Video capture of the circumstances of falls in elderly people residing in long-term care: an observational study

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Summary

Background **Falls in elderly people are a major health burden, especially in the long-term care environment. Yet little objective evidence is available for how and why falls occur in this population. We aimed to provide such evidence by analysing real-life falls in long-term care captured on video.**

Methods **We did this observational study between April 20, 2007, and June 23, 2010, in two long-term care facilities in British Columbia, Canada. Digital video cameras were installed in common areas (dining rooms, lounges, hallways). When a fall occurred, facility staff completed an incident report and contacted our teams so that we could collect video footage. A team reviewed each fall video with a validated questionnaire that probed the cause of imbalance and activity at the time of falling. We then tested whether differences existed in the proportion of participants falling due to the various causes, and while engaging in various activities, with generalised linear models, repeated measures logistic regression, and log-linear Poisson regression.**

Findings **We captured 227 falls from 130 individuals (mean age 78 years, SD 10). The most frequent cause of falling was incorrect weight shifting, which accounted for 41% (93 of 227) of falls, followed by trip or stumble (48, 21%), hit or bump (25, 11%), loss of support (25, 11%), and collapse (24, 11%). Slipping accounted for only 3% (six) of falls. The three activities associated with the highest proportion of falls were forward walking (54 of 227 falls, 24%), standing quietly (29 falls, 13%), and sitting down (28 falls, 12%). Compared with previous reports from the long-term care setting, we identified a higher occurrence of falls during standing and transferring, a lower occurrence during walking, and a larger proportion due to centre-of-mass perturbations than base-of-support perturbations.**

Interpretation **By providing insight into the sequences of events that most commonly lead to falls, our results should lead to more valid and effective approaches for balance assessment and fall prevention in long-term care.**

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Introduction

Falls are the most frequent cause of unintentional injuries in elderly people (aged ≥65 years), accounting for 90% of hip[1] and wrist fractures[2] and 60% of head injuries.[3] About 30% of elderly people living independently and 50% of those in long-term care fall at least once each year.[4,5] Clearly, prevention of falls in elderly adults is a public health priority.

An important unrecognised challenge to care providers in prevention of falls is the scarcity of objective evidence of the mechanisms of falls—ie, how and why they occur. Few previous studies have measured movements of the body during actual falls.[6] Instead, understanding of the circumstances of falls is based on interviews or incident reports, which rely on the recall accuracy of the faller or witness, if any, to describe the event,[7–10] or on laboratory-based simulations in which participants (typically healthy young adults) are made to trip or slip.[11] This scarcity of information makes accurate diagnosis of the cause of falls difficult, and impairs development of improved environments for elderly people, valid fall assessment instruments, and fall prevention programmes.

We aimed to address this barrier by providing objective evidence of the cause and circumstances of falls in elderly adults, on the basis of analysis of real-life falls captured on video in two long-term care facilities.

Methods

Study design and participants

We did this observational study between April 20, 2007, and June 23, 2010, at two long-term care facilities in Canada: Delta View, a 312 bed facility in Delta, BC; and New Vista, a 236 bed facility in Burnaby, BC. We selected these facilities on the basis of their existing networks of video surveillance cameras and operational ties to the Fraser Health Authority. All residents were eligible and included if they had a fall captured on video during the study period.

The study was approved by the Office of Research Ethics at Simon Fraser University (Burnaby, BC). At the time of admission, each resident or proxy provided written permission to the facility to acquire video footage in common areas, for the purpose of resident safety. These data were shared as secondary data with our research team. We also analysed a subset of falls that were captured between Jan 1, and June 30, 2010, for which we obtained written consent from participants for access to their medical records.

Procedures

Digital video cameras were installed in common areas (dining rooms, lounges, hallways); Delta View had a network of 216 cameras, and New Vista had 48. No cameras were located in bedrooms or bathrooms. All cameras were networked to recorders, which stored video at a resolution of 640×480 pixels and frame rate of between 4 and 15 frames per second.

At both facilities, the known occurrence of a fall (defined as "an unintentional coming to rest on the ground, floor or other lower level"[12]) triggered care personnel to complete a structured incident report. Members of our team communicated daily with care providers to review reports, identify falls in common areas, and retrieve corresponding video footage (the feasibility of which depended on the number and orientation of cameras).

