Falls and the physical environment: A review and a new multifactorial falls-risk conceptual framework

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Key words

■ Falls ■ Physical environment ■ Aging ■ Mobility ■ Theory

Mots clés

■ Chutes ■ Environnement physique ■ Vieillissement ■ Mobilité ■ Théorie

Abstract

Background. *Fall-related injuries result in significant physical and psychological suffering to the affected individuals. The physical environment is considered to have an important role in falls.* **Purpose**. *To conduct extensive review of and synthesize related literature, and to develop a conceptual framework to explain the relationship among falls, the physical environment, and older adults.* **Method**. *Review of the literature was conducted to examine: (a) link between environmental hazards and falls, (b) efficacy of home-modification interventions, and (c) role of the physical environment in falls of people with cognitive impairment.* **Results**. *A strong link between environmental hazards and the risk of falls has yet to be established. A conceptual framework is presented that proposes that an individual's risk for falls can be determined by the interaction of three main factors: mobility, risk-taking behaviour, and physical environment.* **Implications**. *Environmental interventions should be combined with other interventions such as exercise programs and education.*

Résumé

Description. *Les blessures associées à des chutes entraînent une importante souffrance physique et psychologique chez les personnes touchées. On considère que l'environnement physique joue un rôle important dans les chutes.* **But**. *Faire une revue exhaustive de la littérature associée aux chutes et en faire la synthèse et concevoir un cadre conceptuel pour expliquer la relation entre les chutes, l'environnement physique et les aînés.* **Méthodologie**. *La revue de littérature a été effectuée afin d'examiner : (a) le lien entre les dangers environnementaux et les chutes, (b) l'efficacité des interventions relatives aux modifications du domicile, et (c) le rôle de l'environnement physique dans les chutes chez les personnes ayant des déficits cognitifs.* **Résultats**. *Les chercheurs doivent toujours établir s'il existe un lien entre les dangers environnementaux et les risques de chutes. Le cadre conceptuel présenté propose que le risque de chutes chez une personne peut être déterminé par l'interaction entre trois principaux facteurs : mobilité, comportement à risque et environnement physique.* **Conséquences.** *Les interventions environnementales doivent être combinées à d'autres interventions, comme les programmes d'exercice et l'éducation.*

Falls and fall-related injuries are major health problems in the older adult population. It is estimated that over 30% of community-dwelling individuals and 50% of nursing home residents over age 65 fall each year (Speechley & Tinetti, 1991). A fall is often defined as a sudden and unintentional change in position resulting in an individual landing at a lower level, such as on an object, the floor, or the ground, with or without injury (Public Health Agency of Canada, 2005). Consequences of falls include fracture of the hip, spine, arm, pelvis, or wrist, and head concussions, bruises, and lacerations. Even when no injury occurs, falls can have psychological effects on the life of the individual. "Fear of falling" results not only in restricted activity, but increased dependency on others and a decrease in social interaction (Cumming et al., 2001; Howland et al., 1993). Fall-related injuries not only bring suffering to the individuals who experience them; they also represent a huge cost to the society.

The injuries associated with falls in older adults account for more than $1 billion in annual health care costs in Canada (National Advisory Council on Aging, 1999). This cost is three times that of injuries related to motor vehicle accidents in this age group. Approximately 90% of hip fractures in older adults are due to falls (Grisso et al., 1991), and in 2005–2006 there were over 28,000 admissions to Canadian hospitals for hip fractures (Canadian Institute for Health Information, 2007). These numbers are projected to increase nearly fourfold by the year 2041, given the aging of the population and the fact that fracture risk increases exponentially with age (The Hygeia Group, 1998). Furthermore, approximately 20% of older adults hospitalized for a hip fracture die within

a year, and only 50% are able to return to their homes or live independently again (Zuckerman, 1996). Clearly, developing improved strategies to reduce the frequency and consequences of falls in older adults is a critical national health priority.

Falls in older adults are a multifactorial phenomenon involving physical, behavioural, cognitive, and environmental factors. Falls may ultimately be caused by either intrinsic (e.g., poor vision, poor balance, muscle weakness, risk-taking behaviour) or by extrinsic (e.g., environmental hazards) factors. Although some studies have shown that a number of falls result from failed attempts at performing daily activities, such as walking, turning, rising, and bending (Nevitt & Cummings, 1993), other studies attribute falls to environmental hazards, such as stairs, loose rugs, poor lighting (Connell & Wolf, 1997; Stevens, Holman, & Bennett, 2001). Moreover, although slips and trips are common self-reported causes for falls, other cited reasons include claims of "loss-of-balance," "leg gave away," "changed posture," or "don't know the cause" (Blake et al., 1988; Brocklehurst, Exton-Smith, Lempert, Hunt, & Palmer, 1978; Cumming & Klineberg, 1994).

