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Research Article

Characterizing Fall Circumstances in Community-Dwelling Older Adults: A Mixed Methods Approach

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Abstract

Background: Understanding fall circumstances can help researchers better identify causes of falls and develop effective and tailored fall prevention programs. This study aims to describe fall circumstances among older adults from quantitative data using conventional statistical approaches and qualitative analyses using a machine learning approach.

Methods: The MOBILIZE Boston Study enrolled 765 community-dwelling adults aged 70 years and older in Boston, MA. Occurrence and circumstances of falls (ie, locations, activities, and self-reported causes of falls) were recorded using monthly fall calendar postcards and fall follow-up interviews with open- and close-ended questions during a 4-year period. Descriptive analyses were used to summarize circumstances of falls. Natural language processing was used to analyze narrative responses from open-ended questions.

Results: During the 4-year follow-up, 490 participants (64%) had at least 1 fall. Among 1 829 falls, 965 falls occurred indoors and 804 falls occurred outdoors. Commonly reported activities when the fall occurred were walking (915, 50.0%), standing (175, 9.6%), and going down stairs (125, 6.8%). The most commonly reported causes of falls were slip or trip (943, 51.6%) and inappropriate footwear (444, 24.3%). Using qualitative data, we extracted more detailed information on locations and activities, and additional information on obstacles related to falls and commonly reported scenarios such as "lost my balance and fell."

Conclusions: Self-reported fall circumstances provide important information on both intrinsic and extrinsic factors contributing to falls. Future studies are warranted to replicate our findings and optimize approaches to analyzing narrative data on fall circumstances in older adults.

Keywords: Aging, Falls, Machine learning, Mobility, Natural language processing

Falls are the second leading cause of unintentional injury death globally (1) and over 1 out of 4 older adults fall every year in the United States (2). Risk for falls and fall-related injuries increases with age, with greatest hazards among those aged 85 and older, one of the fastest-growing age groups in the United States (3). Given the high prevalence of falls and risk of severe injuries and death, understanding fall circumstances such as locations of falls and activities at the time of falls is critical to helping researchers better identify direct and indirect causes of falls and facilitate effective tailored fall prevention programs for older adults.

Previous studies described the circumstances of falls from location, activities, direction, and attributed cause of falls (4–7). Studies found most of falls happened in living rooms and in bathrooms were more likely to cause severe injuries (4,6,8). The common activities at the time of falls were walking and transferring in both indoor falls and outdoor falls (5,9,10). The mostly reported perceived causes of falls were slip or trip and loss of balance (7,9,10). Sex differences in circumstances of falls have been reported in several studies (5,7,11,12), with consistent findings showing that older women more often fell inside the home than older men. Falls among men most often resulted from slips, whereas falls by women were more likely due to trips (11,12). Older women were more likely to report falls in a forward direction (7). There were also sex differences in activities when falls occurred; older men were more likely to report falls while seated or while rising, and less likely to fall while walking (11). However, only a few studies have examined age differences in circumstances of falls and they reported that older age was associated with more reports of falls inside the home (7,13). More thorough analyses on age differences in locations of falls, activities when falls occurred, and causes of falls are needed to inform individualized interventions to prevent falls among older adults according to age groups.

There are a variety of approaches to collect fall circumstances data. Some were collected using questionnaire (10,14) or retrieved from emergency department records

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(15). A few studies used digital video camera to capture fall circumstances for older adults living in long-term care facilities (16,17). Wearable sensors such as accelerometer were also used to detect causes of falls (18,19). However, in community settings, using questionnaire is currently the most common and feasible approach to obtain information about fall circumstances. Previous studies collected quantitative data using close-ended questions by providing a list of predefined locations, activities, and environmental conditions (7,10,20). The classifications of fall circumstances were based on the Clinical Practice Guideline by the American Geriatrics Society/British Geriatrics Society (20). A few studies have also collected qualitative data using semistructured questionnaire and employed thematic analysis to classify locations (4,6,20). The qualitative data may disclose potentially important factors that would be overlooked in predefined response options for questions.