Each fall video was analysed by a team of at least three experts (research assistant and graduate students trained by one of the lead authors [SNR]), who sought consensus on the circumstances of the fall by selecting the best available answers in a structured questionnaire. From a biomechanical perspective, a fall can be divided into initiation, descent, and impact stages.[13,14] Our questionnaire focused on two aspects of fall initiation that are traditionally difficult to understand: cause of imbalance and activity leading to the fall. We divided cause of fall into seven categories (incorrect transfer or shift of bodyweight, trip or stumble, hit or bump, loss of support with external object, collapse or loss of consciousness, slip, or could not tell). We defined incorrect transfer or shifting of bodyweight as a seemingly self-induced shifting of bodyweight, causing the centre of gravity to move outside the base of support. This definition differs from slip, trip, or stumble, and hit or bump because the cause of imbalance is an internal rather than external perturbation. Examples of incorrect shifting of bodyweight include leaning too far from the base of support during walking or standing; failure to establish a stable final position during transferring or gait termination; excessive trunk sway; an improperly placed step during walking, with no obvious trip or stumble; or freezing during walking as is common in Parkinson's disease. Collapse or loss of consciousness included sudden loss in muscle tone, syncope, or seizure. We divided activity at the time of the fall into 11 categories (walking forward, standing quietly, sitting down or lowering, initiation of walking, getting up or rising, walking backwards or sideways, walking and turning, standing and turning, seated or wheeling in wheelchair, standing and reaching, or could not tell). Cases of seated or wheeling in wheelchair included toppling over or slipping off the chair.

	New Vista residents* (n=180)	Delta View residents* (n=191)	Residents with captured falls† (n=32)	Residents with uncaptured falls† (n=79)	Residents not falling† (n=152)
Demographics					
Age (years)	80·8 (12·4)	81·6 (10·3)	82·8 (10·7)	83·8 (11·5)	81·4 (12·1)
Women	120 (67%)	116 (61%)	20 (63%)	50 (63%)	94 (62%)
Diagnoses					
Alzheimer's disease	31 (17%)	72 (38%)	11 (34%)	13 (16%)	32 (21%)
Diabetes	28 (16%)	37 (19%)	4 (13%)	12 (15%)	26 (17%)
Cardiac arrhythmia	6 (3%)	13 (7%)	2 (6%)	2 (3%)	4 (3%)
Hypertension	60 (33%)	87 (46%)	10 (31%)	31 (39%)	56 (37%)
Hypotension	1 (1%)	0	0	4 (5%)	1 (1%)
Stroke	24 (13%)	40 (21%)	6 (19%)	13 (16%)	21 (14%)
Parkinson's disease	4 (2%)	11 (9%)	2 (6%)	3 (4%)	6 (4%)
COPD	15 (8%)	17 (9%)	3 (9%)	4 (5%)	13 (9%)

Data are mean (SD) or n (%). COPD=chronic obstructive pulmonary disease. *Data summarise the characteristics of all residents with electronic medical records for January–December, 2010. †Data are for January–June, 2010, when 32 residents with video-captured falls provided consent to access of medical records; of the 231 additional residents consenting, 79 fell outside of camera view, and 152 did not fall during this period.

Table 1: **Characteristics of residents**

Statistical analysis

For each category of cause of fall and activity at the time of the fall, we examined the total number of associated falls, the proportion of participants falling at least once, and the average number of falls per participant. In cases in which a resident fell more than once, we could not assume that the repeated falls were independent occurrences rather than indicative of consistent underlying risk factors. Accordingly, we used generalised linear models to test whether there were differences between the various causes of falls, and between the various activities at the time of falling, in the proportion of participants falling at least once (defined as [participants captured falling at least once due to a specific cause or activity]/[all participants captured falling]*100), and in the average number of falls per participant.

We analysed two response variables (fall and number of falls) with the GLIMMIX procedure of SAS System (version 9.2). We ran separate models with cause of fall and activity at the time of the fall as the explanatory variable. We analysed the binary variable fall (1 when a participant fell at least once and 0 when they never fell, for each category of cause or activity) with repeated measures logistic regression. We computed estimated odds ratios and corresponding 95% CIs comparing categories of the explanatory variables. We analysed number of falls with log-linear Poisson regression with repeated measures. We computed estimated ratios of the counts, comparing categories of the explanatory variables and corresponding 95% CIs. We used Kenward-Rogers degrees of freedom for all comparisons.

We examined all possible pairwise comparisons of estimates between causes, and between activities, with a null hypothesis of equality between proportions (or number of falls).

Role of the funding source

The sponsors of this study were not involved in development of the study protocol, data collection, data analysis, data interpretation, or writing of the report.

The corresponding author had access to all data in the study and final responsibility for the decision to submit for publication.

Results

Residents with electronic health records at New Vista (n=180) had a mean age of 81 years (SD 12), 67% were women, and 17% were diagnosed with Alzheimer's disease (table 1). Residents at Delta View (n=191) had a mean age of 82 years (SD 10), 61% were women, and 38% were diagnosed with Alzheimer's disease. In 2010, at Delta View, 45% of falls documented on incident report occurred in common areas, of which 65% were captured on video. At New Vista, 34% of documented falls occurred in common areas, of which 28% were captured on video. Of the 130 individuals with captured falls, mean age was 78 years (SD 10), and 52% were women. 86 participants had one video-captured fall, 26 had two falls, nine had three, and nine had four or more, with a total of 227 falls. We excluded from our statistical analysis fall videos with missing resident identifications (six) and videos for which the team could not work out the cause of fall (six) or activity before the fall (three), leaving the analysis with 227 falls for frequency of falls, 215 falls for cause of fall, 218 falls for activity at the time of the fall, and 212 falls for cause of fall and activity together. The Figure and videos 1–5 show examples of falls.

