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Risk Factors for Injurious Falls: A Prospective Study

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We conducted a prospective study of the consequences of falls in 325 elderly community-dwelling persons, all of whom had fallen in the previous year. We contacted subjects every week for one year to ascertain falls and to determine the circumstances and consequences of falls. Only 6% of 539 falls resulted in a major injury (fracture, dislocation, or laceration requiring suture), but over half (55%) resulted in minor soft tissue injury. One in ten falls left the faller unable to get up for at least 5 minutes, and one in four falls caused subjects to limit their activities. The risk of injury per fall was about the same regardless of the number of falls a person had during follow-up. The risk of major injury was increased (age- and sex-adjusted odds ratio: 5.9; 95% confidence interval: 2.3–14.9) in falls associated with loss of consciousness compared to nonsyncopal falls. In multivariate analyses of nonsyncopal falls, the risk of major injury per fall was higher in persons having a previous fall with fracture (6.7; 2.1–21.5), a slower Trail Making B time (1.9; 1.1–3.2), and in Whites (18.4; 7.5–44.6). The risk that a nonsyncopal fall would result in minor injury (versus no injury) was increased in persons with a slower hand reaction time (1.8; 1.0–3.2), decreased grip strength (1.5; 1.0–2.3), in Whites (2.0; 1.0–3.7), in falls while using stairs and steps (2.2; 1.0–5.0), and turning around or reaching (3.5; 1.7–7.3). Our findings suggest that neuromuscular and cognitive impairment, as well as the circumstances of falls, affect the risk of injury when a fall occurs.

FALLS are the most frequent cause of injury-related morbidity and mortality among the elderly (1,2). The risk of falling exceeds 20% per year among persons aged 65 and older and living in the community, and reaches 35% per year among those aged 75 and older (3–5). Hip fracture is one of the most severe consequences of falling in the elderly, but occurs in only about 1% of falls (3,6,7). About 3 to 5% of falls among elderly residing in the community result in fractures other than of the hip (3,6,7,8), about 5 to 10% in other serious injuries requiring medical care (7,9), and another 30 to 50% in minor soft tissue injuries that do not receive medical attention (6,7,10). In addition to injury, a fall can result in fear of falling, limitation of activity, and a potentially dangerous and frightening "long lie" before help arrives (11).

While there have been several recent prospective studies of risk factors for falls in older persons (3,5,6,12,13), there are few prospective studies of factors affecting the risk of injury when a fall occurs (7,14), and none involving elderly persons living in the community. There is also little information from prospective studies on the consequences of falls other than injury.

To describe the consequences of falls, and to identify characteristics of fallers and circumstances of falls that are associated with the risk of injury when a fall occurs, we conducted a prospective study among elderly men and women living in the community who had a history of at least one fall in the prior year. This study was unique because we prospectively followed subjects every week for one year and interviewed and examined those who fell shortly after every fall. This allowed us to measure the occurrence of falls accurately (15) and to describe their consequences in detail.

METHODS

Subjects and data collection. — Details of the design of our study have been published (6,15). We enrolled 325 women and men who were 60 years of age or older, ambulatory, and who had fallen at least once during the previous 12 months. Participants were recruited from senior centers, senior residences, church groups, and outpatient medical clinics in San Francisco. All eligible subjects underwent a baseline examination and interview that included a medical history, a physical examination, and tests of neuromuscular, visual, mental, and physical function (6).

Subjects were followed by mail or telephone every week for 12 months to ascertain falls and their consequences (15). Follow-up contacts were 99% complete. A nurse visited participants at home as soon as possible after each reported "fall." Seventy-five percent of these visits were completed within 14 days of the fall; four interviews were conducted by telephone. The nurse used a standardized interview to ask subjects about the circumstances of each fall and examined them for visible or palpable injuries at the self-reported site(s) of trauma. Information about falls, injuries, and circumstances of falls was also obtained from a spouse or caregiver for a small number of subjects whom the nurse considered unreliable respondents.

A fall was defined for participants as "falling all the way down to the floor or ground, or falling and hitting an object like a chair or stair." We reviewed the circumstances of each reported "fall" to determine if it was consistent with a standard definition of a fall (11). Of the 593 reported "falls," 54 (9%) were excluded because the participant caught him- or herself before landing on the floor, ground, or other lower level, moved intentionally to a chair, bed, or other lower level, or was knocked down by a substantial external force, like a moving vehicle. If the subject unintentionally landed on an object or lower level other than the floor or ground, we considered this a fall.

