# Heterogeneity of Falls Among Older Adults: Implications for Public Health Prevention

Jennifer L. Kelsey, PhD, Elizabeth Procter-Gray, PhD, MPH, Marian T. Hannan, DSc, MPH, and Wenjun Li, PhD

*Objectives.* We examined risk factors for falls among older people according to indoor and outdoor activity at the time of the fall and explored risk factors for seriously injurious falls.

*Methods.* Data came from MOBILIZE Boston, a prospective cohort study of 765 community-dwelling women and men, mainly aged 70 years or older. Over 4.3 years, 1737 falls were recorded, along with indoor or outdoor activity at the time of the fall.

*Results.* Participants with poor baseline health characteristics had elevated rates of indoor falls while transitioning, walking, or not moving. Healthy, active people had elevated rates of outdoor falls during walking and vigorous activity. For instance, participants with fast, rather than normal, gait speed, had a rate ratio of 7.36 (95% confidence interval [CI] = 2.54, 21.28) for outdoor falls during vigorous activity. The likelihood of a seriously injurious fall also varied by personal characteristics, activity, and location. For example, the odds ratio for serious injury from an outdoor fall while walking outside compared to inside a participant's neighborhood was 3.31 (95% CI = 1.33, 8.23).

*Conclusions.* Fall prevention programs should be tailored to personal characteristics, activities, and locations. (*Am J Public Health.* 2012;102:2149–2156. doi: 10.2105/AJPH.2012.300677)

Falls in older people are a major public health problem. In the United States, about one third of community-dwelling people aged 65 years or older fall each year, with about 10% of falls resulting in serious injury.[1–3] These falls and injuries can lead to disability, loss of independence, and fear of falling.[1] Several fall prevention strategies have been developed, most of which emphasize strength, balance, and gait training; use of assistive devices; treatment of medical conditions; reduction in the use of certain medications; improvement in vision; and elimination of home hazards.[1–6] However, about 50% of falls in community-dwelling older people occur outdoors, mainly in healthy, active people.[7–13] Knowing which people are likely to fall under what circumstances should help prevention efforts by enabling different recommendations to be emphasized to different people, a strategy recommended in the 1990s by Northridge et al.[14,15] and Speechley and Tinetti,[16] but seldom implemented as policy.

Previous studies have reported on people's activities at the time they fall, with walking by far most frequent.[9,17–19] However, only limited data are available on whether certain personal characteristics affect the likelihood of falls during specific activities, and on which combinations of fall-related activities, personal characteristics, and location are most likely to result in serious injury among those who fall.[14,17]

Our objectives were (1) to examine whether particular personal characteristics (e.g., demographic, lifestyle, and health attributes; functional and cognitive status; fall history) are associated with falls during certain indoor and outdoor activities and (2) to explore, with smaller numbers of events, risk factors for serious injury from falls according to personal characteristics, activity, and location. Such information can contribute to the development of more effective public health prevention strategies tailored to specific groups of people and activities.

## METHODS

Our data came from MOBILIZE Boston, a prospective cohort study investigating risk factors and mechanisms of falls among 765 community-dwelling men and women, mainly aged 70 years or older, who live in the Boston, Massachusetts, area (described in detail elsewhere[20,21]). Other eligibility criteria were ability to read and speak English, ability to walk 20 feet without the assistance of another person (including people who used a cane or walker, but excluding those confined to a wheelchair), intention to stay in the Boston area for at least 2 years, and adequate cognition (scoring ≥ 18 points on the Mini-Mental Status Examination[22]).

Participants were enrolled from September 2005 to December 2007, through door-to-door recruitment in randomly sampled households with at least 1 member aged 70 years or older as recorded in annual Massachusetts town lists. From 5655 sampled households, 4303 people aged 70 years and older were identified. Of these, 1581 were not eligible, and 1973 either refused to participate or were unable to be contacted. Sixteen persons aged 64 to 69 years who were spouses of or living with a participant were added to the cohort, for a total of 765 participants. Our data were derived from fall events during 4.3 years of follow-up (September 2005–December 2009).

### Baseline Measures

At baseline, participants underwent comprehensive assessments during a home visit and a clinic examination. For our analysis of associations between baseline data and subsequent falls, we decided a priori to consider age, gender, self-reported number of falls in the year before baseline, and 13 key indicators of health status. From the clinic examination, body mass index (BMI; defined as weight in kilograms divided by the square of height in meters) was derived from weight measured on a standard balance beam scale and stadiometer-measured height and was categorized into normal (< 25 kg/m$^2$), overweight (25–29.9 kg/m$^2$), and obese (≥ 30 kg/m$^2$).

Balance was measured with the Berg Balance Scale,[23] a multicomponent assessment of standing balance, with a summed score of 0 to 56. Inability to perform chair stands (unable or used arms) was our indicator of poor lower-extremity muscle strength. Gait speed (m/sec) was the shortest time in 2 trials for a usual-paced 4-meter walk.[24] Distance vision was tested at 10 feet (wearing corrective lenses, if used), with poor vision defined as vision worse than 40/100.