See Online for videos

We assessed inter-rater reliability of the questionnaire by comparing responses from two teams, each consisting of three members, who analysed 15 randomly selected videos. In keeping with our team approach to analysis in the main study, we did not record or compare responses from individual members, but rather only consensus responses from each team. For cause of fall, percentage agreement between teams was 87%. Corresponding Cohen's κ was 0·79 (95% CI 0·53–1·0), showing strong internal consistency. For activity at time of fall, the teams agreed in 93% of cases, with corresponding κ of 0·91 (0·73–1·0). We also examined intra-rater reliability by having one team reanalyse the same 15 videos

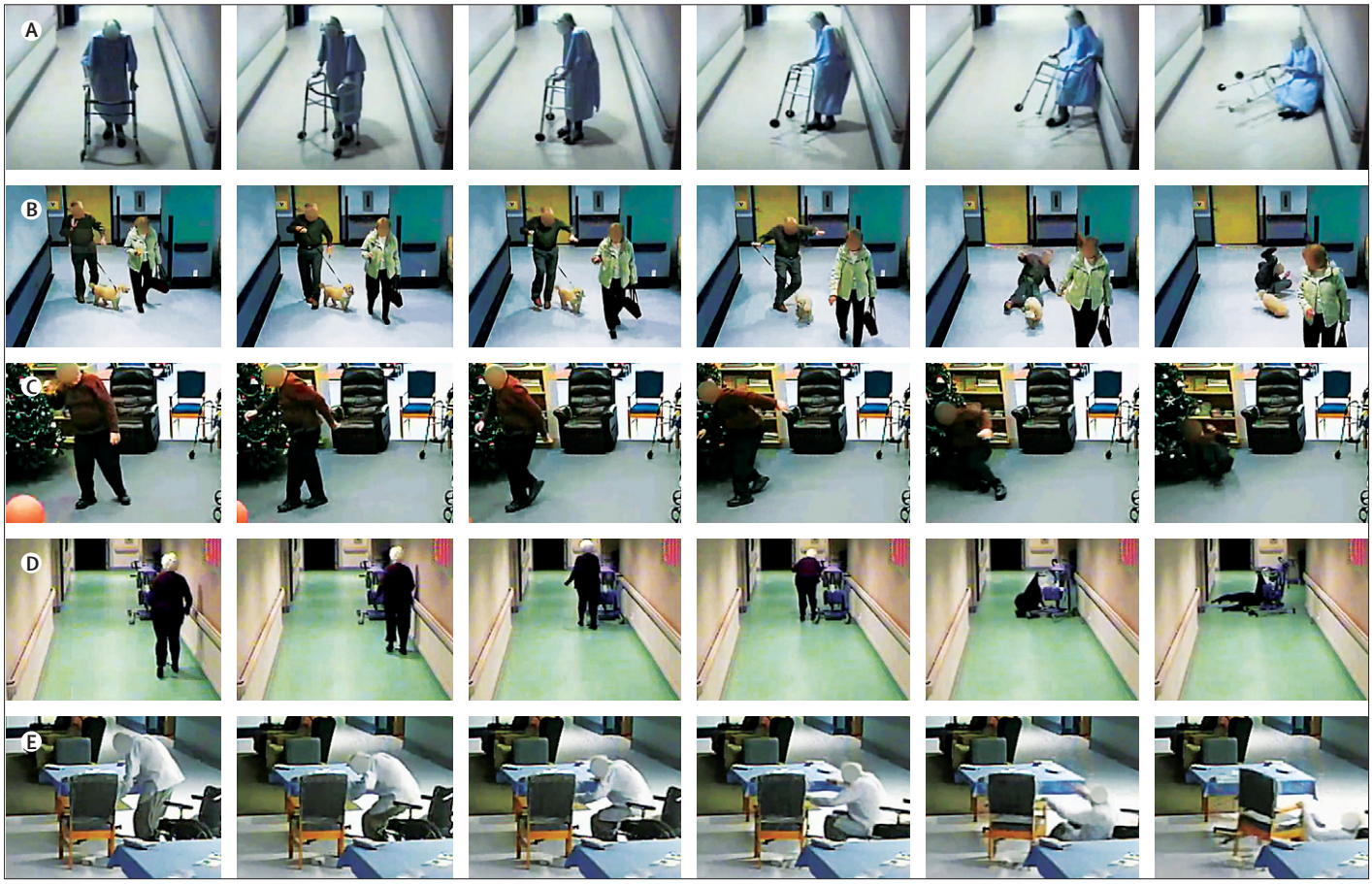

Figure: **Example falls by elderly adults**
(A) Incorrect weight shifting while standing and turning. While initiating a turn, this woman rotates her walker and upper body 180 degrees, while her feet remain stationary (typical of Parkinson-like freezing). Despite eventual steps, a backward fall ensues. (B) Incorrect weight shifting while walking forward. While stepping around his dog, this man establishes too narrow a base of support, causing a sideways fall. (C) Trip while walking and turning. While playing ball, this man initiates a turn by crossing his left leg in front of his right. He loses balance during the next step, after the toe of his right foot collides with his left heel, resulting in a backward fall. (D) Trip while walking forward. This woman seems to attempt to steer around the foot of a lifting device, but trips on the obstacle. (E) Loss of support with external object while sitting down. Note that the wheelchair rolls backward on contact, and is unable to provide the support necessary to complete the transfer. Videos 1–5 show these falls in full.

12 months after their first assessment. For cause of fall, percentage agreement was 93%, and κ was 0·90 (0·72–1·0). For activity at the time of the fall, percentage agreement was 93%, with a corresponding κ of 0·91 (0·74–1·0).

The most common cause of falls was incorrect transfer or shifting of bodyweight, which accounted for 41% (93 of 227) of all falls captured (table 2). The estimated proportion of participants falling because of incorrect transfer or shifting of bodyweight (51%, table 2), and the estimated number of falls per participant attributable to this cause (mean 0·72 falls, table 2) were significantly greater than for all other causes (table 3).

The next most common causes of falls were trip or stumble, loss of support with an external object, hit or bump, and collapse or loss of consciousness (table 2). Differences between these four causes in the estimated proportion of participants falling were not significant. The least common cause was slipping, which accounted for only 3% of falls.