Consequences of falls. — We categorized fall injuries

based on the nurse's interview and examination of injuries following the fall. We defined major injuries as fracture, joint dislocation, or laceration requiring sutures. Minor injuries included lacerations without sutures, bruises, abrasions, sprains, and other minor soft tissue injury. Falls that resulted in both major and minor injuries were classified as major injury falls.

We defined a fall with a "long lie" as one in which the participant said that he or she lay on the floor or ground for 5 minutes or more before being able to get up or help arrived. Activity limitations related to a fall were defined as any reduction in a participant's usual activities that occurred after a fall. The participants were asked whether the limitation was due to an injury from the fall, fear of falling, a physician's instructions, or other causes.

Predictor variables. — We identified characteristics of fallers and circumstances of falls that might predict injurious falls from a review of the literature on determinants of the severity of trauma given a fall (14,16–20). Characteristics of fallers that were analyzed as predictors of injury included age ≥80, female gender, Caucasian race, the subject's report of an injury from a fall in the year prior to the study, height, body mass index (weight in kg/(height in m)^2), isometric grip strength measured in kilograms with an adjustable hand dynamometer (Jamar Model 1A, Asimow Engineering, Santa Monica, CA), simple light-cued hand reaction time (10^{-2} s for signal detection time plus motor response time plus movement time), walking speed in meters per second over a 10-meter distance, proximal leg strength (ability and seconds to rise from a chair without using one's arms), seconds to complete the Trail Making B test of cognitive function (21), Mini-Mental State Examination score (22), Geriatric Depression Scale score (23), and corrected visual acuity in both eyes (24).

Circumstances of the fall were obtained from the nurse's interview following the fall. Circumstances that were analyzed as risk factors for injury included loss of consciousness, use of sedative-hypnotic drugs in the 24 hours before the fall, alcohol within 6 hours prior to the fall, and an activity-limiting acute illness within 7 days prior to the fall. We defined "loss-of-consciousness" falls as those in which the respondent answered "yes" when asked if he or she "fainted," "blacked out," "passed out," or "lost consciousness" just before the fall. Included in this category were two falls that occurred during seizure-like activity.

Circumstances of falls also included the subject's report of activity in progress during the fall, the presence of environmental hazards which might have contributed to the fall, the hardness of the landing surface (concrete, asphalt, pavement, ceramic tile, etc. versus carpeting, dirt, grass, wood floor, etc.), and the place of occurrence of the fall (in or around the subject's residence vs elsewhere). We categorized physical activity at the time of the fall as (a) transferring, stooping, bending, or standing still (reference category), (b) walking, (c) turning around or reaching for something, (d) going up or down stairs, steps or curbs, and (e) "high risk" activities like running or standing on a chair. Falls in which an environmental hazard was involved were those in which a respondent said that he or she "slipped or tripped" and could describe a specific hazard, said that a specific hazard caused the fall, or said that the fall occurred on stairs, steps, a curb, or another change of level.

Table 1 Baseline Characteristics of Study Participants

Characteristic	Number (%)
Age	
60–69	121 (37)
70–79	138 (43)
≥80	66 (20)
Women	266 (82)
White	266 (82)
Reported falls in previous year	
1	146 (45)
2	92 (28)
≥3	87 (27)
Fearful of falling again	
Very	52 (16)
Somewhat	52 (16)
A little	102 (31)
Not at all	119 (37)

Analysis. — We analyzed predictors of the risk of injury per fall among study subjects who fell at least once during the 12 months of follow-up, using a method that takes into account the correlation among outcomes of falls in persons with multiple falls. This approach (25) is an extension of generalized linear models to the analysis of data in which multiple observations on the same individual (cluster) may be correlated, and the correlation for repeated measures of a particular outcome (e.g., major injury) is considered a "nuisance" parameter. We used a logit link function to estimate age- and sex-adjusted logistic regression coefficients, and their standard errors, separately for each predictor variable (26). Associations are reported as odds ratios and their 95% confidence intervals. Since our minimum cluster size was one (persons with one fall), we provided an exchangeable correlation matrix where the off-diagonal elements were equal to a weighted average correlation among each of the observed outcomes (27). Predictor variables individually associated with the risk of injury at $p < .10$, after adjusting for age and sex, are reported in the tables. These variables were entered, along with age and sex, into multivariate models of the predictors of major and minor injury. Odds ratios for continuous predictors are for an approximately one standard deviation change in the risk factor; these units are provided in the tables.