Recently, machine learning has been used in health care and medicine to help solve complex problems (21). For example, due to the vast amount of data in electronic health records (EHRs), machine learning has provided a new approach to identify patients with highest risk for health conditions (22). Other studies have used machine learning approaches to identify geriatric syndromes using unstructured EHR data (23,24). This approach captured more information about geriatric syndromes than a traditional quantitative approach, especially when these syndromes are not well represented by the coding standards (24). Similarly, using machine learning to analyze the vast volume of narrative descriptions of falls in population-based studies may be more informative than conventional approaches for qualitative data analysis. However, to date, there have been no published studies that used machine learning to analyze fall circumstances data. Thus, our study aims to describe fall circumstances among community-dwelling older adults from quantitative data using a conventional statistical approach alongside qualitative data analysis using a machine learning approach, and further to determine age differences in circumstances of falls from the quantitative data.

Method

The MOBILIZE Boston Study (MBS), a population-based cohort study investigating novel fall risk factors in older adults, enrolled 765 community-dwelling adults aged ≥70 years in Boston and surrounding areas from 2005 to 2008. The detailed description of the study methods was published elsewhere (25). Briefly, study participants were recruited door-to-door based on random samples of city/town lists of older residents living within a 5-mile radius of the Hebrew Rehabilitation Center (HRC) in Boston where the study center was based. To be eligible, participants were aged 70 years and older, English speakers, expected to live in the area for at least 2 years, and able to walk 20 feet without personal assistance at the time of enrollment. Spouses aged ≥65 years of eligible participants who met the other eligibility criteria were also welcomed in the study. Older adults who had terminal disease, severe vision or hearing deficits, or moderate-to-severe cognitive impairment (Mini-Mental State Examination <18) were excluded from the study (26). The MBS baseline data collection comprised an in-home health interview followed by a clinical assessment at HRC. During the home interview, informed consent was obtained from participants. The MBS was approved by the Institutional Review Boards of the HRC and collaborating institutions in Boston.

Fall Ascertainment

A fall was defined as "unintentionally coming to rest on the ground or other lower level not as a result of a major intrinsic event (eg, myocardial infarction or stroke) or an overwhelming external hazard (eg, hit by a vehicle)" (27). At the baseline home visit, participants were instructed to fill out the monthly fall calendar postcards each day, recording whether or not they fell. During the 4-year follow-up period, participants mailed the completed postage-paid postcards to the research center at the end of each month. When calendars were missing or incomplete, study staff contacted participants by phone to complete the fall calendars.

Fall Circumstances

Each reported fall was followed by a telephone interview with the participant or proxy about circumstances and consequences of the fall. Detailed descriptions of the fall circumstances, including the locations and activities when the fall occurred, were asked in open-ended questions. For example, participants were asked "what were you doing (when you fell)" to understand the activities at the time the fall occurred. Participants' responses on these questions were recorded verbatim. The interview also included a list of close-ended questions about circumstances of falls regarding locations (indoor or outdoor, living or dining rooms, bedroom, stairs, kitchen, sidewalk, garden or yard, etc.), activities (walking, standing, going down stairs, going up stairs, getting onto/out of a chair/sofa/bed/toilet, sitting or lying, etc.), and self-reported causes of falls (slip or trip, inappropriate footwear, health problems, snow or ice on the surface, dizzy or faint, or dark environment). A list of close-ended questions about locations and activities at the time of falls were answered/coded by the research interviewer following the interview based on the participants' narrative responses on circumstances of falls. Accordingly, responses from the open-ended questions are qualitative data while answers from close-ended questions are the quantitative data for these analyses. We used the parallel concurrent design, as described by Creswell and colleagues (28). With this approach, the quantitative and qualitative data were collected at the same time using a single instrument but integrated in the interpretations and discussions.

Covariates Measurements

Sociodemographic characteristics including age, gender, education, and race were self-reported in the home interview. Racial groups included White, Black or African American, Asian, American Indian or Alaskan Native, and Native Hawaiian or Pacific Islander. Height and weight were measured during the MBS clinic visit and body mass index was calculated as weight in kilograms divided by height in squared meters. Chronic conditions including osteoarthritis, peripheral arterial disease, diabetes, and peripheral neuropathy were assessed using disease algorithms, reported previously (25). Physician diagnosis of other chronic conditions including heart disease and stroke were self-reported. Presence of any mobility difficulty was based on 2 questions regarding ability to walk ¼ mile without assistance, and ability to walk upstairs to the second floor (29). Depressive symptoms were assessed using the Center for Epidemiological Studies Depression Scale-Revised questionnaire (30). Vision deficit

was determined by the 10-foot distant vision test by using the Good-Lite Chart (31). In addition, medication use including daily analgesic medications and psychiatric medications was determined using the brown bag method, where the names and frequency of all medications used in the previous 2 weeks were recorded.