During the home visit, an interviewer administered a questionnaire and derived a score on the Activities of Daily Living Scale according to ability to perform 5 activities (bathing, dressing, toileting, transferring, eating).[25,26] Number of comorbid conditions was summed from the participant's response to whether a health care provider had told the participant that she or he had any of several major medical conditions.[27] Number of medications was the number of prescription and over-the-counter medications used during the previous 2 weeks, coded according to the Iowa Drug Information System ingredient codes.[28] Topical medications, vitamins, and herbal supplements were excluded. Psychotropic medication use was defined as use of antidepressants, hypnotics, benzodiazepines, antipsychotics, and other sedatives.

The Falls Efficacy Scale measured fear of falling.[29] The Mini-Mental State Exam assessed cognitive function.[22] Two health indicators were obtained from a self-administered questionnaire given to participants at the end of the baseline home interview: self-rated health (classified as excellent, good, fair, or poor) and physical activity in the previous week, measured by the Physical Activity Scale for the Elderly, a brief questionnaire that assesses time spent in common activities of older people.[30]

### Ascertainment of Fall Occurrence

A fall was defined as unintentionally coming to rest on the ground or other lower level. During the home visit, interviewers instructed participants on how to use a calendar during follow-up to record each day whether a fall occurred. At the end of each month, participants mailed their calendars to the study office. Study staff phoned participants who did not return calendars within 10 days of the end of a month or returned an incomplete calendar. Information on whether a fall had occurred was obtained for 98.5% of follow-up months in the first year, 90.8% in the second year, 88.2% in the third year, and 81.2% in the fourth year. More than 90% of participants who reported a fall were successfully contacted for a telephone interview within a month.

When participants reported a fall, a structured telephone interview was conducted to determine the circumstances. The first question was, "Could you please describe to me, what happened when you fell on [date]?" As needed, this was followed by, "What were you doing when you fell?" and "Where were you exactly when you fell?" Location of the fall (indoors vs outdoors) was available for 1737 (98.4%) of the 1766 reported falls; we analyzed data only for falls of known location. An indoor fall was one reported to have occurred inside the participant's home, inside someone else's home, inside another building, or inside, other location. Outdoor falls were those reported to have occurred anywhere outside a building.

Activity at the time of the fall was available for 1706 (98.2%) of the falls. For our analysis, 2 members of the research team (E. P.-G. and W. L.) initially grouped the activities into 12 categories without prior knowledge of characteristics of the individuals who fell (Table 1). On the basis of adequacy of numbers (≥ 100 falls either indoors or outdoors) and similarity of risk factors, we further grouped them for analysis into the following categories, separately for indoor and outdoor falls: (1) not moving at all or transitioning (e.g., getting in or out of a chair, bed, car, or tub or shower), (2) ascending or descending stairs, (3) walking, and (4) engaging in vigorous physical activity. The "other" category was diverse and had relatively few falls in any individual activity; we therefore omitted it from detailed analyses.

### Seriously Injurious Falls

Self-reported injury information was available for all but 5 indoor falls and 1 outdoor fall. We defined seriously injurious falls as falls reported to have resulted in fractures; sprains or pulled or torn muscles, ligaments, or tendons; dislocated joints; or concussions. We considered 4 additional variables as potential predictors of serious injury among those who fell. Baseline height was measured as described in "Baseline Measures." Footwear worn at the time of the fall was derived from participants' answers to the question, "What type of shoes were you wearing (if any) when you fell?" in the telephone interview that followed a fall. Outdoor falls were classified as probably on a hard surface (stairs, sidewalk, street, curb, parking lot or garage, driveway, gas station, or porch,

**TABLE 1—Distribution of Falls Among Older Persons by Activity and Location at Time of Fall: MOBILIZE Boston Study, September 2005–December 2009**

| Activity | Indoor Falls (n = 929), % | Outdoor Falls (n =808), % | Total Falls (n = 1737),% |
|---|---|---|---|
| Transitioning/not moving | 25.8 | 6.1 | 16.6 |
| Transitioning | 15.4 | 3.5 | 9.8 |
| Not moving | 10.4 | 2.6 | 6.8 |
| Using stairs | 15.0 | 14.0 | 14.5 |
| Ascending stairs | 6.7 | 7.7 | 7.1 |
| Descending stairs | 8.3 | 6.3 | 7.4 |
| Walking | 35.5 | 45.4 | 40.1 |
| Engaging in vigorous activity | 4.0 | 13.9 | 8.6 |
| Other | 19.7 | 20.7 | 20.2 |
| Doing household tasks | 5.1 | 1.4 | 3.3 |
| Gardening/lawn care | 0.0 | 5.8 | 2.7 |
| Bending | 4.0 | 1.9 | 3.0 |
| Traversing curb/single step | 0.4 | 6.3 | 3.2 |
| Other | 7.5 | 4.6 | 6.2 |
| Did not recall | 2.7 | 0.7 | 1.8 |

deck, or patio; n = 507), probably on a soft surface (garden or yard, urban public park, forest or forest park, beach or shore, or cemetery; n = 180), or indeterminate (n = 121). We did not have enough information to classify the landing surfaces for indoor falls. A person's own neighborhood was defined as within 6 blocks of home.

