedipine		1.6 (1.16–2.30)	1.7 (1.29–2.32)
Diltiazem	1.8 (0.99–3.21)		1.4 (1.01–1.88)
Drugs improving peripheral circulation		1.6 (1.16–2.30)	1.5 (1.08–2.18)
Anti-inflammatory drugs		1.4 (1.04–1.76)	1.5 (1.14–1.85)
Antidiabetic drugs		1.5 (1.17–2.05)	1.6 (1.18–2.05)
Vitamins			1.4 (1.00–1.96)
Short step			$p = 0.0101$
Slow gait			$p = 0.0266$

skin-fold thickness, poor distant visual acuity, short step length, multipharmacy and the use of tranquillizers (and also, separately, long-acting benzodiazepines), calcium blockers (and also, separately, verapamil) and antidiabetic drugs.

Men and women did not differ from each other in the incidence of falls leading to major injuries. Again, analyses made for both sexes combined revealed more numerous risk factors than those made separately for men and women.

Multivariate models for risk factors: The independent risk factors for injurious falls in men were the use of digitalis glycosides and gait disturbances, whereas in women the use of calcium blockers or drugs for improving peripheral circulation and short step length were independently related to injurious falls (Table IV).

The logistic regression analysis showed that the independent risk factors for injurious falls in the total population differed from those in either men or women: weakness of iliopsoas muscle, gait disturbances, use of long-acting benzodiazepines or calcium blockers and poor pulmonary function emerged in the model.

The use of calcium blockers and gait disturbances were risk factors for falls leading to minor injuries both in men and in women (Table V). In addition, lower age and the use of anti-inflammatory drugs emerged as risk factors in the model for women.

The independent risk factors for minor injurious falls in the total population were weakness of iliopsoas muscle, path deviation and the use of calcium-blockers or anti-inflammatory drugs.

Gait disturbance was a risk factor for falls leading to major injuries in both men and women (Table VI). Furthermore, an absence of the quadriceps reflex and the use of digitalis glycosides emerged in the model for men, and foot deformity and the use of long-acting benzodiazepines and calcium blockers in the model for women.

In the total population, an absence of the Achilles

Table III. Significant associations (RR and their 95% CI or p values) in bivariate analyses between physiological test measures, tests for balance and gait, medications and major injuries in home-dwelling elderly people

	RR (95% CI)		
	Men	Women	Total population
No. of subjects	33	79	112
Bunion		1.4 (0.97–1.94)	1.4 (1.03–1.85)
Absence of reflex:			
Achilles	1.9 (1.12–3.37)		1.5 (1.11–2.08)
Quadriceps	2.2 (1.30–3.67)		1.3 (0.97–1.82)
Reduced sternal pain sense	2.2 (1.16–4.25)	1.7 (1.13–2.56)	1.8 (1.31–2.61)
Reduced muscle strength:			
Iliopsoas		1.4 (0.97–1.93)	1.4 (1.07–1.96)
Tibialis anterior	2.1 (1.12–4.07)		1.4 (1.03–2.01)
Peroneal muscles	1.8 (0.97–3.41)		
Impaired balance:			
In one-foot standing	1.3 (0.96–1.85)		
Impaired gait:			
Difficulty in initiation			1.6 (1.04–2.41)
Step height	1.7 (0.99–3.06)		1.3 (0.96–1.82)
Step asymmetry	1.8 (0.97–3.41)		1.4 (0.97–1.90)
Path deviation	2.0 (1.13–3.54)		1.4 (0.99–1.85)
Incomplete step continuity	1.9 (1.10–3.26)	1.4 (0.95–1.94)	1.5 (1.12–2.03)
Disturbed gait (Tinetti score)	2.3 (1.27–4.05)		1.4 (1.08–1.94)
Small mid-arm circumference	1.8 (0.97–3.20)		1.4 (1.04–1.90)
Poor distant visual acuity (<0.3)		1.4 (1.02–2.00)	1.4 (1.04–1.91)
The use of medications:			
More than 4 drugs in use		1.4 (1.00–1.98)	1.4 (1.05–1.86)
Tranquillizers		1.4 (0.97–1.93)	1.3 (0.95–1.70)
Long-acting benzodiazepines	2.0 (1.04–3.74)	1.7 (1.18–2.40)	1.8 (1.30–2.43)
Digitalis glycosides	1.8 (1.05–3.00)		
Calcium blockers		1.6 (1.14–2.23)	1.5 (1.10–2.04)
Verapamil		2.0 (1.32–2.93)	2.1 (1.41–3.06)
Antidiabetic drugs		1.5 (0.97–2.21)	1.4 (0.97–2.11)
Reduced peak expiratory flow			p = 0.0255
Short step		p = 0.0376	p = 0.0151
Slow gait			p = 0.0347