Statistical Analysis

Demographic and health characteristics were described using frequencies (percentages) for categorical variables. These characteristics were compared between participants who have at least 1 fall versus those without falls during the follow-up period using Chi-square tests. The categories of locations, activities, and self-reported causes of all falls in the follow-up period were identified according to the close-ended questions of circumstances of falls in fall follow-up questionnaire (quantitative data). The fall records without completed follow-up interviews were excluded from the analysis. The number and percent of falls classified into categories of locations, activities, and self-reported causes of falls were calculated. We further compared differences in circumstances of falls between participants aged ≥80 years versus those aged 70–79 years using Chi-square tests. The analysis was conducted using SAS software 9.4 (SAS Institute Inc., Cary, NC).

The qualitative data were analyzed using machine learning methods to identify the circumstances of falls from the narrative fall descriptions collected in the telephone interviews. Specifically, N-grams, an approach in natural language processing (NLP), was used to describe the frequencies of words or phrases reported in the narrative descriptions of falls. This analysis provided the most frequently reported words and the 2-, 3-, 4-, and 5-word combinations found in the data. In addition, to examine the most commonly reported locations or activities, this approach presented the most frequently reported scenarios or other information that may not be available in quantitative data.

Results

Sample Characteristics

The average age of the 765 participants was 78.1 (standard deviation = 5.4). Over half (63.9%) were women and 16.1% were African American. The average follow-up time was 2.78 ± 0.95 years. During up to 4.3 years of follow-up, 490 (64.1%) participants had at least 1 fall. Among the fallers, 157 (32.0%) had only 1 fall and 101 (20.6%) had 2 falls. A total of 232 (47.3%) participants had 3 and more falls. The sample characteristics by fall status are presented in Table 1. We found a greater proportion of Whites among participants who had a fall compared to those without a fall ($p = .004$). Other characteristics related to fall status included education, osteoarthritis, depression, vision impairment, daily analgesic use, and psychiatric medication use ($p < .05$).

Circumstances of Falls From Quantitative Data

Among the 1 829 falls, 60 (3.2%) were missing in information for locations, 965 (52.8%) falls occurred indoors, and 804 (44.0%) falls occurred outdoors (Table 2; Figure 1). The most common reported locations of indoor falls were living room or dining room (248, 14.0%), bedroom (176, 10.0%), and stairs (125, 7.1%). For outdoor falls, commonly reported locations were sidewalk (202, 11.4%), garden or yard (128, 7.2%), and stairs (100, 5.7%). The commonly reported activities at the time of the fall were walking (915, 50.0%), standing (175, 9.6%); less common were reports of falls while going down stairs (125, 6.8%) or going up stairs (116, 6.3%). Participants commonly reported the causes of falls as slip or trip (943, 51.6%) and inappropriate footwear (444, 24.3%). Among 113 older adults who reported health problems as a cause of falls, 17 (15.0%) explicitly reported dizziness or lightheaded, mostly due to side effects of medications. Fourteen participants (12.4%) reported balance problems. Other reported health problems included arthritis, muscle weakness, low blood pressure, low blood sugar, legs or knees giving way, and vision problems.

Comparing fall circumstances between older adults aged 70–79 and those aged ≥80 years, we found a greater proportion of indoor falls, falls in the living or dining room, bedroom, and kitchen among those aged ≥80 years ($p < .05$ for all; Table 2; Figure 1). Participants aged ≥80 years were less likely to report falls on stairs ($p < 0.001$). Regarding activities at the time of the fall, a greater proportion of participants aged ≥80 years reported falls while getting onto/out of a chair/sofa/bed/toilet compared to those aged 70–79 years (8.1% vs 5.6%, $p = .043$). Participants aged ≥80 years were less likely to report falls while going up stairs or stepping on/off a curb, falls due to a slip/trip, or falls due to snow/ice on the floor, but they were more likely to report health problems as causes of falls compared to those aged 70–79 years ($p < .05$ for all).