### Statistical Analysis

We first examined the frequency of indoor and outdoor falls during various activities. We then used negative binomial regression models to estimate the effects of baseline characteristics on the rates of indoor and outdoor falls during various activities. The effect of each characteristic or risk factor was expressed as a rate ratio (RR), which was the average number of falls per year of follow-up in people with the characteristic divided by the average number of falls per year of follow-up in a referent group.

We used mixed-effects logistic regression models, which took into account correlations among multiple falls reported by the same person, to estimate odds ratios (ORs) for serious injury from falls. These analyses should be considered exploratory because the number of falls in some categories was relatively small. Unadjusted RRs and ORs were similar to those adjusted for age, gender, and other variables, so we have presented only the unadjusted estimates. We tested goodness of fit of models. We performed all statistical analyses in Stata version 11.2 (StataCorp LP, College Station, TX).

## RESULTS

Among the 765 participants, 1737 falls occurred over the 4.3 years of follow-up, of which 173 (10%) were classified as seriously injurious. The average annual rate of falls per person was 0.83 (95% confidence interval [CI] = 0.76, 0.92). About 36.6% percent of participants had no falls over the 4.3 years, 35.3% averaged less than 1 fall per year, 15.7% averaged 1 to 1.9 falls per year, and 12.4% averaged 2 or more falls per year.

Of the 1737 falls, 929 were indoors and 808 outdoors. Among all falls, 40.1% occurred while walking (35.5% of indoor falls and 45.4% of outdoor falls; Table 1). About three quarters of indoor falls occurred while walking, while transitioning or not moving, or on stairs; about three quarters of outdoor falls occurred while walking, on stairs, or during vigorous activity. We therefore focused on falls during these activities.

### Rate Ratios for Falls

Table 2 shows that in general, people with poor health characteristics, such as poor balance, poor leg strength, slow gait speed, difficulty with activities of daily living, multiple comorbidities, multiple medications, use of psychotropic medications, fair or poor self-rated health, and low physical activity level, had elevated rates of indoor falls while transitioning or not moving and while walking. Healthy, active people, on the other hand, generally had elevated RRs for outdoor falls while walking and engaging in vigorous activity relative to less healthy people, as indicated either by their low RRs for characteristics associated with poor health (e.g., poor balance) or their high RRs for characteristics associated with good health (e.g., fast gait speed). We observed a particularly high RR for outdoor falls during vigorous activity among people with fast gait speed. The number of outdoor falls over curbs or single steps was too small (n = 50) for inclusion in Table 2, but the RR for such falls was elevated among those with multifocal or bifocal lenses relative to those with single lenses or no glasses (RR = 2.29; 95% CI = 1.22, 4.29]). We detected no notable risk factors for falls on indoor or outdoor stairs.

Falls at home accounted for 81.3% of indoor falls. Almost all the RRs associated with indicators of poor health were higher for indoor falls at home than for indoor falls elsewhere among falls while walking (Table 3). We observed little difference between the RRs for outdoor falls while walking in a participant's own neighborhood and outdoor falls while walking elsewhere (data not shown).

### Odds Ratios for Serious Injury From Falls

About 10.0% (173) of the 1737 falls resulted in serious injury (10.7% of all indoor falls and 9.2% of all outdoor falls). Among the serious injuries, 46.3% were fractures and 48.6% sprains or tears of muscles, ligaments, or tendons without fracture.

Among outdoor falls, those on hard surfaces were more likely to result in serious injury than those on softer surfaces (OR = 2.61; 95% CI = 1.15, 5.92). The result was similar when restricted to falls while walking. Among outdoor falls while walking, the OR for a serious injury was 3.31 (95% CI = 1.33, 8.23) if the fall occurred outside a person's own neighborhood compared to within the neighborhood. Among indoor falls while walking, the OR was 2.68 (95% CI = 0.68, 10.50) for falls away from home compared with those inside a person's home. These differences could not be attributed to hardness of landing surface (for outdoor falls), condition of the surface, whether the participant was tripped or knocked down, or personal characteristics.

Table 4 shows the ORs for seriously injurious falls by place, activity, and personal characteristics for activity or place categories in which 100 or more individuals fell. For these analyses, we combined falls during vigorous activity (37 indoor falls by 30 people, 112 outdoor falls by 52 people) with falls while walking (330 indoor falls by 191 people, 367 outdoor falls by 209 people).