Of the 48 falls caused by trip or stumble, 31% (15) were attributable to the foot catching on the ground or difficulty in raising the foot, 29% (14) to the foot catching on equipment (eg, wheelchair, walker, or laundry or food cart), 25% (12) to the foot catching on furniture (eg, table or chair), 6% (three) to one foot colliding with the other, and 6% (three) to being tripped by another person. Of the 25 falls caused by hit or bump, 80% (20) were attributable to being pushed or pulled by another person, and 20% (five) to collisions with environmental objects.

The most common activity at the time of a fall was walking forward, which accounted for 24% (54 of 227) of falls (table 4). Three other activities were also commonly associated with falls: standing quietly, sitting down or lowering, and initiation of walking. Indeed, forward walking, standing quietly, and sitting down or lowering did not differ significantly in estimated proportion of participants falling (table 5). The activities associated with fewest falls were standing and reaching, standing and turning, and seated or wheeling in a wheelchair (table 4). 21% of falls (48 of 277) occurred while the participant was using a mobility aid, split evenly between wheelchairs and walkers.

Of the 60 possible combinations of cause and activity, 17 combinations were associated with six or more falls (table 6). For more than half these combinations, cause of fall was incorrect transfer or shifting of bodyweight. However, the combination with the greatest number of falls was trip or stumble while walking forward, which accounted for 23 of 212 falls (11%). The next most common combinations were incorrect transfer or shifting of bodyweight during sitting down or lowering, getting up or rising, walking forward, and initiation of walking (table 6). 15 falls occurred while tripping on level ground during walking, about a third of which seemed to have resulted from incorrect termination of gait.[15] Falls caused by hit or bump occurred most often while the participant was standing quietly. Falls caused by collapse or loss of consciousness occurred most often during forward walking, whereas those attributable to loss of support with an external object occurred most often during sitting down or lowering and getting up or rising (table 6).

For our subanalysis of participants who granted us access to their medical records (n=263), between Jan 1 and June 30, 2010, residents with captured falls had characteristics that were much the same as those who fell but were not captured on video (table 1). We did not identify differences between groups in sex (p=0·9 from χ^2)

	Frequency*		Participants falling due to this cause†		Number of falls per participant†	
	Number	Percentage of falls captured	Estimated proportion, % (SE)	95% CI	Estimated count, n (SE)	95% CI
Incorrect transfer or shift of bodyweight	93	41%	51·2% (4·5)	42·5–59·8	0·72 (0·078)	0·59–0·90
Trip or stumble	48	21%	26·0% (3·9)	19·1–34·3	0·35 (0·054)	0·26–0·47
Hit or bump	25	11%	17·3% (3·4)	11·7–25·0	0·19 (0·040)	0·13–0·28
Loss of support with external object	25	11%	18·9% (3·5)	13·0–26·7	0·20 (0·041)	0·13–0·30
Collapse or loss of consciousness	24	11%	16·5% (3·3)	11·0–24·1	0·17 (0·039)	0·11–0·27
Slip	6	3%	4·7% (1·9)	2·1–10·2	0·047 (0·020)	0·021–0·11
Could not tell	6	3%	..	..	..	..