Circumstances of Falls From Qualitative Data

The total number of falls included in the N-grams analysis was 1 742, excluding falls without narrative responses to the question, "what were you doing when you fell?" and missing data for the question, "did the fall happen inside or outside?" The narrative descriptions of indoor falls and outdoor falls were analyzed separately. In indoor locations, the most frequently reported locations were stairs, living room, and bathroom, followed by bedroom and kitchen (Table 3). Among 943 indoor falls, there were 534 mentions of furniture or obstacles that may have been related to falls. The most frequently reported furniture or obstacles were bed, chair, rug, steps, or door. Among 799 outdoor falls, the most frequently reported locations, in 747 mentions, were sidewalk or pavement, ground or floor, street, house, steps, and yard/garden. In outdoor falls, there were 218 mentions of "ice" or "snow" reported as weather factors related to falls. In terms of activities when the fall occurred, the commonly reported words were "tripped," "walking," or "slipped," with 567 mentions among the indoor falls and 707 mentions in the outdoor fall descriptions. For the phrases reported in the narrative descriptions of falls, "lost my balance and fell" was the most commonly reported scenario for both indoor and outdoor falls.

Discussion

Our study described commonly reported locations, activities, and self-reported causes of falls during 4-year follow-up among community-dwelling older adults using both quantitative and qualitative data. We found that over half of falls occurred indoors. Commonly reported locations were living or dining room, bedroom, stairs for indoor falls, and sidewalk, garden or yard, and stairs for outdoor falls. Walking, standing, going up or down stairs were commonly reported activities when falls occurred. Participants tended to attribute

Table 1. Baseline Sociodemographic Characteristics, Chronic Conditions, and Fall Risk Factors According to Occurrence of Falls During 4-Year Follow-up, 765 Older Adults, MOBILIZE Boston Study

Characteristics	Total *n* (%)	No Fall (*N* = 275)	Fall (*N* = 490)	*p* Value*
		n (%)		
Age (years)†				.337
65–79	478 (62.5)	178 (64.7)	300 (61.2)	
≥80	287 (37.5)	97 (35.3)	190 (38.8)	
Gender				.973
Male	276 (36.1)	99 (36.0)	177 (36.1)	
Female	489 (63.9)	176 (64.0)	313 (63.9)	
Race‡				**.004**
White	593 (77.6)	193 (70.2)	400 (81.8)	
African American	123 (16.1)	63 (22.9)	60 (12.2)	
Other	48 (6.3)	19 (6.9)	29 (5.9)	
Education				**<.001**
Less than high school	85 (11.1)	41 (15.0)	44 (9.0)	
High school graduate	323 (42.3)	129 (47.1)	194 (39.6)	
College graduate	356 (46.6)	104 (37.9)	252 (51.4)	
Body mass index				.611
<25	222 (29.7)	76 (28.7)	146 (30.3)	
25–29	320 (42.8)	114 (43.0)	206 (42.7)	
≥30	205 (27.4)	75 (28.3)	130 (27.0)	
Mobility difficulty	272 (35.6)	92 (33.6)	180 (36.7)	.382
MMSE <24	92 (12.0)	40 (14.6)	52 (10.6)	.109
Heart disease	319 (41.7)	105 (38.2)	214 (43.7)	.140
Diabetes	153 (20.0)	60 (21.8)	93 (19.0)	.347
Osteoarthritis				**.030**
Neither site	484 (63.4)	186 (67.9)	298 (60.8)	
Knee only	134 (17.5)	44 (16.0)	90 (18.4)	
Hand only	88 (11.5)	30 (11.0)	58 (11.8)	
Hand and knee	58 (7.6)	14 (5.1)	44 (9.0)	
Peripheral neuropathy	92 (12.2)	25 (9.3)	67 (13.8)	.069
Peripheral artery disease	73 (9.5)	28 (10.2)	45 (9.2)	.652
Stroke	76 (9.9)	27 (9.8)	49 (10.0)	.936
Depressive symptoms	56 (7.3)	8 (2.9)	48 (9.8)	**<.001**
Vision impairment	189 (24.8)	80 (29.3)	109 (22.3)	**.032**
Daily analgesic use	189 (24.7)	56 (20.4)	133 (27.1)	**.040**
Psychiatric medication use	158 (20.7)	42 (15.3)	116 (23.7)	**.006**

Notes: MMSE = Mini-Mental State Examination.
*Chi-square test, $df = (r - 1)(c - 1)$. Bolded values indicate statistically significant results.
†There were 16 spouses aged 65–69 who were permitted to join the study.
‡The "other" group included Asian, American Indian or Alaskan Native, and Native Hawaiian or Pacific Islander.

falls to slip or trip and inappropriate footwear. These circumstances of falls differ by age groups. Participants aged 80 years and older had more reports of falls indoors, falls while standing up or sitting down, and falls resulted from health problems, but fewer reports of falls while going up stairs or stepping on/off a curb, or falls due to slipping or tripping or snow/ice on the floor compared to those aged 70–79 years. From qualitative data (narrative responses of fall circumstances) analyzed using machine learning, we extracted more detailed information on locations and activities, and additional information on obstacles related to falls and commonly reported scenarios. To the best of our knowledge, this is the first study to analyze narrative responses about circumstances of falls using a machine learning data analysis approach. This method allows researchers and health care providers to obtain extensive information from qualitative data on fall circumstances in an efficient way.