The odds that a person suffered a serious injury as a result of a fall were higher for women than men in all activity and location categories and, except for the indoor transitioning–not moving category, tended to be higher for people who had poor lower-extremity strength or who had difficulty with activities of daily living. The percentage with serious injury among participants who fell indoors while transitioning or not moving tended to be higher among thin people, those with fast gait speed, and those who were not wearing shoes at the time of their fall than among other participants. The odds of serious injury among participants who fell indoors while walking or engaging in vigorous activity tended to be elevated among those with several indicators of poor health. Characteristics associated with seriously injurious falls during outdoor walking or vigorous activity were poor balance, difficulty with activities of daily living, number of comorbid conditions, and use of psychotropic medications. Serious injury among participants who fell on indoor stairs tended to be especially likely among obese people and those with

**TABLE 2—Rate Ratios for Falls During 4 Categories of Activity by Baseline Characteristics and Location of Fall: MOBILIZE Boston, September 2005–December 2009**

| Baseline Characteristics | Indoor Falls | | | | Outdoor Falls | | | |
|---|---|---|---|---|---|---|---|---|
| | Transitioning/Not Moving, RR (95% CI) | Ascending or Descending Stairs, RR (95% CI) | Walking, RR (95% CI) | Vigorous Activity, RR (95% CI) | Transitioning/Not Moving, RR (95% CI) | Ascending or Descending Stairs, RR (95% CI) | Walking, RR (95% CI) | Vigorous Activity, RR (95% CI) |
| Age, per 5 y | 1.27 (1.09, 1.48) | 0.82 (0.67, 0.99) | 1.13 (0.96, 1.31) | 1.37 (0.99, 1.88) | 1.28 (0.94, 1.73) | 0.96 (0.79, 1.17) | 0.87 (0.76, 1.00) | 0.54 (0.37, 0.79) |
| Female | 1.15 (0.79, 1.68) | 0.69 (0.45, 1.06) | 1.17 (0.83, 1.67) | 1.88 (0.76, 4.63) | 0.63 (0.33, 1.21) | 0.93 (0.59, 1.47) | 0.84 (0.62, 1.14) | 0.39 (0.19, 0.82) |
| Falls in year before baseline, no. | 1.26 (1.12, 1.41) | 1.10 (1.02, 1.19) | 1.38 (1.24, 1.53) | 1.35 (1.04, 1.77) | 1.18 (0.95, 1.46) | 1.07 (0.96, 1.20) | 1.23 (1.10, 1.38) | 1.53 (1.17, 2.00) |
| Body mass index, kg/m$^2$ | | | | | | | | |
| < 25.0 | 1.04 (0.68, 1.61) | 0.86 (0.54, 1.38) | 1.01 (0.68, 1.51) | 0.89 (0.36, 2.21) | 1.48 (0.69, 3.16) | 1.07 (0.64, 1.79) | 1.10 (0.79, 1.52) | 0.94 (0.42, 2.13) |
| 25.0–29.9 (Ref) | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| ≥ 30.0 | 1.35 (0.87, 2.08) | 0.46 (0.25, 0.82) | 1.33 (0.88, 1.99) | 0.72 (0.26, 1.98) | 1.17 (0.50, 2.72) | 1.00 (0.58, 1.74) | 0.46 (0.31, 0.70) | 0.32 (0.12, 0.87) |
| Berg Balance Scale score[a] | | | | | | | | |