In descending order of frequency. *Of 227 total falls captured. †Of 215 falls analysed, after exclusion of cases for which the faller could not be identified (six), and cases for which the team could not identify the cause of the fall (six).

Table 2: **Estimated proportion of participants falling at least once, and average number of falls per participant, attributable to various causes of falling**

	Participants falling due to this cause		Number of falls per participant	
	Odds ratio (95% CI)	p value*	Ratio of counts (95% CI)	p value*
Incorrect transfer or shift of bodyweight *vs*				
Loss of support with external object†	4·5 (2·6–7·9)	<0·0001	3·7 (2·3–5·8)	<0·0001
Slip†	21·1 (8·6–51·8)	<0·0001	15·3 (6·5–36·1)	<0·0001
Collapse or loss of consciousness†	5·3 (2·9–9·5)	<0·0001	4·2 (2·6–6·8)	<0·0001
Hit or bump†	5·0 (2·8–8·9)	<0·0001	3·8 (2·4–6·1)	<0·0001
Trip or stumble†	3·0 (1·8–5·1)	<0·0001	2·1 (1·4–3·0)	0·0001
Trip or stumble *vs*				
Hit or bump†	1·7 (0·9–3·1)	0·097	1·8 (1·1–3·1)	0·02
Collapse or loss of consciousness†	1·8 (0·9–3·3)	0·069	2·0 (1·2–3·4)	0·01
Loss of support with external object†	1·5 (0·8–2·7)	0·18	1·8 (1·1–2·9)	0·03
Slip *vs*				
Trip or stumble‡	0·1 (0·05–0·4)	<0·0001	0·1 (0·05–0·3)	<0·0001
Collapse or loss of consciousness‡	0·3 (0·1–0·6)	0·004	0·3 (0·1–0·7)	0·007
Loss of support with external object‡	0·2 (0·08–0·5)	0·001	0·2 (0·09–0·6)	0·003
Hit or bump‡	0·2 (0·09–0·6)	0·003	0·2 (0·09–0·6)	0·003

*p values are not adjusted for the 24 multiple comparisons. †Proportion was greater for cause in heading than for this cause. ‡Proportion was greater for this cause than for cause in heading. Table 2 shows exact number per category.

Table 3: **Differences from pairwise comparison of proportions of participants falling, and average number of falls per participant, attributable to various causes of falling**

or mean age (p=0·7 from *t* test). Whereas the rate of Alzheimer's disease was greater in fallers captured versus not captured (34% *vs* 16%; p=0·04 from χ^2), differences between groups in the percentage diagnosed with diabetes, cardiac arrhythmia, hypertension, hypotension, stroke, dementia, and Parkinson's disease were not significant (data not shown).

Discussion

This study provides long-missing objective evidence of the cause and circumstances of falls in elderly adults, and shows new avenues for prevention of fall injury in long-term care. Our results show that incorrect weight shifting was the most common cause of falls, and that three major classes of activities—walking, sitting down, and standing—were the most common precipitants of falls. Our findings emphasise the need to target each of these activities in fall risk assessment and prevention strategies. Several validated clinical instruments incorporate such a multitask approach, including the timed up-and-go test,[16] short physical performance battery,[17] and Berg balance scale.[18] However, residents of long-term care facilities are often unable to complete these measures because of mobility problems or cognitive impairment, showing the need to develop instruments for assessment of mobility and balance that are more applicable to this population.

Our results also show that many falls in long-term care result from sudden external perturbations to balance. Tripping was the second most common cause of falls, and hit or bump was the sixth most common. Clinical assessments of fall risk rarely include external perturbations, and most laboratory-based studies simulate slips, which we showed account for only 3% of falls. Our results show the need to develop and incorporate safe methods to simulate trips and bumps[19,20] into routine clinical examinations—a new direction in assessment.

Our results also have implications for environmental modifications and the design of assistive devices for the long-term care setting. We showed that 25% of trips occurred due to the foot being caught on a chair or table leg, suggesting the need for improved staff awareness of this hazard, and improvements in environmental planning and furniture design. 21% of falls occurred during transferring, suggesting the need for exercises to enhance muscle strength, and improved assistive devices that provide adequate body support (eg, locking of wheels) when moving to and from chairs. Furthermore, although at least 74% of residents were classified as habitual users of assistive devices, only 21% of falls occurred while using an assistive device, showing the high risk of transferring to and from, or neglecting to use the device. Most of the falls we captured happened mid-afternoon, agreeing with findings reported by Rapp and colleagues[21] from the analysis of more than 70 000 falls (including both public and private areas) from residents of nursing homes in Germany.