Our analysis of risk factors focuses primarily on nonsyncopal falls. There were two few syncopal falls to examine risk factors for the consequences of this type of fall. Analyses of predictors of minor injury exclude falls causing major injury, thus addressing the question: "In falls that do not cause major injury, what factors are associated with the risk of a minor injury versus having no injury at all?"

RESULTS

Characteristics of the subjects are described in Table 1. Most were White (82%) and a majority were women (82%). The average age was 70.3 years. Over one-half reported

falling two or more times in the previous year. Nearly two-thirds of subjects expressed fear of falling again.

Six participants died and three dropped out prior to completing all 52 weeks of follow-up. During follow-up, 189 (58%) participants reported 539 falls that met the study criteria. Forty-nine falls (9%) in 23 subjects were preceded by loss of consciousness. Of participants who fell, 40 (21%) fell twice, 68 (36%) suffered three or more falls, 5 (3%) reported only syncopal falls, and 18 (9%) reported at least one fall of both types.

Consequences of falls. — Most falls caused an injury of some type, usually minor soft tissue injuries, such as bruises and scrapes (Table 2). Only two falls (0.4%) resulted in a fractured hip. About one in ten falls was followed by a long lie, and about one in four resulted in an activity limitation. Participants were able to get up without help after most falls. However, 14% of subjects who fell reported lying on the floor or ground, unable to get up for 5 minutes or more after at least one fall. Lies of longer than 20 minutes were reported after only 17 falls (3%), and lies of 8 hours or longer after only 3 falls. Over the course of follow-up, 42% of subjects who fell limited their activities at least temporarily as a result of one or more falls. The most common reason for limiting activities after a fall was an injury, followed by fear of falling and orders from a physician.

Loss of consciousness and the consequences of falls. — Falls associated with loss of consciousness were much more likely to result in a major injury, and more likely to be associated with a long lie or limitation in activity (Table 3). The greater limitation of activity after syncopal falls appeared to be due, in part, to the greater risk of severe injury; adjusting for injury reduced the odds ratio for the risk of an activity limitation from 2.1 to 1.7 (95% confidence interval: 0.8–3.6).

Circumstances of nonsyncopal falls. — Most nonsyncopal falls occurred in or around the subject's residence (52%). Persons aged 80 and older were more likely to fall at home (61%) than younger subjects (47%). Most falls at home happened indoors (89%), while those occurring elsewhere more often happened outdoors (63%). An environmental hazard, such as an obstacle, slippery surface, curb, or stair that may have played a role in the fall was identified for 47% of falls. In 25% of falls, the participant landed on a hard surface consisting of concrete, asphalt, pavement, ceramic tile, and the like.

Walking was the most common activity at the time of nonsyncopal falls (39%), followed by going up or down stairs, steps, or curbs (20%), transferring (e.g., getting in or out of bed or a chair), stooping, bending, or standing still (24%), and turning around or reaching for something (13%). Only 2% of these falls occurred during a potentially high-risk activity such as running, standing on a chair, or climbing a ladder. Another 2% of falls occurred during other miscellaneous activities.

Frequency of nonsyncopal falls and risk of injury. — The risk of injury during a nonsyncopal fall was slightly, but not significantly, lower in persons with more falls during follow-up (Table 4). Since the risk of injury per fall was relatively constant, the cumulative risk of injury increased steadily with the number of falls that a person had.

Table 2. Consequences of Falls

Consequence	Percent of falls*	Percent of those who fell†
Any injury	60	82
Major injury	6	13
Fracture	4	10
Hip fracture	0.4	1
Dislocation, laceration with sutures	2	4
Minor injury only (Bruise, abrasion, sprain, laceration without sutures)	55	77
Unable to get up without help	41	50
Long lie (≥ 5 minutes)	9	14
Limited usual activity because of fall	27	42
Due to injury‡	19	36
Due to fear of falling	11	16
Doctor's orders	3	9

*Smallest denominator for any category was 508 falls because of missing data.

†Smallest denominator for any category was 182 subjects because of missing data. For subjects reporting multiple falls, at least one fall resulted in the consequence.

