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Non-syncopal Falls in the Elderly in Relation to Home Environments

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Abstract. Methods of prevention of falls in the home may differ for healthy and frail individuals. We therefore sought to determine whether measures of health and functioning in older persons are more useful in predicting falls at home not involving home hazards (non-environmental falls) than falls at home related to home hazards (environmental falls), and whether these relationships differ among those who fell once and those who fell multiple times during follow-up. Data for this analysis are from a 1-year prospective cohort study of 325 community-dwelling volunteers aged 60–93 years who had fallen during the year before baseline. In general, associations were stronger between poor functional ability and non-environmental falls than between poor functional ability and environmental falls. Independent predictors of non-environmental first falls during follow-up included Parkinson's disease (adjusted odds ratio (AOR) 7.66, 95% confidence interval (95% CI) 1.15–51.1) and being home alone 10 or more hours per day (AOR 2.36, 95% CI 1.20–4.61); independent predictors of environmental first falls during follow-up included arthritis (AOR 2.60, 95% CI 1.32–5.09) and poor depth perception (AOR 0.73, 95% CI 0.59–0.89, for each unit increase in depth perception score). Also, associations between poor function and falls were generally stronger among participants who fell repeatedly than among individuals who fell only once during the follow-up year. In conclusion, poor function predisposes to non-environmental falls at home in older persons and, to a lesser extent, environmental falls in those who fall repeatedly. Certain functional characteristics such as poor depth perception may predispose to environmental falls to a greater extent than do other disabilities.

Keywords: Accidental falls; Elderly; Frail elderly; Functionally impaired elderly; Housing for the elderly; Prevention and control

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Introduction

Osteoporosis is an important public health concern because of the increased risk for fractures. Falls among older persons are increasingly recognized as significant causes of fractures [1]. Host risk factors for falls include deficiencies in gait and visual perception, decreased muscle strength, impaired balance, confinement to the home, dementia, depression, and acute and chronic illness [2–8]. Environmental factors (such as floor obstacles, rugs and lighting) may also play a role in an estimated 30%–50% of falls [9,10]. Most falls in the elderly probably result from the interaction of many factors, both host and environmental [11,12], as well as others, such as psychotropic medications [13], that may be difficult to classify.

Research has indicated that recurrent falls are more frequent in those with chronic functional impairment than in less impaired individuals [5,13–15], and that recurrent falls are more predictable than single, isolated falls. On the other hand, environmental hazards may be risk factors for falls primarily in healthier older individuals compared with elderly persons who are in poor health or frail [16–18].

Previous research reported by us suggested that vigorous persons living with more home hazards were more likely than vigorous participants living with fewer home hazards to experience environmental falls during follow-up; the effect of living with more home hazards among frail participants was small [18]. Here we extend this research by examining how various baseline measures of health and functioning in a cohort of community-dwelling elderly persons are related to the risk of non-environmental and environmental falls at home, since commonly held notions regarding risk factors for different types of falls have not been well tested empirically. We further consider whether the participants fell once or twice during the year of follow-up, as the roles of fall risk factors may vary within subgroups of older persons, and an understanding of these differences may lead to better targeting of fall prevention strategies.

Subjects and Methods

Participants

Persons aged 60 years or older who reported falling at least once in the previous 12 months were recruited from senior centers, senior residences, churches, and university-affiliated outpatient medical clinics in San Francisco, California. Higher proportions in older age groups were included so as to achieve approximately equal numbers of participants in each age group from 60–64 years to 80 years and older. Those unable to walk without the assistance of another person, unable to answer the interview questions or living in a nursing home were excluded. Three-hundred and twenty-five participants (266 women and 59 men) were enrolled.

Baseline Assessments

All eligible participants underwent a three-part baseline examination consisting of (1) a questionnaire administered by a trained interviewer, (2) a physical examination conducted by an internist, and (3) tests of neuromuscular performance, visual function and mental status carried out by trained lay examiners. These instruments have been described previously as this is a secondary analysis of a previously reported cohort [5,18]; summaries and selected details are provided below.