	Frequency*		Participants falling while undertaking activity†		Number of falls per participant†	
	Number	Percentage of falls captured	Estimated proportion, % (SE)	95% CI	Estimated count, n (SE)	95% CI
Walking forward	54	24%	28·1% (4·0)	21·0–36·6	0·39 (0·06)	0·29–0·53
Standing quietly	29	13%	20·3% (3·6)	14·2–28·2	0·22 (0·04)	0·15–0·33
Sitting down or lowering	28	13%	18·8% (3·5)	12·9–26·5	0·21 (0·04)	0·14–0·32
Initiation of walking	24	11%	15·6% (3·2)	10·3–23·0	0·19 (0·04)	0·12–0·29
Getting up or rising	20	9%	14·5% (3·2)	9·6–22·1	0·15 (0·04)	0·10–0·25
Walking backward or sideways	16	7%	11·7% (2·8)	7·1–18·6	0·13 (0·03)	0·07–0·21
Walking and turning	16	7%	11·7% (2·8)	7·1–18·6	0·13 (0·03)	0·07–0·21
Standing and turning	14	6%	8·6% (2·5)	4·8–14·9	0·10 (0·03)	0·06–0·18
Seated or wheeling in wheelchair	12	5%	8·6% (2·5)	4·8–14·9	0·08 (0·03)	0·05–0·16
Standing and reaching	11	5%	7·8% (2·4)	4·2–13·9	0·09 (0·03)	0·05–0·16
Could not tell	3	1%	..	..	..	..

In descending order of frequency. *Of 227 total falls captured. †Of 218 falls analysed; after exclusion of cases for which the faller could not be identified (six) and cases for which the team could not identify the activity at time of falling (three).

Table 4: **Estimated proportion of participants falling at least once, and average number of falls per participant, for each activity at time of falling**

	Participants falling at least once		Number of falls per participant	
	Odds ratio (95% CI)	p value*	Ratio of counts (95% CI)	p value*
Walking forward *vs*				
Walking backward or sideways†	2·9 (1·5–5·7)	0·0015	3·1 (1·7–5·7)	0·0002
Walking and turning†	2·9 (1·5–5·7)	0·0015	3·1 (1·7–5·7)	0·0002
Initiation of walking†	2·1 (1·1–3·9)	0·0174	2·1 (1·2–3·5)	0·0057
Sitting down or lowering†	1·7 (0·9–3·1)	0·0797	1·9 (1·1–3·1)	0·0157
Getting up or rising†	2·2 (1·2–4·2)	0·0112	2·5 (1·4–4·3)	0·0012
Seated or wheeling in wheelchair†	4·2 (2·0–8·6)	0·0001	4·5 (2·3–9·1)	<0·0001
Standing quietly†	1·5 (0·8–2·7)	0·1478	1·8 (1·1–2·9)	0·0215
Standing and reaching†	4·6 (2·1–9·8)	<0·0001	4·5 (2·3–9·1)	<0·0001
Standing and turning†	4·2 (2·0–8·6)	0·0001	3·8 (2·0–7·4)	<0·0001
Sitting down or lowering *vs*				
Seated or wheeling in wheelchair†	2·4 (1·1–5·2)	0·0214	2·5 (1·2–5·2)	0·0188
Standing and reaching†	2·7 (1·2–6·0)	0·0127	2·5 (1·2–5·2)	0·0188
Standing and turning†	2·4 (1·1–5·2)	0·0214	2·1 (1·02–4·2)	0·0426
Initiation of walking *vs*				
Seated or wheeling in wheelchair†	2·0 (0·9–4·3)	0·0903	2·2 (1·02–4·7)	0·0448
Standing and reaching†	2·1 (0·97–4·9)	0·0575	2·2 (1·02–4·7)	0·0448
Standing quietly *vs*				
Seated or wheeling in wheelchair†	2·7 (1·3–5·8)	0·0099	2·5 (1·2–5·4)	0·0140
Standing and reaching†	3·0 (1·4–6·6)	0·0057	2·5 (1·2–5·4)	0·0140
Standing and turning†	2·7 (1·2–5·8)	0·0099	2·2 (1·1–4·3)	0·0323

*p values are not adjusted for the 34 multiple comparisons. †Proportion was greater for activity in the heading than for this activity. Table 4 shows exact numbers per category.