Table IV. Results of logistic regression analyses on risk factors for injurious falls by sex

	Coefficient	SE	OR (95% CI)
Men			
Gait disturbances (Tinetti scale) (lowest quartile)	1.256	0.461	3.5 (1.40–8.77)
Digitalis glycosides	0.795	0.474	2.2 (0.87–5.67)
(Efficiency of the model 66%)			
Women			
Step length (short)	3.469	1.33	32.1 (2.35–43.8)
Calcium blockers	0.917	0.375	2.5 (1.20–5.24)
Drugs improving peripheral circulation	1.307	0.795	3.7 (0.77–17.7)
(Efficiency of the model 71%)			
Total population			
Weakness of iliopsoas muscle	0.541	0.314	1.8 (0.96–3.32)
Path deviation	0.608	0.295	1.8 (1.03–3.28)
Long-acting benzodiazepines	0.790	0.454	2.2 (0.90–5.38)
Calcium blockers	0.881	0.313	2.4 (1.30–4.47)
	Mean (cases)	Mean (refer.)	
Reduced peak expiratory flow (l/min)	266.5	296.1	p = 0.0181
(Efficiency of the model 66%)			

reflex, foot deformity, decreased sternal pain sense and the use of long-acting benzodiazepines and calcium blockers were risk factors leading to major injuries upon falling.

No interactions were found between the independent risk factors emerging in the multivariate models.

Discussion

An effort was made to make the reliability of falling event registration as good as possible in this community-based study. The reliability of telephone registration, made once in 3 months was tested during a period of 3 months by telephoning the participants once a week. The more frequent calls showed our registration of falls to be reliable [22].

In order to promote the reliability of the registration of injurious falls, the medical records of five health centres, three nursing homes and two hospitals providing care for the population were checked. The

Table V. Results of logistic regression analyses on risk factors for falls leading to minor injuries by sex

	Coefficient	SE	OR (95% CI)
Men			
Gait disturbances (Tinetti scale) (lowest quartile)	1.009	0.500	2.7 (1.01–7.43)
Calcium blockers	1.087	0.579	3.0 (0.94–9.40)
(Efficiency of the model 68%)			
Women			
Age 80+	−0.852	0.383	0.4 (0.20–0.91)
Path deviation	0.851	0.362	2.3 (1.15–4.78)
Calcium blockers	1.030	0.413	2.8 (1.24–6.33)
Anti-inflammatory drugs	0.748	0.359	2.1 (1.04–4.30)
(Efficiency of the model 62%)			
Total population			
Weakness of iliopsoas muscle	0.597	0.317	1.8 (0.97–3.39)
Path deviation	0.846	0.303	2.3 (1.28–4.23)
Calcium blockers	1.035	0.329	2.8 (1.47–5.38)
Anti-inflammatory drugs	0.538	0.301	1.7 (0.95–3.10)
(Efficiency of the model 64%)			

Table VI. Results of logistic regression analyses on risk factors for falls leading to major injuries by sex

	Coefficient	SE	OR (95% CI)
Men			
Absence of quadriceps reflex	1.558	0.711	4.8 (1.15–19.6)
Gait disturbances (Tinetti scale) (lowest quartile)	1.016	0.579	2.8 (0.87–8.78)
Digitalis glycosides	1.054	0.585	2.9 (0.89–9.22)
(Efficiency of the model 74%)			
Women			
Bunion	0.671	0.36	2.0 (0.96–3.96)
Shortened step length	2.761	1.47	15.8 (0.87–288)
Long-acting benzodiazepines	1.375	0.58	4.0 (1.25–12.5)
Calcium blockers	0.876	0.446	2.4 (0.99–5.80)
(Efficiency of the model 66%)			
Total population			
Bunion	0.616	0.316	1.9 (0.99–3.45)
Absence of Achilles reflex	0.748	0.302	2.1 (1.16–3.83)
Decreased sternal pain sense	1.279	0.640	3.6 (1.02–12.7)
Long-acting benzodiazepines	1.213	0.496	3.4 (1.26–8.95)
Calcium blockers	0.711	0.386	2.0 (0.95–4.36)
(Efficiency of the model 69%)			

comparison between the data in the medical records and those obtained by telephone interviews showed a high reliability of our data collecting methods [22].