Although the percentage of indoor falls varied among previous studies, ranging from 58% to 65% of falls (8,12,15), and accounting for 53% of falls in our study, they are consistently more prevalent than outdoor falls. Our study found that circumstances of falls differ by age groups with more indoor falls occurring among older adults aged ≥80 years compared to those younger than 80 years. It has been reported that older adults with age-related conditions (eg, low activity level, poor functional performance, morbidities) had higher rates of indoor falls (13). Oldest-old adults may spend more time at home due to mobility limitation thus are more likely to

Table 2. The Circumstances of Falls Including Locations, Activities, and Self-Reported Causes of Falls From 1 829 Falls During 52-Month Follow-up (*n* = 490)[*]

Fall Circumstances	Total *n* (%)	Age 70–79 y (*n* = 478)	Age ≥80 y (*n* = 287)	*p* Value
		n (%)		
All falls	1 829			
Location[†]				
Indoor	965 (52.8)	575 (50.1)	390 (57.2)	**<.001**
Living or dining room	248 (14.0)	146 (13.1)	102 (16.6)	**.048**
Bedroom	176 (10.0)	87 (7.8)	89 (14.5)	**<.001**
Stairs (indoor)	125 (7.1)	90 (8.1)	35 (5.7)	.067
Kitchen	90 (5.1)	49 (4.4)	41 (6.7)	**.042**
Hallway	79 (4.5)	52 (4.7)	27 (4.4)	.792
Bathroom	51 (2.9)	29 (2.6)	22 (3.6)	.252
Outdoor	804 (44.0)	554 (48.3)	250 (36.7)	**<.001**
Sidewalk	202 (11.4)	128 (11.4)	74 (11.6)	.870
Garden or yard	128 (7.2)	92 (8.2)	36 (5.7)	.051
Stairs (outdoor)	100 (5.7)	65 (5.8)	35 (5.5)	.812
Street	69 (3.9)	51 (4.5)	18 (2.8)	.077
Parking lot	42 (2.4)	27 (2.4)	15 (2.4)	.957
Curb	38 (2.2)	26 (2.3)	12 (1.9)	.557
Stairs (indoor + outdoor)	225 (12.3)	155 (13.5)	70 (10.3)	**<.001**
Activity[‡]				
Walking	915 (50.0)	596 (53.5)	319 (51.5)	.413
Standing	175 (9.6)	102 (9.2)	73 (11.8)	.083
Going down stairs	125 (6.8)	76 (6.8)	49 (7.9)	.404
Going up stairs	116 (6.3)	89 (8.0)	27 (4.4)	**.004**
Getting onto/out of a chair/sofa/bed/toilet	112 (6.1)	62 (5.6)	50 (8.1)	**.043**
Sitting or lying	53 (2.9)	28 (2.5)	25 (4.0)	.078
Getting into/out of a vehicle	26 (1.4)	15 (1.4)	11 (1.8)	.482
Stepping on/off a curb	25 (1.4)	21 (1.9)	4 (0.7)	**.038**
Self-reported cause of falls[§]				
Slip or trip	943 (51.6)	658 (60.0)	285 (46.6)	**<.001**
Inappropriate footwear	444 (24.3)	288 (26.1)	156 (24.8)	.550
Health problem	239 (13.1)	138 (12.5)	101 (16.3)	**.028**
Snow or ice	209 (11.4)	162 (14.6)	47 (7.6)	**<.001**
Dizzy or faint	191 (10.4)	120 (10.6)	71 (11.0)	.801
Dark environment	124 (6.8)	77 (6.9)	47 (7.7)	.530

Notes:
[*]A total of 490 participants fell during the follow-up period and a total of 1 829 falls have completed follow-up interviews.
[†]There were 60 falls with missing information on indoor or outdoor locations of the falls. Among indoor falls, 37 falls with missing information on specific indoor locations. Among outdoor falls, 65 falls with missing information on specific outdoor locations.
[‡]There were 95 falls with missing information on activities at the time of the falls.
[§]The number of missing falls for self-reported causes of falls were 121, 94, 107, 97, 57, and 104, respectively.