| ≥ 51.0 (Ref) | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| 48.0–50.9 | 1.19 (0.77, 1.85) | 1.23 (0.76, 1.99) | 2.76 (1.88, 4.04) | 0.49 (0.16, 1.49) | 1.10 (0.50, 2.42) | 1.28 (0.78, 2.11) | 1.52 (1.09, 2.12) | 0.58 (0.24, 1.39) |
| < 48.0 | 3.18 (2.14, 4.74) | 0.71 (0.40, 1.29) | 3.40 (2.30, 5.03) | 1.47 (0.59, 3.64) | 1.19 (0.53, 2.70) | 0.93 (0.51, 1.68) | 0.66 (0.43, 0.99) | 0.21 (0.07, 0.61) |
| Unable to stand from a chair without using arms | 2.08 (1.14, 3.78) | 0.20 (0.05, 0.88) | 1.97 (1.11, 3.48) | 1.32 (0.31, 5.63) | 0.62 (0.13, 2.93) | 0.36 (0.11, 1.23) | 0.45 (0.22, 0.90) | 0.47 (0.10, 2.25) |
| Gait speed, m/sec | | | | | | | | |
| Slow (< 0.60) | 2.44 (1.45, 4.12) | 0.25 (0.07, 0.84) | 1.95 (1.15, 3.29) | 0.72 (0.14, 3.64) | 2.05 (0.77, 5.42) | 0.74 (0.31, 1.76) | 0.39 (0.20, 0.77) | 0.59 (0.15, 2.35) |
| Middle (0.60–1.29; Ref) | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| Fast (≥ 1.30) | 0.89 (0.46, 1.72) | 1.77 (0.93, 3.38) | 0.81 (0.44, 1.51) | 2.18 (0.67, 7.09) | 2.25 (0.87, 5.80) | 1.53 (0.76, 3.09) | 2.83 (1.84, 4.33) | 7.36 (2.54, 21.28) |
| Vision worse than 40/100 | 0.81 (0.41, 1.63) | 0.52 (0.20, 1.34) | 0.92 (0.50, 1.70) | 0.34 (0.04, 2.94) | 0.74 (0.20, 2.72) | 0.74 (0.31, 1.78) | 1.00 (0.59, 1.69) | 0.39 (0.08, 1.80) |
| Some difficulty with or inability to perform ADLs | 2.66 (1.83, 3.86) | 1.09 (0.66, 1.80) | 1.90 (1.30, 2.77) | 1.52 (0.61, 3.75) | 1.70 (0.83, 3.51) | 0.82 (0.47, 1.44) | 0.75 (0.51, 1.09) | 0.28 (0.10, 0.79) |
| Comorbidities, no. | 1.29 (1.15, 1.44) | 1.06 (0.92, 1.21) | 1.15 (1.04, 1.28) | 1.21 (0.95, 1.53) | 1.32 (1.09, 1.59) | 1.05 (0.91, 1.21) | 0.93 (0.84, 1.02) | 0.82 (0.65, 1.04) |
| > 4 medications | 1.76 (1.17, 2.66) | 0.78 (0.50, 1.22) | 1.40 (0.97, 2.02) | 0.58 (0.26, 1.30) | 1.04 (0.51, 2.14) | 0.56 (0.36, 0.87) | 0.61 (0.45, 0.83) | 0.41 (0.19, 0.86) |
| Psychotropic medication | 2.09 (1.40, 3.13) | 1.12 (0.67, 1.87) | 1.67 (1.14, 2.46) | 1.36 (0.55, 3.36) | 1.31 (0.61, 2.84) | 0.96 (0.56, 1.67) | 1.11 (0.78, 1.60) | 0.55 (0.21, 1.44) |
| Falls Efficacy Scale score < 90[b] | 2.42 (1.55, 3.78) | 0.95 (0.51, 1.77) | 1.85 (1.19, 2.90) | 1.09 (0.35, 3.45) | 2.37 (1.06, 5.31) | 0.94 (0.49, 1.80) | 0.70 (0.44, 1.12) | 0.12 (0.02, 0.64) |
| Impaired cognition, MMSE score 18–24[c] | 1.25 (0.73, 2.13) | 0.89 (0.45, 1.77) | 1.13 (0.67, 1.90) | 0.21 (0.03, 1.76) | 0.91 (0.31, 2.61) | 0.62 (0.28, 1.39) | 0.67 (0.41, 1.12) | 0.26 (0.06, 1.06) |
| Fair/poor self-rated health | 2.21 (1.40, 3.48) | 0.62 (0.31, 1.24) | 1.88 (1.21, 2.92) | 1.57 (0.56, 4.44) | 1.61 (0.68, 3.83) | 0.88 (0.45, 1.71) | 0.80 (0.51, 1.26) | 0.12 (0.02, 0.62) |
| Physical activity, PASE score < 55[d] | 1.98 (1.35, 2.91) | 0.89 (0.53, 1.49) | 1.82 (1.25, 2.64) | 1.47 (0.61, 3.52) | 1.98 (1.00, 3.93) | 0.81 (0.47, 1.40) | 0.54 (0.36, 0.79) | 0.32 (0.12, 0.84) |