‡Subjects could give more than one reason for activity limitation.

Predictors of Major Injury From Nonsyncopal Falls

Characteristics of fallers. — The risk of major injury was moderately, but not significantly, increased for nonsyncopal falls in persons aged 80 and older and in women (Table 5). After adjusting for age and sex, the risk of major injury was greater ($p < .10$) when a fall occurred in Whites, persons who had a fall with a fracture in the previous year, who took more time to complete the Trail Making B test, and who had a decreased Mini-Mental State Examination score, and in persons with slower hand reaction time and with corrected visual acuity of 20/50 or worse.

Body mass index (age- and sex-adjusted odds ratio and 95% confidence interval for a 5 kg/m² increase: 0.7; 0.3–1.6) height (+5 cm: 1.3; 0.7–2.3), grip strength (−10 kg: 1.8; 0.7–4.3), walking speed (−0.5 m/s: 1.2; 0.9–1.5), being unable or taking ≥ 2 s to arise from a chair without using arms (1.5; 0.5–4.2), and depression score (+3 points: 1.2; 0.8–1.7) were not associated with the risk of major injury ($p \geq .10$) after adjusting for age and sex.

Circumstances of falls. — After adjusting for age and sex, the risk of major injury was increased if the faller landed on a hard surface (Table 5) but did not differ significantly ($p \geq .10$) by activity at the time of the fall, for falls occurring at home (0.7; 0.3–1.7) or involving an environmental hazard (1.2; 0.5–3.2), use of sedative-hypnotic medications (0.9; 0.3–2.5) or alcohol (0.5; 0.1–7.4) just prior to the fall, or an activity-limiting acute illness in the week before the fall (0.3; 0.1–1.5).

Table 3. Loss-of-Consciousness Falls and Risk of Injury, Long Lie, and Activity Limitation

	Risk per fall for:							
	Major Injury		Minor Injury*		Long Lie		Activity Limitation	
Type of fall	%	OR (95% CI)†	%	OR (95% CI)	%	OR (95% CI)	%	OR (95% CI)
Loss-of-consciousness	19	5.9 (2.3–14.9)	47	0.6 (0.3–1.1)	16	2.6 (1.0–6.9)	47	2.1 (1.1–4.1)
Nonsyncopal	4	1.0	59	1.0	8	1.0	25	1.0

*Falls causing major injury are excluded.
†Odds ratio and 95% confidence interval. All odds ratios are adjusted for age and sex.

Table 4. Risk of Injury per Nonsyncopal Fall and per Person by Number of Nonsyncopal Falls

	Risk of major injury				Risk of minor injury*			
	per fall		per person†		per fall		per person†	
In persons with:	%	OR (95% CI)‡	%	(OR 95% CI)	%	OR (95% CI)	%	OR (95% CI)
1 fall	5	1.0 —	5	1.0 —	67	1.0 —	68	1.0 —
2 falls	6	1.2 (0.3–5.1)	8	1.4 (0.3–6.9)	57	0.7 (0.4–1.3)	82	2.6 (0.9–7.2)
3 falls	3	0.6 (0.1–3.2)	9	2.0 (0.3–11.7)	56	0.6 (0.3–1.2)	91	5.1 (1.1–24.5)
4 falls	3	0.5 (0.1–2.9)	13	2.5 (0.4–15.3)	59	0.9 (0.4–1.9)	87	5.3 (1.0–27.7)
≥5 falls	4	0.8 (0.2–2.7)	28	7.9 (2.0–30.9)	57	0.7 (0.3–1.6)	96	14.8 (1.8–122.9)
≥2 falls (vs 1)		—		—		0.7 (0.4–1.2)		—
≥3 falls (vs 1 or 2)		0.6 (0.2–1.6)		—		—		—

*Falls causing major injury are excluded.
†Risk of having one or more injury from a fall in persons with one or more falls.
‡Odds ratio and 95 percent confidence interval. All odds ratios are adjusted for age and sex.

Multivariate analysis. — Table 5 also shows the multivariate model including all predictors associated with the risk of major injury at $p < .10$ after age and sex adjustment. A fall with a fracture in the previous year, being White, and slower performance on the Trail Making B test were independently associated with increased risk of major injury ($p < .05$) (Table 5). In addition, we found a nonsignificant trend suggesting an increased risk of major injury for falls on a hard surface. Falls in women and persons aged 80 or older, and falls in those with slower hand reaction times and vision impairment, had odds ratios ranging from 1.8–2.0 for the risk of major injury, but 95% confidence intervals that substantially overlapped 1.0.