Interview. The standardized questionnaire asked questions about demographic characteristics, falls experience over the past 12 months, health and functioning [19], social support [20], life events, physical activity [21] and usual frequency and quantity of alcohol consumed [22]. Functional status was measured by a respondent's answers to questions regarding his or her ability to perform six activities of daily living (ADLs) unaided. Independence was assessed by asking each respondent five questions about difficulties in performing routine daily activities (IADLs).

Physician's Examination. Following a standard interview regarding each person's medical conditions and medication use, a board-certified internist performed a cardiovascular, neurological and musculoskeletal physical examination [23].

Tests of Neuromuscular Performance, Vision and Mental Status. Grip strength of the dominant hand was measured using an adjustable hand dynamometer, and simple reaction times of the dominant hand and foot were assessed with a light-cued timing device.

Each participant was asked to stand up from a chair of standard height and design unaided and without using his or her arms, as a measure of leg muscle strength. Gait speed was assessed by noting the number of steps and how long it took to walk 5 m at the person's normal walking pace; the results of two trials were averaged. Participants performed a tandem walk along a line 2 m long and 5 cm wide and the number of errors made – such as stepping off the line – was recorded. Another measure of balance and gait was the number of steps needed to complete a 180 degree turn. In addition, qualitative abnormalities of gait (such as stepping asymmetry and arrythmicity, weaving, staggering, shuffling and reduced arm swing) [24] were recorded.

Static balance was tested by measuring the time a participant could stand on one leg up to a maximum of 10 s; the mean of four trials (two for each leg) was noted. Finally, the number of times an individual could step onto a single 23-cm step in 10 s was recorded.

Corrected visual acuity was measured by letter charts [25], near depth perception was assessed by the random-dot method [26] and contrast sensitivity was evaluated for both high and low spatial frequencies [27]. The Mini-Mental State Examination [28] and Trailmaker Tests A and B [29] assessed cognitive function, and the Geriatric Depression Scale [30] measured symptoms of depressive illness.

Follow-up Period

Reporting Falls. A fall was defined as "falling all the way to the floor or ground, or falling and hitting an object such as a chair or stair". This was explained to all participants and was printed on a postcard holder containing 52 dated and postage-paid postcards (one for each week of follow-up). Participants were instructed to answer whether they had fallen in the previous week and to mail the card immediately. If a postcard was not received within 10 days of the designated mailing date, the participants were contacted by telephone.

Post-fall Examination and Questionnaire. As soon as possible after each reported fall, a nurse practitioner interviewed the participant about the circumstances of the incident. Falls that occurred other than at home and falls that resulted from loss of consciousness (syncope or seizure) or sudden paralysis were excluded.

Several questions from the post-fall assessment were useful in determining whether there was an environmental contribution to each fall, including whether or not the participant reported (1) that a specific hazard caused the fall, (2) that he or she tripped or slipped over a particular item (such as a throw rug or a slippery floor), or (3) that the fall occurred on stairs, steps, or another change of level. In preliminary analyses each of these three categories was individually considered as well as each possible pairwise combination. A combined measure was devised and used in previous research with these data where a "yes" response on any of these three items meant that the fall was classified as environmental [31]; all other falls were considered non-environmental. This combined measure proved most useful here as well, since small numbers of tripping hazards and stair falls produced unstable results when these items were analyzed separately.

Analysis

Binary associations between each of the individual baseline functional variables and non-environmental and environmental falls were first examined. Results were used to help choose one variable from a group of items that measure similar characteristics or abilities. These and other important baseline items were included in initial multivariate models.

Polytomous logistic regression (a generalization of logistic regression to more than two outcome categories) was used to explore associations between baseline measures and the risk of having non-environmental and environmental first and second falls during the year of follow-up, controlling for the effects of other variables. Variables were sequentially deleted from initial models on the basis of a lack of significant change in the coefficients for the predictor variables. All polytomous logistic regression models were fitted by computing the linear variables iteratively as maximum likelihood estimates using the SYSTAT LOGIT program [32]. The likelihood ratio test was used to assess the significance of adding or deleting a particular item [33].