be exposed to indoor environmental hazards (32). Consistent with previous studies, we found that the most frequently reported indoor locations were living room, bedroom, stairs, and kitchen (6,20,33). Contrary to what might be expected, falls in the bathroom only accounted for 5% of all falls (8,33). From qualitative data, however, we found "stairs" were the most reported fall location, followed by living room and bathroom. For outdoor locations, similar to prior research, the most frequently reported locations were sidewalk, garden or yard, and stairs (8,33,34). Our study provides evidence on locations with high occurrence of falls for future research and practice and emphasizes the importance of identifying fall risks associated with hazardous environments.

As previous studies showed, we found that the most reported activity at the time of a fall was walking (8,9,12,15,33–35), which was also the most frequently reported word from the narrative descriptions of fall circumstances. Possible explanations for falls while walking may be tripping over something such as a rug, carpet, a cord on the floor, or shoes. Other frequently reported activities were standing and going up or down stairs, which was consistent with prior research (9,15). Previous studies found that sitting down, turning, reaching or leaning, and transferring are also common activities at the time of falls (8,18). Although in the close-ended questions, "turning," "reaching," or "leaning" were not separate response options, these activities and words were better

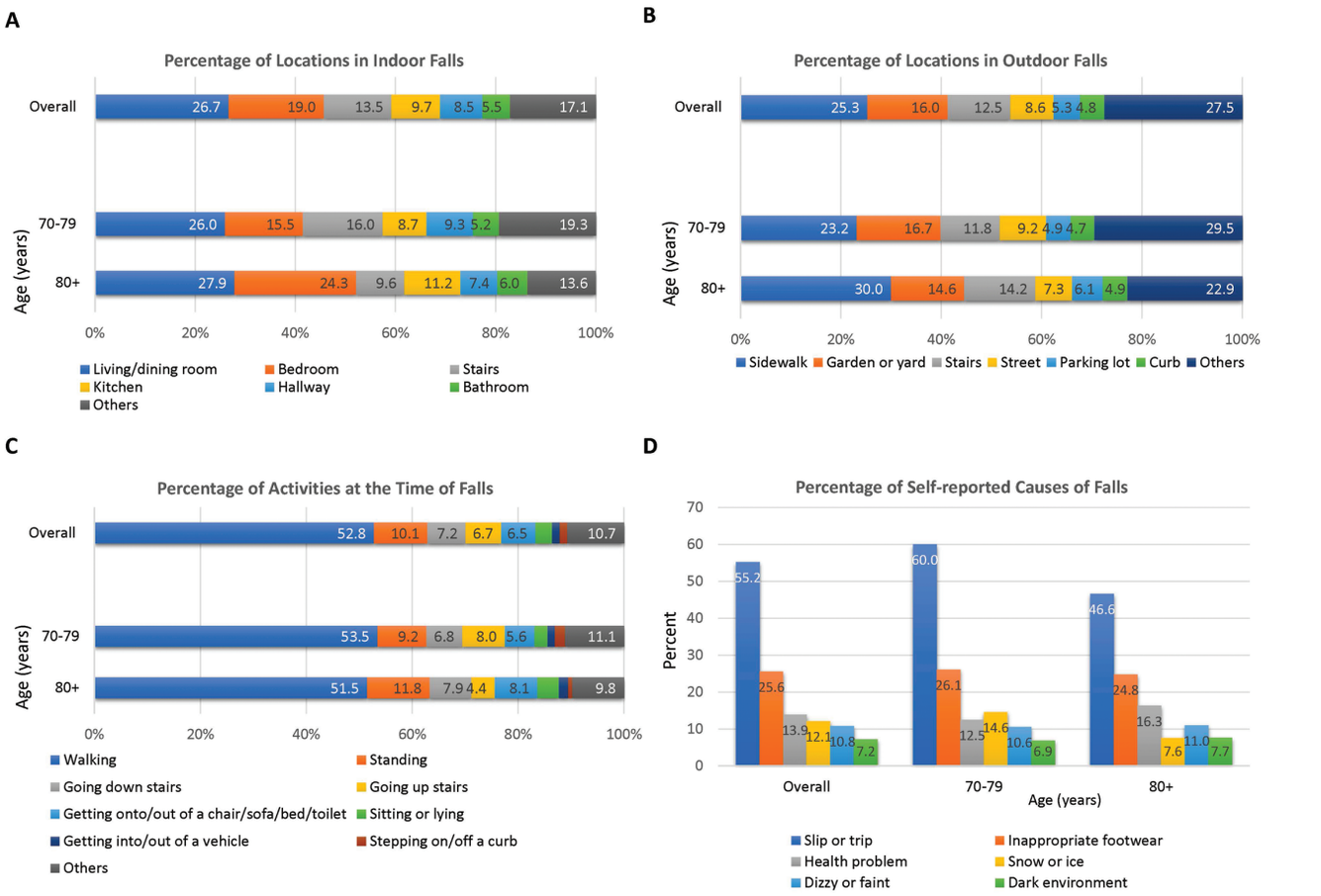

Figure 1. Percentage of locations in indoor falls (A), locations of outdoor falls (B), activities at the time of falls (C), and self-reported causes of falls (D). Self-reported causes of falls are not mutually exclusive.

identified and captured from qualitative data. In reviewing the fall follow-up interview, we found that narrative responses with these activities were mainly categorized into "walking," "sitting," and "standing" in quantitative data (answers from close-ended questions). Our study found that participants aged 80 and older were more likely to report falls while getting onto/out of a chair/sofa/bed/toilet, but less likely to report falls while going up stairs or stepping on/off a curb than the younger group. Age-related decline in musculoskeletal function, chronic conditions such as knee arthritis, and postural hypotension may explain more falls reported while getting up or sitting down in the older age group (36–38). Older adults oftentimes experience mobility difficulties, and the prevalence is increasing with age (32). They may intentionally avoid climbing stairs due to mobility limitation and spend less time outdoors. Although these findings provide insights into possible underlying causes of falls, future studies are needed to explore the interactions between hazardous activities and environmental factors in order to better understand the causes of these falls.