Because the two measures of mental status were highly correlated ($r = .53$), we analyzed each separately. A multivariate model substituting Mini-Mental State score for Trail Making B time yielded essentially the same results for the other predictors, but Mini-Mental State score was not independently associated with the risk of major injury (−3 points: 1.7; 0.8–3.5).

The time taken to complete the Trail Making B test may be affected by vision impairment, arthritis, and hand tremor independently of cognitive function. We therefore included variables for visual acuity impairment and physician diagnoses of osteoarthritis, rheumatoid arthritis, and a physician's diagnosis of Parkinson's disease in analyses of the association of Trail Making B time with major injury. These adjustments did not change our findings.

Table 5. Predictors of Risk of Major Injury Due to Nonsyncopal Falls

	Odds ratio (95% confidence interval)	
	Adjusted for Age and Sex	Multivariate Model†
Characteristics of subjects		
Age ≥ 80	2.3 (0.7–7.6)	2.0 (0.7–5.4)
Women	2.3 (0.6–9.1)	2.0 (0.6–6.6)
White	28.7 (13.6–60.2)*	18.4 (7.5–44.6)‡
Fall with fracture in previous year	7.2 (2.3–22.9)*	6.7 (2.1–21.5)‡
Trail Making B time (+180 s)	1.8 (1.1–3.0)*	1.9 (1.1–3.2)‡
Mini-Mental State Examination (−3 points)	1.8 (1.2–2.8)*	—§
Increased hand reaction time (+0.5 s)	3.5 (0.9–13.1)*	1.8 (0.5–6.9)
Visual acuity ≤ 20/50	2.7 (1.1–7.0)*	1.8 (0.6–4.7)
Circumstances of falls		
On "hard" surface	2.2 (0.9–5.3)*	2.5 (0.9–7.0)

*$p < .10$ after adjustment for age and sex.
†Odds ratios are adjusted for all of the other variables in the table.
‡$p < .05$ in multivariate model.
§Mini-Mental State score is analyzed in a separate multivariate model (see text) due to high correlation ($r = .53$) with Trail Making B time.

Predictors of Minor Injury (vs No Injury) From Nonsyncopal Falls

Characteristics of fallers. — In analyses excluding major injury falls, persons age 80 and older had a lower risk of minor injury when they fell, but women had the same age-adjusted risk as men (Table 6). The age- and sex-adjusted risk of minor injury was increased ($p < .10$) for falls in persons having a fall with an injury in the previous year, in Whites, and in persons with a decreased hand reaction time

Table 6. Predictors of Risk of Minor Injury Due to Nonsyncopal Falls*

	Odds ratio (95% confidence interval)	
	Adjusted for Age and Sex	Multivariate Model‡
Characteristics of subjects		
Age ≥80	0.6 (0.3–0.9)	0.5 (0.3–0.9)§
Women	1.1 (0.6–2.0)	0.8 (0.4–1.4)
White	2.0 (1.0–4. 1)†	2.0 (1.0–3.7)§
Fall with injury in previous year	1.8 (1.1–3.0)†	1.6 (0.9–2.6)
Increased hand reaction time (≥0.750 s)	1.5 (1.0–2.2)†	1.8 (1.0–3.2)§
Decreased grip strength (−10 Kgs)	1.4 (1.0–2.0)†	1.5 (1.0–2.3)§
Unable or ≥ 2 s to arise from chair without using arms	0.7 (0.4–1.1)†	0.5 (0.3–0.9)§
Circumstances of falls		
At home	0.4 (0.3–0.6)†	0.5 (0.3–0.8)§
Hazard present	1.4 (1.0–2.1)†	1.0 (0.6–1.8)
On "hard" surface	2.5 (1.5–4.3)†	1.6 (0.8–3.5)
Walking ‖	1.9 (1.2–3.1)†	1.6 (0.9–2.8)
Up or down stairs, steps, curbs, etc. ‖	2.7 (1.5–5.0)†	2.2 (1.0–5.0)§
Turning, reaching ‖	2.9 (1.5–5.7)†	3.5 (1.7–7.3)§
"High risk" activity ‖	0.9 (0.3–2.8)	0.6 (0.2–2.0)
"Other" activities	1.2 (0.3–5.5)	1.3 (0.3–6.3)

*Falls causing major injury are excluded.
†$p < .10$ for after adjustment for age and sex.
‡Odds ratios are adjusted for all of the other variables in the table.
§$p < .05$ in multivariate model.
‖ Falls while transferring, stooping, bending and standing still are the reference group.

and decreased grip strength. Being unable or taking ≥ 2 s to arise from a chair without using arms was associated with a decreased risk of minor injury.