Cross-validation was used to obtain unbiased estimates of how well the multivariate models would predict outcome when applied to new data. To obtain cross-validation estimates, the data were first divided as evenly as possible into ten groups. Then, nine of the groups (the learning sample) were used to fit the models for first and second falls, and the tenth group (the test sample) was used to test how well the models predicted outcome. This procedure was repeated nine more times, using a different test sample each time, and the overall fractions correctly predicted were determined (i.e. the sum of correct classifications for the three outcomes divided by the sample total used in the given model) along with appropriate standard errors [34]. Overall means and standard errors of the fractions correctly predicted were calculated for both the learning and test samples from the results of the ten trials.

Finally, first falls were divided into those experienced by participants who fell only once during follow-up and those experienced by participants who fell two or more times during follow-up. Polytomous logistic regression was used to examine relationships between baseline functional variables and non-environmental and environmental first falls in both groups.

Results

Descriptive Characteristics

Older age groups were selectively sampled so that approximately equal numbers of subjects were included in each age group from 60–64 years to 80 years and older. Most of the 325 participants were women (82%).

Ninety-seven percent of participants were followed for the entire year of the study. One-hundred and nine individuals (33%) experienced at least one fall, 56 (17%) experienced a second fall, and 26 (8%) experienced three or more falls at home during follow-up; 47% of first falls and 45% of second falls were classified as environmental. Second and subsequent falls were less likely to be classified as environmental [18].

Bivariate Results

Bivariate associations between items from the baseline assessments and non-environmental and environmental falls at home during follow-up that remained important predictors of falls after multivariate adjustment are provided in Table 1. (For complete bivariate results, see Northridge [35].) Age was signficantly associated with first and second non-environmental falls, but not with environmental falls. Increasing numbers of falls in the year before baseline and self-report of a physician's diagnosis of arthritis were important predictors of both first and second falls, whether or not a home hazard was involved. Most of the other items from the structured interview were significant predictors of non-environmental falls only, although the direction of the effect was the same for environmental falls.

All three of the variables shown in Table 1 from the neuromuscular examination (i.e. chair stand performance, tandem walk performance and balance on one leg) were significantly associated with first and second non-environmental falls at home during follow-up. Fewer items were important predictors of environmental falls, although again, the direction of the effect for all the items was essentially the same.

Of the vision tests measured, only depth perception was significantly related to first falls, and only to those with an environmental component. However, most of the other relationships were very close to significance. Again, the pattern of the results for the vision tests was generally consistent across outcomes, although the strengths of the associations varied somewhat.

Finally, associations between poorer performance on

Table 1. Odds ratios (OR) and 95% confidence intervals (CI)[a] for bivariate associations between selected individual items from the baseline assessments and non-environmental and environmental non-syncopal falls at home during follow-up: first and second falls (n=325)

Individual baseline functional items by specified domains[b] (unit increase)	First falls during follow-up		Second falls during follow-up	
	Non-environmental (n=58) OR (95% CI)	Environmental (n=51) OR (95% CI)	Non-environmental (n=31) OR (95% CI)	Environmental (n=25) OR (95% CI)
Demographic characteristics (units)				
Age (5 years older)	1.32 (1.10–1.59)	1.12 (0.91–1.37)	1.34 (1.06–1.70)	1.11 (0.85–1.45)
Items from structured interview				
No. of falls in past year (1 more fall)	1.24 (1.09–1.40)	1.24 (1.09–1.41)	1.24 (1.10–1.40)	1.16 (1.02–1.33)
Fall with injury in past year (yes/no)	2.50 (1.16–5.38)	1.34 (0.67–2.68)	2.69 (1.00–8.73)	2.30 (0.77–6.92)
Confinement to the house[c] (1 level more)	1.69 (1.27–2.25)	1.24 (0.89–1.73)	1.40 (1.00–1.94)	1.57 (1.13–2.18)
Home alone 10 or more h/day[d] (yes/no)	2.68 (1.47–4.89)	0.85 (0.40–1.76)	2.83 (1.33–6.02)	1.70 (0.72–4.02)
Arthritis (yes/no)	1.98 (1.07–3.66)	2.45 (1.30–4.64)	2.39 (1.12–5.10)	2.68 (1.17–6.14)
Parkinson's disease (yes/no)	12.4 (2.42–62.9)	2.14 (0.19–24.1)	13.1 (2.79–61.8)	7.71 (1.22–48.5)
Ever feel light-headed, dizzy (yes/no)	1.36 (0.76–2.46)	1.93 (1.02–3.66)	0.87 (0.41–1.84)	1.04 (0.46–2.38)
Items from neuromuscular examination				
Chair stand performance[e] (1 level worse)	2.09 (1.56–2.80)	1.32 (0.97–1.80)	2.43 (1.66–3.56)	1.90 (1.27–2.83)
Tandem walk performance[f] (1 level worse)	2.09 (1.55–2.81)	1.39 (1.04–1.85)	2.75 (1.78–4.24)	1.33 (0.91–1.94)
Balance on one leg (1 s longer)	0.78 (0.69–0.88)	0.93 (0.84–1.03)	0.58 (0.45–0.75)	0.94 (0.81–1.08)
Vision tests				
Corrected visual acuity[g] (5 units worse)	1.11 (0.98–1.26)	1.11 (0.98–1.27)	1.25 (1.08–1.44)	1.19 (1.01–1.40)
Depth perception score[h] (1 unit better)	0.96 (0.86–1.08)	0.80 (0.70–0.92)	0.85 (0.72–1.00)	0.86 (0.72–1.03)
Mental status tests				
Trailmaker B score (1 min longer)	1.28 (1.14–1.45)	1.08 (0.93–1.25)	1.20 (1.03–1.39)	1.11 (0.94–1.32)