In order to assess possible risk factors for injurious falls, two separate research teams, each consisting of a physician, a physiotherapist and two nurses examined the participants. One team (supported by an ophthalmologist and a trained assistant) examined the participants in three municipalities and the other team in two municipalities. The inter-observer consistency between these teams was evaluated and found to be high [24].

Only a few studies have been made on the risk factors for injurious falls in random samples of community-dwelling elderly populations. In addition, there are restrictions in these studies: the study series consists of populations having fallen once during the year previous to the data collection [20], analyses have not been made separately for men and women [20, 21] or the materials consist of only injurious falls requiring medical treatment [2, 19]. Owing to the small number of studies on the risk factors for injurious falls, we will also take into account community-based studies on risk factors for fractures in our discussion [10–12, 14, 15, 19, 29, 30].

Nonrecurrent male fallers were more likely to sustain major injury than recurrent male fallers, and recurrent female fallers were more prone to minor injuries than nonrecurrent ones. By age, the above results were found in older men and in younger women. These findings might be explained by the better health status and functional abilities of elderly men compared with elderly women [31]. It may be that men, who have reduced protective reflexes and peripheral neuropathy, are more prone to high-energy falling injuries when walking and sustain major injuries, whereas the younger women, who have a poor health status and impaired orthostatic reaction, have limited mobility and are careful, and thus incur low-energy minor injuries.

According to the majority of previous studies, the risk of injurious falls or fractures in the elderly increases with increasing age [2, 5, 10, 11, 19, 21, 32], although the findings of Nevitt *et al.* [20] are an exception. The risk of falls leading to minor injuries decreases above the age of 80 years. Our results show higher age to be a risk factor for all injurious falls and falls leading to minor injuries in men, while among women the risk of falls leading to minor injuries decreases with increasing age. The finding that old-old men have a higher risk of falls leading to minor injuries has not been reported before and might be explained by the increased vulnerability of tissues associated with ageing. The finding of the decreased risk associated with increasing age among women may be explained by cautiousness induced by poor health.

A low BMI was found by Malmivaara *et al.* [19], though not by us, to be a risk factor for injuries due to falling. Farmer *et al.* [33] found an association between a thin triceps skin-fold thickness and a high risk for hip fracture. We also used measures other than BMI to assess nutritional status, viz. mid-arm circumference and skin-fold thicknesses of the mid-arm and the lower scapular regions. The findings we obtained by using these measures support the idea that a poor nutritional status is a risk factor for falls leading to injurious falls or major injurious falls, but not for falls leading to minor injuries. The differences between our results and those obtained by Malmivaara *et al.* [19] can be explained by differences in data collection. They described the risk

factors for falls leading to hospital treatment, and hence major injuries, including fractures, are overpresented in their series. A low BMI is a well known risk factor for osteoporosis [13, 33, 34], and osteoporosis is a risk factor for fractures [10, 34].

Foot deformities have also previously been found to be a risk factor for injurious falls [35]. Foot deformities contribute to the risk presumably through a disturbing effect on gait.

There is evidence to suggest that impaired orthostatic reactions are a risk factor for falls by elderly people [25]. Our findings support the idea that women with such impairments know that they are at risk for falling and are cautious when getting up. Thus, impaired orthostatic reactions are a risk factor for minor but not major injuries. The difference between men and women can be explained by the use of medication. A greater number of variables representing the use of drugs causing orthostatic hypotension and diseases impairing orthostatic reactions, such as diabetes mellitus [25], were risk factors for women compared with men.

Poor pulmonary function as a risk factor for injurious falling is a new finding. The explanation for this finding may be as follows: poor pulmonary function is connected with overall frailty and disability [36, 37] and these factors are well known risk factors for injurious falls and fractures [3, 15]. Diagnosed respiratory disorder has been found to be a risk factor for injurious falls [20].

Poor visual acuity is a risk factor for fractures [29, 38]. We found that a poor corrected distant visual acuity was a risk for falls leading to major injuries in the total population and in women. The small number of men with poor visual acuity means that only a very large effect of poor distant visual acuity on the risk of major injurious falls would be detectable.

We found the absence of the Achilles reflex to be an independent risk factor for major injurious falls in the total population and the absence of the quadriceps reflex to be a risk factor for major injuries in men. Diminished sternal pain sense was an independent risk factor for major injuries in the total population. These findings support previous results showing peripheral neuropathy to be a risk factor for injurious falls [6, 15] and fractures [13, 38].