This study found that slips or trips are among the most reported causes of falls, accounting for about half of falls among our participants; estimates from other studies range from 27% to 69% of falls in older adults (8,9,12,35). Several studies found that loss of balance was frequently reported as the cause of falls (7,12). In our study, the qualitative data showed that many people reported that they lost their balance and fell, but this was not well captured from quantitative data (answers from close-ended questions). Other causes found in our study such as feeling dizzy or faint, wet surface, or slippery footwear were also frequently mentioned in previous studies (7,39). A number of participants reported their "legs gave out" or "legs gave way," which is consistent with previous studies (7,35). Although our study suggests that older adults aged ≥80 years were more likely to report falls due to health problems such as arthritis and less likely than their younger counterparts to report slipping or tripping, both intrinsic factors and extrinsic factors play important roles in causing falls. Falls prevention interventions are often multicomponent, reflecting the need to address multiple factors to reduce fall risk in the community (40). In addition, these intervention programs should be tailored by age groups.

Slip or trip was a grouped response option in the close-ended questions in our study, similar to other studies (7,41). It is important to differentiate the possible mechanisms and causes of a trip and a slip. Trips often occurred when a person was unable to lift their feet as high as the hazardous obstacles on the floor. This may also happen due to vision impairment or misjudgment of the obstacles. The contributors for slips, however, may be snow or ice, a loose rug on the floor or hazardous footwear. These 2 circumstances may reflect different abilities to avoid falls. Future studies are needed investigate distinctive mechanisms leading to falls and to examine individualized prevention plans for older adults according to different patterns of fall circumstances.

Table 3. Frequently Reported Words or Phrases in Narrative Descriptions of 1 742 Falls Analyzed Using N-Grams

Indoor Falls (*n* = 943)		Outdoor Falls (799)	
Fall Circumstances Words or Phrases	***n****	**Fall Circumstances Words or Phrases**	***n****
Location		Location	
Home, house, or apartment	224	Sidewalk or pavement	182
Stairs	139	House or home	156
Living room	118	Ground or floor	151
Bathroom	82	Step or steps	147
Bedroom	81	Garden, yard, or backyard	111
Kitchen	76	Street	99
Furniture or obstacle		Car	74
Bed	129	Stair or stairs	63
Chair	114	Curb	63
Rug	51	Driveway	39
Steps	44	Parking lot	36
Door	43	Weather	
Shoe or shoes	27	Ice or icy	155
Table	24	Snow	63
Activity		Activity	
Tripped	253	Walking, walk, or walked	292
Walking or walked	228	Tripped or trip	222
Slipped	86	Slipped	193
Sitting or lying	54	Stepped or stepping	53
Standing or stood	52	Crossing	24
Turn or turned	45	Standing	18
Running, rushing, or ran	33	Stumbled	13
Stepped or stepping	30	Carrying or holding	12
Reaching, reached, or leaned	24	Running	7
Scenarios		Scenarios	
Lost my balance and fell	103	Lost my balance and fell	49

Note:
*The number of times that this word or phrase was reported in the narrative descriptions of falls in the telephone fall follow-up interviews by fallers.