Body mass index (+5 kg/m²: 1.0; 0.7–1.2), height (+5 cm: 0.9; 0.6–1.3), walking speed (−0.5 m/s: 1.0; 0.9–1.2), Trail Making B time (+180 s: 0.9; 0.7–1.2), Mini-Mental State score (−3 points: 0.8; 0.6–1.1), corrected acuity ≤ 20/50 (1.0; 0.6–1.7) and depression score (+3 points: 1.3; 0.9–1.9) were not significantly associated with the risk of minor injury ($p \geq .10$) after adjusting for age and sex.

Circumstances of falls. — The age- and sex-adjusted risk of minor injury per fall was greater for falls that involved an environmental hazard and when the faller landed on a hard surface, but was lower for falls that occurred at home (Table 6). Minor injuries were more likely when the faller was turning or reaching, going up or down stairs, steps, or curbs, or walking compared to falls that occurred during transferring, stooping, bending, or during quiet standing.

Engaging in "high risk" (0.9; 0.3–2.8) or "other" activities (1.2; 0.3–5.5), use of sedative-hypnotic medications (1.2; 0.7–2.1) or alcohol (1.6; 0.5–5.0) just prior to the fall, or an activity-limiting acute illness in the week before the fall (1.3; 0.6–2.9) were not associated ($p \geq .10$) with minor injury.

Multivariate analysis. — Predictors independently associated ($p < .05$) with an increased risk of minor injury per fall (versus no injury) were being White, a slow hand reaction time, decreased grip strength, going up or down stairs, steps, or curbs during the fall, and turning around or reaching during the fall (Table 6). We found a decreased risk of minor injury per fall in persons age 80 or greater, in those with difficulty arising from a chair, and in falls occurring at home. Falls on a hard surface and falls while walking were also associated with a moderately increased risk of minor injury, but with 95% confidence intervals for the odds ratio that overlapped 1.0.

History of a fall with injury in the year before the study. — It is possible that including variables for previous fall-related injuries in the multivariate models might mask the association of certain predictors with the risk of injury if these same variables affected the risk of injury in the year prior to the study. However, we repeated the multivariate analyses for major and minor injury, excluding the variable for a history of previous fall injury, and obtained essentially the same results for the other predictors in the models.

Effect of injury on other consequences of falls. — Persons suffering an injury from a fall were much more likely to report a limitation of activity following the fall than those who were not injured. The odds ratio for a fall-related activity limitation was 31.2 (11.8–82.1) for those suffering a major injury and 3.2 (2.0–5.3) for those suffering a minor injury in a multivariate model that adjusted for age, sex, Trail Making B score, depression score, hand reaction time, and lower extremity strength. Neither major nor minor injury due to a fall was associated with the risk of a long lie following that fall ($p > .10$).

Discussion

We have found that falls in a cohort of older women and men are frequently associated with minor consequences. Soft tissue injuries are common but major injuries occur in only about 6% of falls. In particular, fewer than 1% of falls in this cohort resulted in hip fractures. These injuries often cause older persons to limit their activities, at least temporarily.

Several of our findings suggest that the ability of a faller to protect him- or herself during a fall may affect the risk of injury. In our study, syncopal falls were associated with a substantially increased risk of major injury. Loss of consciousness causes a loss of normal responses that might help protect against fractures or other serious injury during a fall (19,20).

In addition, we found that upper extremity strength and reaction time, Trail Making B time, mental status, and visual acuity were each associated with the risk of injury from nonsyncopal falls after adjustment for age and sex. In multivariate models, Trail Making B time was an independent predictor of major injury, and upper extremity strength and reaction time were independent predictors of minor injury. These variables measure functions that may affect the speed and effectiveness of protective responses during a fall.