*Note*. ADL = activities of daily living; CI = confidence interval; MMSE = Mini-Mental State Exam; PACE = Physical Activity Scale for the Elderly; RR = rate ratio. Results are from binomial regression models with number of falls per year as the outcome.

[a]Possible score, 0–56.

[b]Possible score, 10–100.

[c]Possible score,0–30; score of 18–24 indicates impaired cognition.

[d]Possible score, 0–361; < 55 is lowest quartile.

**TABLE 3—Rate Ratios for Falls While Walking Inside Participants' Own Home and Inside Another Building by Baseline Characteristics: MOBILIZE Boston, September 2005–December 2009**

| Baseline Characteristics | Inside Own Home, RR (95% CI) | Inside Another Building, RR (95% CI) |
|---|---|---|
| Age/5 y | 1.24 (1.03, 1.48) | 0.78 (0.59, 1.04) |
| Female | 1.05 (0.70, 1.58) | 1.84 (0.96, 3.54) |
| Falls in year before baseline, no. | 1.40 (1.24, 1.59) | 1.23 (1.02, 1.49) |
| Body mass index, kg/m$^2$ | | |
| < 25.0 | 0.90 (0.57, 1.42) | 1.55 (0.78, 3.07) |
| 25.0–29.9 (Ref) | 1.00 | 1.00 |
| 30.0 | 1.29 (0.81, 2.06) | 1.42 (0.68, 2.97) |
| Berg Balance Scale score[a] | | |
| ≥ 51.0 (Ref) | 1.00 | 1.00 |
| 48.0–50.9 | 3.48 (2.23, 5.42) | 1.47 (0.76, 2.86) |
| < 48.0 | 4.79 (3.06, 7.51) | 0.96 (0.44, 2.09) |
| Unable to stand from a chair without using arms | 2.21 (1.15, 4.24) | 1.10 (0.36, 3.33) |
| Gait speed, m/sec | | |
| Slow (< 0.60) | 2.16 (1.18, 3.92) | 1.10 (0.39, 3.08) |
| Middle (0.60–1.29; Ref) | 1.00 | 1.00 |
| Fast (≥ 1.30) | 0.67 (0.32, 1.42) | 1.34 (0.51, 3.49) |
| Vision worse than 40/100 | 1.11 (0.56, 2.19) | 0.18 (0.02, 1.39) |
| Some difficulty with or inability to perform ADLs | 2.20 (1.43, 3.39) | 0.97 (0.48, 1.99) |
| Comorbidities, no. | 1.20 (1.06, 1.36) | 0.97 (0.80, 1.19) |
| > 4 medications | 1.50 (0.98, 2.30) | 1.04 (0.55, 1.97) |
| Psychotropic medication | 1.76 (1.13, 2.76) | 1.30 (0.65, 2.60) |
| Falls Efficacy Scale score < 90[b] | 2.29 (1.38, 3.81) | 0.52 (0.18, 1.46) |
| Impaired cognition, MMSE score 18–24[c] | 1.38 (0.77, 2.48) | 0.25 (0.06, 1.11) |
| Fair/poor self-rated health | 2.37 (1.44, 3.90) | 0.50 (0.18, 1.41) |
| Physical activity, PASE score < 55[d] | 2.22 (1.45, 3.41) | 0.70 (0.34, 1.47) |

*Note*. ADL = activities of daily living; CI = confidence interval; MMSE = Mini-Mental State Exam; PACE = Physical Activity Scale for the Elderly; RR = rate ratio. Rate ratios were estimated from negative binomial regression models with number of falls per year as the outcome.
[a]Possible score, 0–56.
[b]Possible score, 10–100.
[c]Possible score, 0 –30; score of 18–24 indicates impaired cognition.
[d]Possible score, 0 –361; < 55 is lowest quartile.

poor balance, poor lower-extremity strength, slow gait speed, and poor vision, although these results were derived from small numbers and wide CIs.

## DISCUSSION

Our results suggest that among older people, personal risk factors for falls vary considerably by location and activity at the time of the fall. Participants with poor baseline health characteristics had elevated rates of indoor falls while transitioning or not moving and while walking, whereas healthy, active people had elevated rates of outdoor falls during walking and vigorous activity.

This heterogeneity of fall risk factors has received limited research attention.[14–16] Northridge et al. found that environmental hazards in the home were related to likelihood of falling in vigorous, but not frail, older people.[14,15] Speechley and Tinetti found that frail older people almost always fell at home and during routine nondisplacing daily activities (typical activities that do not involve a major displacement of a person's space, such as occurs while climbing stairs or ladders or during sports activities), whereas active older people tended to fall while away from home, on stairs, in the presence of environmental hazards, or during displacing activities.[16] Our finding that outdoor falls on single steps or curbs were associated with wearing multifocal or bifocal lenses is consistent with the results of several studies, including a recent randomized trial.[31]

Our results and those from previous studies[14–16,31] thus suggest that preventive measures are likely to be more effective if tailored to groups with specific risk profiles and a tendency to engage in specific activities. Evidence clearly indicates that the emphasis of preventive measures needs to differ for healthy, active people and less healthy, frail people.[7–13] Many of the preventive strategies to date, such as improving strength, balance, and gait; treating medical conditions; reducing the use of certain medications; and improving vision,[1–6] are more likely to benefit relatively frail, inactive people, who tend to fall indoors while transitioning or not moving or while walking. However, in our study as well as others, almost half of falls occurred outdoors.[7–13] Prevention of outdoor falls has received little attention to date.

As in other community-based studies,[9,17–19] we found that by far the most common activity at the time of a fall was walking, especially for outdoor falls. Recent reports indicate that fast gait speed is a marker of good health and longevity,[32] but fast walkers have a substantially increased rate of outdoor falls, especially during vigorous activity. Although the numbers were small and the CI wide, we found that persons with fast gait speed also appeared to have an elevated risk of serious injury if they fell outdoors during vigorous activity (OR = 4.44; 95% CI = 0.12, 165.56). Activity should be strongly encouraged among healthy older people, but fall prevention measures, such as walking more slowly and carefully, should be emphasized as well.