Other fall circumstances such as direction (left, right, forward, or backward, etc.), season, and time (morning, afternoon, etc.) of the falls were also collected in previous studies (7,42). Studies found that older adults were more likely to fall in a forward direction, in summer, and afternoon (7,42). These circumstances may also provide valuable information on possible contributors to falls and factors that lead to fall-related injuries. However, participants may not be able to recall the circumstances of a fall in this level of detail such as direction of falls. Using digital video cameras or real-time monitors to record falls and using machine learning approach such as artificial neural networks to process the data may provide important information for fall detection and fall classification among older adults (18,43–45).

Our study used monthly fall calendars, which is a gold standard measure of falls, followed by a fall follow-up interview with both open- and close-ended questions. As the responses from close-ended questions are predefined, the most accurate or complete information may not be captured from these responses. The narrative descriptions of falls in responses to open-ended questions may provide a more complete picture of fall circumstances compared to the set of closed-ended questions. In previous studies on fall circumstances, only a few studies collected data on narrative descriptions of falls (34,42). For example, Timsina and colleagues (42) developed a coding taxonomy to describe the circumstances of injurious falls from 8 categories: place, activity, initiating event, hazards, level, work-relatedness, contributing factors, and direction of fall. In our study, we used N-grams, one of the NLP approaches, to analyze the qualitative data of fall circumstances and this approach provides more detailed information on the factors that were not considered in quantitative data such as obstacles that are related to the fall. The scenarios such as "lost my balance and fell" captured by the NLP approach were not an option from close-ended questions. This data-driven approach may better summarize patterns of fall circumstances directly from narrative data reported by participants from multiple dimensions. Alternatively, the findings of this study may be applied to development of new closed-ended questions to assess fall circumstances. Our study is novel to adapt the NLP method to analyze text data (also called unstructured data in computer science) on fall circumstances and understand the patterns of participants' reports on fall circumstances. With its advantage in efficiency and accuracy, this NLP approach could be applied in future cohort studies with larger sample sizes and longer follow-up intervals for managing and coding the extensive text data.

Our study has several limitations. First, the circumstances of falls that were reported in the fall follow-up interview rely on participants' recall. Participants may not be completely able to describe what actually occurred during a fall, especially if they experienced an injury. Thus, we may not have thorough or completely accurate information on both intrinsic and extrinsic factors related to the fall (46). In addition, as falls are multifactorial, multiple factors may interact and contribute to falls. For instance, the activity at the time of the fall may interact with environmental factors and lead to the fall. Second, the MBS cohort has a relatively higher education level than the general older population. This may limit the generalizability of these results to older populations with lower education levels. Third, this is the first study to analyze unstructured fall report data using a machine learning approach. Other machine learning approaches may better depict fall circumstances based on narrative fall data. Future studies are needed to examine alternate approaches and determine optimal analytic strategies for narrative fall report data. Fourth, although the data were collected 10 years ago, the MBS provided unique and extensive information on circumstances of falls among a large population-based sample of older adults. Our findings obtained from thorough analyses and novel machine learning approaches are valuable and relevant to current research evidence.

In conclusion, our study findings were consistent with prior reports examining fall circumstances, with more falls occurring indoors and often while walking. Participants tended to attribute falls to a slip or trip and inappropriate footwear. Using the machine learning approach to analyze narrative responses of fall circumstances, we retrieved additional information on obstacles related to falls and commonly reported scenarios when falls occurred. The study findings also highlight the difference in circumstances of falls by age. Greater attention to indoor and outdoor locations and particular activities tailored to age groups could be considered in fall prevention strategies. Future studies are warranted to better understand the person–environment interactions that lead to falls perhaps using modern approaches for analyzing narrative data on fall circumstances in order to inform fall prevention strategies for older populations.

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Conflict of Interest

None.

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