Table 5: **Differences from pairwise comparison of proportions of participants falling while undertaking various activities**

	Number of falls	Percentage*
Trip or stumble *while*		
Walking forward	23	11%
Initiation of walking	9	4%
Walking backward or sideways	6	3%
Incorrect transfer or shifting of bodyweight *while*		
Sitting down or lowering	16	8%
Getting up or rising	13	6%
Walking forward	12	6%
Initiation of walking	11	5%
Walking and turning	9	4%
Standing and turning	8	4%
Walking backward or sideways	7	3%
Standing quietly	7	3%
Standing and reaching	6	3%
Hit or bump *while*		
Standing quietly	10	5%
Collapse or loss of consciousness *while*		
Walking forward	9	4%
Standing quietly	6	3%
Loss of support with external object *while*		
Sitting down or lowering	7	3%
Getting up or rising	6	3%

Causes are shown as main headings in bold text. In descending order of frequency.
*Of 212 total falls.

Table 6: **Combinations of cause and activity associated with six or more falls**

Panel: Research in context

Systematic review

We searched PubMed for combinations of the title words "falls", "fractures", "imbalance", "elderly", "type of fall", and "cause of fall" and identified six previous studies that provided detailed information on the cause and circumstances of falls in older adults. Three of these involved surveys of community-dwelling older adults regarding falls over the past 12 months,[7–9] one involved surveys of older adults in assisted living,[10] and one involved surveys of patients admitted to hospital for hip fracture.[23] Collectively, these studies implicate slips and trips as the most common cause of falls, and walking as the most common activity associated with falls in older adults. A final study,[24] considerably smaller than ours (n=25), analysed video footage of falls in older adults residing in long-term care.

Interpretation

Our study provides the first comprehensive evidence, based on video capture, of the mechanisms of falls in the high-risk long-term care environment. Our results show that the causes of falls in this population are different than described previously, with most being due to self-induced weight shifting, and occurring with equal frequency during walking, transferring, and standing.

Our results also inform the design of wearable sensor systems for provision of information about movement quality during daily activities, and for automatic detection of falls in elderly people—a rapidly developing discipline.[6,14,22] In particular, our results identify the most common sequence of events, including activities leading to falls, and subsequent causes of imbalance, that should be considered in designing and testing of fall detection algorithms appropriate for the long-term care population.

Our results differ substantially from existing scientific literature of self-reported mechanisms of falls in community-dwelling elderly adults (panel). When compared with our findings, Nevitt and Cummings[9] reported that community-dwelling seniors were more likely to fall during walking, and less likely to fall during standing and transferring. Participants in Overstall and colleagues'[7] study were more likely than those in ours to fall because of tripping, and less likely to fall because of incorrect weight shifting. We recorded results similar to these previous studies in the proportion of falls attributable to collapse or loss of consciousness (ranging between 6% and 12%). For residents of assisted living facilities, Topper and colleagues[10] reported a substantially higher proportion of falls (54% *vs* 24%) attributable to base-of-support perturbations (trips, stumbles, or slips), and a much lower percentage (32% *vs* 52%) attributable to centre-of-mass perturbations (self-induced displacements or externally-applied pushes or collisions) than those which we identified.

These differences are probably partly attributable to the relatively higher prevalence of cognitive and physical impairment in the long-term care population we studied than in community-dwelling elderly people, with corresponding differences in fall mechanisms.[25–27] Typically, the rate of falls in long-term care is two to three times higher than the rate recorded in the community,[4] and fall prevention strategies that are effective with community-dwelling elderly people have not worked in the long-term care setting.[28] These differences might also relate to differences in the locations of falls. We included only falls in common areas, whereas previous studies of self-reported falls have included falls in bedrooms and bathrooms, which present a different environmental and situational context, in need of further investigation. Conversely, the differences between our results and those reported previously might be attributable to errors in self-reported fall circumstances. Accurately recalling the circumstances of a fall is a challenging task even for young adults,[29–31] and fallers might tend to rationalise falls as having an external, unavoidable cause, to avoid the perception of vulnerability.

We are aware of only one previous study with video recordings of real-life falls in elderly adults, undertaken by Holliday and colleagues,[24] who analysed the activities associated with 25 falls by 17 individuals captured on video in a long-term care facility in the Toronto (ON, Canada) area. Our results are in general agreement,

although we recorded a slightly smaller percentage of falls while walking (49% *vs* 68%), and a higher proportion of falls while standing (24% *vs* 12%) and sitting down or lowering (12% *vs* 8%).

Our study had important limitations. In analysis of video data, the team often faced challenges related to frame rate and camera resolution, distance between faller and camera, and occlusion of body parts from view. However, we recorded strong inter-rater and intra-rater reliability for our outcomes. We were also limited, because of the nature of our video footage, in identification of the contribution to falls of factors relating to the built environment such as lighting, and situational factors, such as changes from usual behaviour or secondary attention tasks (eg, talking). We did not examine the association between fall mechanisms and medical status of participants, because of the small number of participants who provided permission to access medical records and subsequently fell (41), and large number of established risk factors to consider. We did not measure (and were unable to incorporate in a risk analysis) the amount of time spent doing the various activities associated with falls. Nor did we acquire or analyse footage of near falls (imbalance episodes followed by successful balance recovery). We did not distinguish true episodes of syncope from, for example, collapse due to fatigue. An important question is whether the participants captured on video falling in common areas were representative of all fallers in the long-term care facilities that we studied. The demographics of individuals who fell between January and June, 2010, and had a fall captured on video were much the same as those who fell but were not captured on video. We stress that our results summarise the situational context of falls in common areas of the long-term care environment.