[a]Odds ratios (95% confidence intervals) estimated by polytomous logistic regression.
[b]See Methods for descriptions of variables used.
[c]Response to the question "About how often, on the average, do you get out of your house/apartment in good weather?" Higher scores indicate greater confinement (range=1 to 8, where 1=every day and 8=never or hardly ever).
[d]Categorized response to the question "On average, how many waking hours per day do you spend at home alone? Assume that there are about 16 hours in your average waking day."
[e]Higher scores indicate more time required to stand (range=1–4, where 1=0–0.85 s and 4=over 1.99 s).
[f]Higher scores indicate more errors on tandem walk (range=1–4, where 1=0–1 error and 4=10 or more errors).
[g]Bailey–Lovie visual acuity score (number of letters missed). Higher scores indicate poorer visual acuity (range=10–70, where 10=best score and 70=worst score).
[h]Higher scores indicate better depth perception (range=0–10, where 0=worst score and 10=best score).

the Trailmaker B test and non-environmental falls were stronger than were associations between poorer performance on the Trailmaker B test and environmental falls. Among the baseline items tested and not found to be significant predictors of falls (based on Wald statistics and likelihood ratio tests) were gender, severity of joint pain for those with arthritis, change in systolic blood pressure measured from a lying to a standing position, number of seconds required for dark adaptation, and contrast sensitivity over all spatial frequencies. In general, however, poorer function on the last four items was associated with a slightly increased risk of falls during follow-up.

Multivariate Results

Although most of the baseline functional variables were predictors of non-environmental (and, to a lesser extent, environmental) falls at home in bivariate analyses, many of them were highly correlated with each other and thus were no longer important after controlling for other items in multivariate analyses. A backward elimination procedure was used to help determine which of the variables that appeared important in bivariate analyses were independent predictors of non-environmental and environmental falls in multivariate polytomous logistic regression models. Items were sequentially deleted using the likelihood ratio test to assess the significance of a particular predictor by comparing models with and without the variable in question.

The multivariate polytomous logistic regression models derived for first (Table 2) and second (Table 3) falls contained six items each. Adding an additional variable to the six variables selected in each model made little difference (2% or less) to the predictive ability of the models to classify outcome into no fall, non-environmental fall or environmental fall at home during follow-up.