During a fall there is a very short period of time in which to make protective responses; slowed reaction time may

decrease the ability to execute protective responses quickly (20). Decreased grip strength may indicate reduced effectiveness of protective arm responses. The Trail Making B test is a measure of brain dysfunction that is purported to tap dimensions of motor speed, coordination, visual scanning, and central processing time (21). Each of these functions potentially plays a role in the ability of a faller to protect him- or herself from injury during a fall. While our findings are suggestive of a role for protective responses in determining the risk of injury when a fall occurs, these findings need to be confirmed in other studies.

The risk that a fall would result in a major injury was increased in Whites and in those with a history of a fall with a fracture in the previous year. Three-quarters of the major injuries in our study were fractures. Elderly Whites and those with previous fractures have lower bone mass and an increased risk of a fracture (17,28,29). Thus, elderly with low bone mass may especially benefit from interventions to prevent falls.

We found only limited evidence to support the idea that older people who fall most frequently somehow learn how to fall more safely. The risk of injury during a fall was slightly, but not significantly, lower in persons with more falls during follow-up. The number of falls a person had, on the other hand, was strongly related to the cumulative risk of injury during the study.

We did find that some factors might decrease the risk of minor injury, including age 80 or older, lower extremity weakness, falls at home, and falls while transferring, stooping, bending, and standing still. Falls at home may be less likely to cause minor injury than falls outside if surfaces in the home (e.g., carpeted floors) are more forgiving than outside surfaces, such as sidewalks. Falls while transferring, stooping, bending, or standing still may carry a lower risk of minor injury than falls during other activities because the potential energy of the fall may be lower or because the way a person falls minimizes the risk of minor injury (16,19).

We found trends suggesting an association between an increased injury risk and falls on hard, man-made surfaces such as pavement or concrete which do not dissipate energy. However, another study failed to find an association between fracture risk and the hardness of the landing surface (30). The ability of energy-absorbing surfaces and unobtrusive protective clothing to prevent fall injuries merits additional investigation (31).

About one out of ten falls left the subject unable to get up again for at least five minutes. This is a lower rate of falls with a "long lie" than in a previous report (32), but fallers in that study had all received medical attention for the fall, possibly resulting in an overrepresentation of long lies. Although very few fallers in our study lay on the ground long enough to suffer physical consequences of the lie, this inability to get up again independently may cause feelings of frustration, helplessness, and fear. About one quarter of falls caused subjects to limit their activities in some way, usually due to injury, but sometimes due to fear of falling again. The risk of an activity limitation was moderately increased when the fall caused minor injury and greatly increased when a major injury occurred.

This study has several limitations. All subjects had a history of falling at least once during the previous year. Thus, our results may not be generalizable to older men and women who have no history of falling in the past year. Furthermore, participants in our study were living independently in the community. Therefore, our findings may not be applicable to persons residing in long-term care institutions. Although we recruited subjects from a variety of community-based sources, primarily senior citizens centers, residences, and churches, the cohort was not a random sample of the elderly population.

Information on falls, injuries, and the circumstances of falls in our study was based, in part, on self-report, which may be unreliable. However, we followed subjects weekly, and interviewed those who fell and examined them for injury soon after the fall occurred. We did not require x-ray reports for fractures but relied instead on the subject's report and the nurse's focused examination for visible or palpable signs of injury. As a result we may have misclassified some fractures and missed some minor soft tissue injuries which the participant did not report and which were not visible at the time of the home examination. However, our findings on the rate of major and minor injury per fall are similar to those of other prospective studies (3,7,8). Finally, a tendency to overreport injury might partly account for the association between self-report of previous fall injuries and injuries during follow-up. However, it is unlikely that this entirely accounts for the strong association we found between previous fractures and incident major injuries.

In conclusion, we have found that falls in older persons commonly cause minor injuries and activity limitations and infrequently cause major injury and long lies. The cumulative risk of injury is approximately proportional to the number of falls. We also found that neuromuscular and cognitive deficits, as well as factors related to the circumstances of the fall, affect the risk of injury when a fall occurs. In particular, several factors suggestive of impaired protective responses during a fall are associated with an increased risk of injury per fall. These risk factors may help identify elderly at greatest risk for damaging falls. Interventions intended to reduce the risk of falling by improving neuromuscular function, such as exercise and strength training programs, may also improve the effectiveness of protective responses and reduce the risk of injury when a fall occurs.

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