Prevention programs also need to take into account the risk of serious injury from a fall. Our finding of a greater likelihood of serious injury from outdoor falls on hard surfaces has been reported by others,[4] and indicates that, when possible, older people should avoid hard surfaces when this is an option, as perhaps in recreational walking. If replicated by others, our observations that serious injury from an

**TABLE 4—Odds Ratios for Serious Injury Resulting From Falls for Selected Activities by Baseline Characteristics and Location of Fall: MOBILIZE Boston, September 2005–December 2009**

| | Indoor Falls | | | Outdoor Falls |
|---|---|---|---|---|
| | Transitioning/Not Moving, No., %, or OR (95% CI) | Ascending or Descending Stairs, No., %, or OR (95% CI) | Walking/Vigorous Activity, No., %, or OR (95% CI) | Walking/Vigorous Activity, No., %, or OR (95% CI) |
| Individuals who fell | 149 | 100 | 202 | 233 |
| Falls | | | | |
| Total no. | 237 | 139 | 365 | 479 |
| % resulting in serious injury | 13.5 | 9.4 | 11.8 | 8.6 |
| **Baseline Characteristics** | | | | |
| Age/5 y | 0.92 (0.67, 1.27) | 0.96 (0.52, 1.78) | 0.84 (0.48, 1.49) | 1.18 (0.80, 1.74) |
| Female | 2.35 (0.92, 5.96) | 4.98 (0.87, 28.45) | 3.08 (0.69, 13.80) | 1.60 (0.72, 3.53) |
| Falls in year before baseline, no. | 0.76 (0.57, 1.02) | 0.96 (0.85, 1.09) | 0.90 (0.65, 1.26) | 0.99 (0.89, 1.10) |
| Body mass index, kg/m$^2$ | | | | |
| < 25.0 | 2.44 (1.00, 5.97) | 1.14 (0.24, 5.35) | 1.62 (0.37, 7.11) | 0.75 (0.32, 1.77) |
| 25.0–29.9 (Ref) | 1.00 | 1.00 | 1.00 | 1.00 |
| ≥ 30.0 | 1.03 (0.38, 2.82) | 7.18 (1.79, 28.82) | 2.49 (0.55, 11.26) | 1.03 (0.33, 3.21) |
| Berg Balance Scale score[a] | | | | |
| ≥ 51.0 (Ref) | 1.00 | 1.00 | 1.00 | 1.00 |
| 48.0–50.9 | 0.64 (0.21, 1.89) | 4.22 (0.71, 25.04) | 1.04 (0.21, 5.10) | 1.46 (0.58, 3.65) |
| < 48.0 | 0.79 (0.35, 1.79) | 7.29 (0.75, 70.72) | 2.16 (0.46, 10.08) | 3.19 (1.10, 9.21) |
| Unable to stand from a chair without using arms | 0.93 (0.29, 2.99) | 15.45 (0.25, 949.50) | 6.47 (0.99, 42.17) | 1.75 (0.28, 11.03) |
| Gait speed, m/sec | | | | |
| Slow (< 0.60) | 0.68 (0.22, 2.08) | 5.79 (0.23, 145.79) | 4.14 (0.82, 20.94) | 0.71 (0.07, 7.31) |
| Middle (0.60–1.29; Ref) | 1.00 | 1.00 | 1.00 | 1.00 |
| Fast (≥ 1.30) | 3.79 (1.27, 11.29) | 0.44 (0.04, 4.50) | 0.15 (0.01, 3.76) | 1.11 (0.41, 2.95) |
| Vision worse than 40/100 | 0.96 (0.19, 4.83) | 6.93 (0.41, 117.93) | 2.59 (0.27, 25.11) | 1.06 (0.22, 5.20) |
| Some difficulty with or inability to perform ADLs | 1.14 (0.49, 2.67) | 2.78 (0.51, 15.29) | 3.17 (0.83, 12.16) | 3.09 (1.48, 6.45) |
| Comorbidities, no. | 1.18 (0.92, 1.51) | 1.24 (0.74, 2.06) | 1.10 (0.76, 1.60) | 1.34 (1.05, 1.72) |
| > 4 medications | 0.65 (0.28, 1.52) | 3.24 (0.68, 15.45) | 1.19 (0.30, 4.68) | 1.58 (0.72, 3.48) |
| Psychotropic medication | 1.30 (0.55, 3.05) | 1.72 (0.37, 8.05) | 1.59 (0.41, 6.14) | 2.94 (1.46, 5.91) |
| Falls Efficacy Scale score < 90[b] | 0.61 (0.24, 1.57) | 1.42 (0.19, 10.78) | 3.15 (0.61, 16.29) | 1.82 (0.56, 5.90) |
| Impaired cognition, MMSE score 18–24[c] | 0.65 (0.18, 2.35) | . . . | 4.96 (0.79, 31.03) | 1.10 (0.26, 4.77) |
| Fair/poor self-rated health | 0.75 (0.29, 1.97) | 2.54 (0.28, 23.25) | 2.54 (0.54, 12.09) | 0.49 (0.10, 2.52) |
| Physical activity, PASE score < 55[d] | 0.90 (0.41, 1.98) | 1.83 (0.41, 8.24) | 0.76 (0.19, 2.99) | 1.16 (0.39, 3.43) |
| Height, tallest quartile for gender | 0.76 (0.32, 1.79) | 0.43 (0.07, 2.43) | 1.02 (0.27, 3.85) | 0.45 (0.17, 1.17) |
| Wearing slippers, bare feet, or socks at time of fall (indoors only) | 2.46 (0.96, 6.29) | 0.85 (0.19, 3.71) | 1.17 (0.39, 3.48) | . . . |