Only increasing numbers of falls in the past year and arthritis were independent predictors in both multivariate models. However, both models included functional

Table 2. Adjusted odds ratios (OR) and 95% confidence intervals (CI) for selected times from the baseline assessments for first non-syncopal falls at home during follow-up, according to whether a home hazard was involved in the fall (non-environmental and environmental)

Baseline functional predictor[a] (unit increase)	Non-environmental fall (n=58) Adjusted OR (95% CI)[b]	Environmental fall (n=51) Adjusted OR (95% CI)[b]
No. falls, year before baseline (1 fall)	1.15 (1.01–1.31)	1.20 (1.05–1.36)
Home alone 10 or more h/day[c] (yes/no)	2.36 (1.20–4.61)	0.60 (0.27–1.32)
Arthritis (yes/no)	1.72 (0.87–3.40)	2.60 (1.32–5.09)
Parkinson's disease (yes/no)	7.66 (1.15–51.1)	0.78 (0.04–13.7)
Tandem walk performance[d] (1 level worse)	1.96 (1.44–2.68)	1.24 (0.91–1.69)
Depth perception score[e] (1 unit better)	1.04 (0.92–1.18)	0.81 (0.70–0.94)

[a]See Methods for descriptions of variables used.
[b]Adjusted OR (95% CI) were estimated by multivariate polytomous logistic regression; each OR is adjusted for all the other variables in the table.
[c]Categorized response to the question "On average, how many waking hours per day do you spend at home alone? Assume that there are about 16 hours in your average waking day."
[d]Higher scores indicate more errors on tandem walk (range=1–4, where 1=0–1 error and 4=10 or more errors).
[e]Higher scores indicate better depth perception (range=0–10, where 0=worst score and 10=best score).

Table 3. Adjusted odds ratios (OR) and 95% confidence intervals (CI) for selected times from the baseline assessments for second non-syncopal falls at home during follow-up, according to whether a home hazard was involved in the fall (non-environmental and environmental)

Baseline functional predictor[a] (unit increase)	Non-environmental fall (n=31) Adjusted OR (95% CI)[b]	Environmental fall (n=25) Adjusted OR (95% CI)[b]
No. falls, year before baseline (1 fall)	1.19 (1.05–1.36)	1.15 (1.00–1.32)
Confinement to the house[c] (1 level more)	1.13 (0.75–1.70)	1.42 (1.00–2.02)
Arthritis (yes/no)	2.69 (1.12–6.50)	2.87 (1.17–7.04)
Chair stand performance[d] (1 level worse)	1.37 (0.85–2.21)	1.80 (1.12–2.88)
Balance on one leg (1 s longer)	0.71 (0.55–0.93)	1.12 (0.94–1.32)
Corrected visual acuity[e] (5 units worse)	1.18 (1.00–1.39)	1.22 (1.02–1.46)

[a]See Methods for descriptions of variables used.
[b]Adjusted OR (95% CI) were estimated by multivariate polytomous logistic regression; each OR is adjusted for all the other variables in the table.
[c]Response to the question "About how often, on the average, do you get out of your house/apartment in good weather?" Higher scores indicate greater confinement (range=1–8, where 1=every day and 8=never or hardly ever).
[d]Higher scores indicate more time required to stand up (range=1–4, where 1=0–0.85 s and 4=over 1.99 s).
[e]Bailey-Lovie visual acuity score (number of letters missed). Higher scores indicate poorer visual acuity (range=10–70, where 10=best score and 70=worse score).

items that measured different components of the same general characteristics (e.g. neuromuscular function, vision, and being alone or confined to the house).

The cross-validation studies demonstrated that, on average, 55.8 ± 1.7% of first falls and 74.3 ± 0.9% of second falls were accurately predicted using the test samples. These percentages are similar to those obtained when all of the data were used (57.0% of first falls and 75.4% of second falls).

Associations Among Participants Who Fell Only Once and Among Participants Who Fell Two or More Times During Follow-up

Table 4 identifies the independent predictors of environmental and non-environmental falls among participants who fell only once during follow-up, along with their corresponding odds ratios (ORs) and 95% confidence intervals (CIs), estimated using multivariate polytomous logistic regression. Only four items were included in this model, and feeling dizzy in the past month was the only independent predictor of both non-environmental and environmental falls. Among those who fell two or more times during follow-up, findings for first falls were similar to findings for second falls (data not shown).