In summary, through video capture and analysis of real-life falls of elderly people in long-term care facilities, we show that the most common causes of falls are incorrect weight shifting and tripping, and the most common activities leading to falls are forward walking, standing quietly, and sitting down. Our approach avoids the usual trade-off in falls research between the high control but artificiality of the laboratory environment, and the questionable accuracy of individuals in recalling the circumstances of real-life falls, and our results provide insight into the causes and activities leading to falls in long-term care.

Contributors

SNR participated in the experimental design, data collection, data analysis, and preparation and review of the report. FF participated in the experimental design, data collection, and review of the report. YY participated in the experimental design, data collection, data analysis, preparation, and review of the report. RS participated in the data collection, data analysis, and preparation and review of the report. PML participated in the experimental design, data collection, and review of the report. TS participated in the experimental design, data analysis, and review of the report. JS-G and ML participated in data analysis, preparation, and review of the report.

Conflicts of interest

We declare that we have no conflicts of interest.

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What videos can tell us about falling

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In 2004, a videotape of a fall by Fidel Castro, then Cuban President, gained extensive press coverage and elicited a range of reactions.[1] The sequence captured a key shot for researchers who study falls. In the film, Castro, after one of his exhausting speeches and probably dazzled by lights, misses a step, starts falling after an unsuccessful stepping attempt, and turns in the air to reduce the impact of his head on the ground at the expense of an upper limb; the fall resulted in a broken shoulder and patella.

Falls and fall-related injuries are a major health burden. Despite many epidemiological studies of predisposing risk factors,[2] many assumptions and decisions about falls are still based on subjective and often biased information.[3] Fewer than 10% of falls are witnessed and, even when reports are available, they often do not provide detailed and objective information about the context and circumstances of the fall, or what happened during the fall. This absence of understanding is one of the reasons why efforts to prevent falls have had little success, although some progress has been achieved.[4-6]

In *The Lancet*, Stephen Robinovitch and colleagues[7] present results of an observational study of videotaped falls. They extensively studied falls in two long-term care institutions in British Columbia, Canada, between 2007 and 2010, using more than 200 public video cameras that were preinstalled for safety purposes. With a well-defined protocol, they were able to match staff incident reports of falls to video footage, making this a unique study. The researchers recorded 227 falls by 130 individuals whose mean age was 78 years (SD 10). Studies of this type are important because falls by elderly people are much more frequent in long-term care facilities than in the community; more than 90% of all hip fractures are caused by falls, and 20% of all hip fractures occur among residents of long-term care.[8]

Robinovitch and colleagues' report provides some important findings. Among these is the high occurrence of falls caused by incorrect weight shifting (the most frequent cause of falls, 93 [41%] of 227 falls) and external perturbations, such as hit or bump events (which accounted for 25 [11%] falls). A further notable aspect is the improved understanding of the role of poor ergonomic design and environmental factors—eg, of the 48 falls caused by trip or stumble, 14 were attributable to a foot catching on equipment and 12 to a foot catching on furniture. This understanding should lead to revised housing norms and improved design of furniture and assistive devices. However, the study has some major limitations. Robinovitch and colleagues present data from publicly accessible spaces and not from private areas, such as bedrooms and toilets. More than 50% of falls in long-term care facilities occur in private areas that cannot be supervised by video footage.[9] Other objective approaches are needed to study falls in these rooms, such as sensors worn on the body. Although some findings might apply to people who depend on care but live at home, independent seniors probably have different risk factors and environmental cofactors that contribute to falls. Thus, the findings might not be applicable to community-dwelling seniors.

Where could this study take fall prevention research? Robinovitch and colleagues build a strong case for classification of falls and a taxonomy of causes leading to falls. Currently, falls are most often presented as composite endpoints. Video footage, including that captured by members of the public with smartphones, will be one valuable source of information to generate new research hypotheses. High-speed video footage can also be used to study balance recovery reactions and landing responses in other groups, such as children and athletes.

To study falls in the community, we will need a technological shift. Evidence provided by Robinovitch and colleagues of the movement patterns that lead

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to falls is helpful in guiding the design of sensor-based fall monitoring systems. The next step will require coordinated action and possibly an open-access database that would allow real-world fall data, obtained through different sensors, to be shared. This objective is included in the roadmap of the research community, and is currently being funded by the European Commission.

For the **European Commission research project**, see http://farseeingresearch.eu

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