*Note*. ADL = activities of daily living; CI = confidence interval; MMSE = Mini-Mental State Exam; PACE = Physical Activity Scale for the Elderly; OR = odds ratio. Ellipses indicate no serious injuries in a category. Odds ratios were estimated with mixed-effects logistic regression models.
[a]Possible score, 0–56.
[b]Possible score, 10–100.
[c]Possible score, 0–30; score of 18–24 indicates impaired cognition.
[d]Possible score, 0–361; < 55 is lowest quartile.

outdoor fall is more likely when walking outside one's own neighborhood and from an indoor fall when walking in a building other than one's own home suggest that being in unfamiliar surroundings may be especially hazardous when a person falls. It may be useful to incorporate a warning about a possibly increased risk in unfamiliar surroundings in public health messages.

The likelihood of serious injury from a fall was greater in women than men for both indoor and outdoor falls, and, except for indoor falls while transitioning or not moving, tended to be higher among those with poor lower-extremity strength, difficulty with activities of daily living, and other indicators of poor health. Women are probably more likely to experience serious injury if they fall because their higher prevalence of osteoporosis makes them more susceptible to fractures.[33] People with certain indicators of poor health and who use psychotropic

medications have a greater risk of serious injury if they fall because such factors as slow reaction time or poor muscle strength make them less likely to be able to break or slow a fall if it occurs.[17]

Our finding that persons who were not wearing shoes at the time of an indoor fall while transitioning or not moving were at increased odds of serious injury is consistent with results of previous reports,[34] including from MOBILIZE Boston,[35] that inadequate footwear increases the likelihood of serious injury among those who fall. Balance and likelihood of slipping can be affected by going barefoot, wearing socks without shoes, or wearing slippers.[36–39] Consideration should be given to including wearing proper footwear as part of fall prevention programs.

## Limitations

Our data lacked information on certain aspects of falls and had limited information on environmental hazards. When we categorized the data by activity and location, relatively small numbers of seriously injurious falls occurred in some categories, and we could not consider individual types of injury. We did not know the amount of time participants spent indoors and outdoors and in various activities.

Some of the data, such as information on fall and injury occurrence and on some risk factors, were based on self-report. This information may not be entirely accurate, especially in a geriatric population, in whom memory, fatigue, frustration with detail, a tendency to ramble, vision and hearing problems, and illness may be problematic.[40] On the other hand, the cohort was relatively large, follow-up was good, falls were carefully ascertained, and detailed measurements were made at baseline of many potential fall risk factors. It will be important to have our findings evaluated in other studies.

## Conclusions

Our findings, along with the work of Northridge et al.[14,15] and Speechley and Tinetti,[16] indicate that fall prevention efforts should reach all older people, but that they are likely to be more effective if tailored to certain activities among certain subgroups. In addition to developing separate prevention programs for relatively frail people who are likely to fall at home during transferring, not moving, or walking and for healthy, active people who are more likely to fall outdoors during walking or vigorous activity, the likelihood of serious injury from a fall should be considered. In view of the large personal and societal burden from falls in general and seriously injurious falls in particular, further fall prevention efforts are urgently needed, especially those that take into account the heterogeneity of falls. ■

## About the Authors

*Jennifer L. Kelsey, Elizabeth Procter-Gray, and Wenjun Li are with the Department of Medicine, University of Massachusetts Medical School, Worcester. Marian T. Hannan is with the Institute for Aging Research, Hebrew SeniorLife, and the Beth Israel Deaconess Medical Center, Harvard Medical School, Boston.*

*Correspondence should be sent to Wenjun Li, PhD, University of Massachusetts Medical School, Department of Medicine, Division of Preventive and Behavioral Medicine, 55 Lake Ave N, Shaw Building, Worcester MA 01655 (e-mail: Wenjun.Li@umassmed.edu). Reprints can be ordered at http://www.ajph.org by clicking the "Reprints" link.*

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## Contributors

J. L. Kelsey conceptualized the study and wrote the article, with assistance from all the authors. J. L. Kelsey led analysis and interpretation of the data, with assistance from E. Procter-Gray and M. T. Hannan and oversight by W. Li. M. T. Hannan participated in the conception and design of the entire MOBILIZE Boston study and was the liaison to the parent study from which this study was derived.

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## Human Participant Protection

This study was approved by the institutional review board of Hebrew SeniorLife; all participants signed a consent form.

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