Discussion

As expected [2,4,5,6,10,14], most of the items indicative of poor function were important risk factors for first and second non-syncopal falls at home in this cohort of community-dwelling elderly. The findings regarding non-environmental versus environmental falls have not been previously reported. In general, it appears that associations were stronger between poor functional ability and falls not involving home hazards than

Table 4. Adjusted odds ratios (OR) and 95% confidence intervals (CI) for selected times from the baseline assessments for non-environmental and environmental falls for participants who experienced one non-syncopal fall at home during the follow-up year

Baseline functional predictor[a] (unit increase)	Non-environmental fall (n=26) Adjusted OR (95% CI)[b]	Environmental fall (n=27) Adjusted OR (95% CI)[b]
Age (5 years older)	1.42 (1.05–1.92)	0.83 (0.61–1.13)
Ever feel light-headed, dizzy (yes/no)	2.91 (1.06–8.00)	3.39 (1.34–8.58)
Depth perception score[c] (1 unit better)	1.18 (0.99–1.41)	0.73 (0.59–0.89)
Trailmaker B Test (1 min longer)	1.38 (1.14–1.66)	0.99 (0.78–1.28)

[a]See Methods for descriptions of variables used.
[b]Adjusted OR (95% CI) were estimated by multivariate polytomous logistic regression; each OR is adjusted for all of the other variables in the table.
[c]Higher scores indicate better depth perception (range=0–10, where 0=no depth perception and 10=best score).

between poor functional ability and falls involving home hazards. This is consistent with the finding that falls attributed to environmental hazards are relatively infrequent in impaired, institutionalized populations [36], but more structured living environments may also decrease the opportunities for encountering hazards. Certain functional characteristics (notably arthritis and poor depth perception) may predispose to environmental falls as well as to non-environmental falls. Finally, associations between poor functional ability and falls at home were generally stronger among participants who fell two or more times than they were among participants who fell only once during the follow-up year, especially for falls involving home hazards. This conforms to the notion that infrequent or isolated falls are more unpredictable and less likely to be the result of underlying neurological or musculoskeletal problems, whereas multiple falls are more predictable and more likely to be associated with underlying disorders [5].

Our findings regarding independent risk factors for environmental falls seem plausible. Arthritis may make it difficult to recover from a trip or to stand up from a chair or bed, thus accounting for the relations between environmental falls and self-report of a physician's diagnosis of arthritis. Poor depth perception was important in predicting environmental falls, consistent with observations that accurate perception of spatial relationships is important in avoiding hazards and judging distances and may also contribute to postural stability [5,37]. Environmental cues to depth (e.g. high-contrast tape or lines on step edges) may be useful in preventing falls among older persons with poor depth perception.

An important strength of this study was the intensive follow-up system used. Falls were ascertained weekly and a detailed post-fall assessment was completed as soon as possible after each reported fall. This permitted us to classify falls according to whether or not a home hazard was involved more accurately than if participants had been asked to recall the circumstances surrounding each fall after longer time periods.

An important limitation of this study is potential misclassification of falls as non-environmental or environmental, since the classification system used here is based entirely upon self-report and was not collected until the post-fall interview was conducted. However, most falls at home among community-living elderly are not directly observed and validation of circumstances is difficult. Modifications of this classification system will be necessary to take into account falls that occur away from home.

A second restriction is the limited sample size in this study. Many of the distinctions between the magnitudes of association between risk factors and environmental and non-environmental falls were not definitive, although trends and patterns were evident. Confirmation using a larger sample size is needed.

A third limitation of this study is its lack of generalizability to all older persons. Since eligible participants were volunteers who resided in the San Francisco community and had a history of falls in the year before baseline, results may not apply to those who are institutionalized, have no history of falling in the past year, or reside in communities which are different from this one. Also, the participants in this study represent a screened subset who were oriented enough to complete the interview.

Finally, it is possible that frail individuals already have safer home environments than do healthier older persons. Thus, the finding that healthier participants had more environmental falls than frail participants may be explained by differences in their homes.

In conclusion, this study has identified several functional characteristics in older persons that are independently related to non-environmental falls at home. Fewer functional characteristics are independently related to environmental falls, suggesting that prevention strategies which intervene on health status may be of limited effectiveness for this type of fall. Instead, it may be important to modify home environments of healthy as well as frail individuals in order to prevent environmental falls at home.

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