Slow hand reactions [20] and prolonged reaction time [11] have been identified as risk factors for injurious falls, for falls leading to minor injuries and for fractures. These findings were not confirmed by our study. The explanation may lie in differences between the populations studied.

Poor muscle strength is a factor for falls leading to injuries [15], for fractures [3] and for osteoporotic fractures [6]. We also found muscle weakness in the lower extremities (hip flexion) was an independent risk factor for injurious falls and falls leading to minor injuries among the total population. Muscle strength presumably contributes through a role in the maintenance of upright position and in walking.

Impaired balance is a risk factor for injurious falls [15] and falls leading to minor injuries [20]. We were able to show that poor balance increases the risk for injurious falls and falls leading to minor injuries in the total population and for falls leading to major injuries among men. The mechanism of maintaining balance is complicated, and musculoskeletal, neurological and cardiovascular factors as well as the use of medications affect the maintenance of an upright position. The balance assessments used may not be sensitive enough to detect the disturbance in the chain of events leading to injury.

In our study, gait disturbances were independent risk factors for injurious falls and falls leading to minor or major injuries both among the total population and separately among men and women. Previous reports have also identified gait impairment as a risk factor for injuries [15]. The majority of falls occur during walking [22] and it is not surprising that factors affecting the maintenance of an upright position are risk factors for injurious falls.

Previous findings indicate the use of sedatives [15] and diuretics [39] to be risk factors for injurious falls. The use of short-acting benzodiazepines [40], psychotropic drugs [19, 41], drugs causing hypotension [41], long-acting psychotropic drugs and sedatives [6] and a high number of prescribed medications is related to injurious falls requiring medical treatment, and the use of sedatives [42] is associated with falls leading to fractures. Prolonged use of thiazides diminishes the risk of fractures due to falls [43].

Our results confirm that long-acting benzodiazepines are a risk factor for injurious and major injurious falls. Our study suggested that in the group of fallers who sustained an injury, the use of long-acting benzodiazepines may be associated with reduced sternal pain sense ($p = 0.08$). Long-acting benzodiazepines may therefore contribute to falls by disturbing the peripheral nervous system.

Although previous reports indicated the use of calcium blockers [41, 44] and anti-inflammatory drugs [39] was a risk factor for falls, but not for injurious falls in home-dwelling populations, our results support the idea that they are also risk factors for injurious falls. Side-effects of calcium-blockers include hypotonia, tiredness and dizziness, and it is probably via these pathways that they lead to injurious falls. In our group of fallers who sustained injuries, the use of calcium blockers was related to the use of psychopharmacological medications ($p = 0.02$) and of anti-inflammatory drugs ($p = 0.02$) and tended to be related to low walking speed ($p = 0.07$) and reduced iliopsoas muscle strength ($p = 0.10$). This finding suggests that there may be a synergistic effect in the use of calcium blockers with psychopharmacological and anti-inflammatory drugs. Calcium blockers also seemed to be associated with walking difficulties and muscle weakness.

The associations between injurious falls and the use of digitalis glycosides [21] and drugs for improving peripheral circulation are new findings. The use of

digitalis may indicate the relationship between myocardial insufficiency and the risk for injurious falls. One of the effects of medications improving peripheral circulation is vasodilatation of peripheral arteries, which may cause orthostatic hypotension and dizziness and thereby lead to injurious falls. In the group of fallers using digitalis glycosides, injurious falls tended to be related to gait disturbances ($p = 0.1$). This suggests that the fallers with injurious events using digitalis are more disabled than those with noninjurious falling events.

In conclusion, we can state that there are only a few studies concerning the risk factors for injurious falling in home-dwelling populations. The present study showed some physiological factors and the use of some medications to be risk factors. Lower-extremity muscle weakness, peripheral neuropathy, low pulmonary capacity, difficulties in gait and the use of long-acting benzodiazepines and cardiovascular medications were the most important risk factors for injurious falls.

The differences between the injury groups indicated the more chronic and serious disorders to be risk factors for major injuries compared with minor ones. There were sex-related differences. The women at risk for minor injuries were more frail than the men, but this was not apparent for major injuries.

The results suggest some ways of preventing injurious falls among home-dwelling elderly people. The aetiology of injurious falls is multifactorial and the elderly population is heterogeneous. There is need to pay attention to the prescription of tranquillizers, especially long-acting benzodiazepines, cardiovascular medications, such as digitalis glycosides, calcium blockers and medications aimed at improving peripheral circulation. The majority of injurious falls occur when walking or taking a seat [9], and, thus, training of the lower extremities and walking [45] should be recommended for elderly people.

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