The purpose of this paper is to review the literature on falls and the physical environment, synthesize the major substantive issues, and to propose a conceptual framework to explain the relationship among falls (or falls prevention), physical environment, and older adults.

Method

The MEDLINE and Ageline databases were searched to identify articles related to the topic of this research paper. Key words used in combination with each other included fall, environment, hazard, house, home, residence, built environment, design, physical environment, care facility, institution, nursing home, and dementia. After prescreening the abstracts of all empirical articles in the English language from 1985 to 2007 in terms of conceptual rigour, empirical study, inclusion of the physical environment, and using participants over the age of 60, the first author identified three key areas as subareas of research within the focus of this paper. These subareas were: (a) linkage between environmental hazards and falls, (b) efficacy of home-modification interventions, and (c) role of the physical environment in falls of people with cognitive impairment. Major themes within each of these three aspects are presented in this paper. Key findings from the review of the literature are also summarized in Table 1.

Results

Links between environmental hazards and falls

Environmental hazards have been recognized as contributing to falls in older people. Previous studies have shown that 50%–70% of falls happen in or around the home, and 40%–60% of falls are due to environmental hazards (Nevitt, Cummings, Kidd, & Black, 1989; Tinetti, Speechley, & Ginter, 1988). Therefore, modifying the home environment to prevent or decrease the number of falls seems reasonable. Furthermore, unlike interventions that target health and behavioural factors, modifying the environment has the potential to decrease the risk of fall for everyone using the safer environment. To understand the relation between falls and environmental hazards, first it is necessary to identify the environmental hazards that increase or decrease someone's risk for falls and the prevalence of these hazards in the homes of different populations. Most common hazards found in older adults' homes are related to poor lighting, floor surfaces, stairs, objects on pathway, poor design of furniture, bad placement of furniture, and toilet design (Rogers, Rogers, Takeshima, & Islam, 2004).

Prevalence of environmental hazards in the homes of older adults

The prevalence of environmental hazards in the homes of older adults is quite high. The study by Carter, Campbell, Sanson-Fisher, Redman, and Gillespie (1997) showed that for the 37 different hazards that were assessed, 80% (n = 342) of homes of community-dwelling individuals over the age of 70 had at least one hazard, and 39% (n = 164) had more than 5 hazards. Within the house, the bathroom was identified as the most hazardous room, with 66% (n = 279) of bathrooms having at least one hazard. After assessment was made of the home environments of 1,212 people aged 65 years and older, Huang (2005) showed that environmental hazards were found in the majority of homes (60.4%) where community-dwelling elders lived with the bathroom being the most common site for environmental hazards. Major potential home environmental hazards were dim lighting (31.8%), floors that were slippery or had obstacles (18.2%), storage areas out of reach (14.6%), carpeting or rugs that weren't anchored or did not have nonskid backing (14.6%), and loose or non-existent grab bars or handrails (13.0%) (Carter et al.). Significant predictors of potential home environmental hazards for older adults were residence in an urban area, poor awareness of one's health status, family dysfunction, fear of falling, poor gait, and poor balance.

Another study by Gill, Robison, Williams, and Tinetti (1999) showed that with the exception of no grab bars in the tub or shower, environmental hazards were as prevalent and sometimes more prevalent in the homes of participants without specific deficits in physical capabilities as they were

TABLE 1
Summary of issues and findings in the relevant literature on falls and the physical environment.

Study	Title	Focus of Study	Research design	Setting	Sample	Outcome measures	Major findings
Campbell et al., 1990	Circumstances and Consequences of Falls Experienced by a Community Population 70 Years And Over During a Prospective Study	To investigate the circumstances and consequences of falls and to determine the factors that are important in causing falls.	Prospective study	Community-dwelling from of a rural township	761 subjects 70 years and over were drawn from general-practice records of a rural township.	Each subject was assessed and followed for 1 year to determine the incidence of and factors related to falls.	20% of falls were associated with trips and slips, but there was no evidence that inspection of homes and installation of safety features would have decreased the fall rate.
Carter et al., 1997	Environmental Hazards in the Homes of Older People	To investigate (i) the prevalence of environmental safety hazards in the homes of people aged 70 years and over, (ii) their knowledge of causes of injuries to older people and the safety measures they can implement to prevent such injuries, and (iii) the relationship between socio-demographic characteristics of this population group and levels of home environmental hazards.	Cross-sectional survey	Community-dwelling	425 people aged 70 years and older living in the community	Number of hazards in each room or area of older people's homes (including outside areas)	80% (n = 342) of homes inspected had at least one hazard and 39% (n = 164) had > 5 hazards. The bathroom was identified as the most hazardous room, with 66% (n = 279) of bathrooms having at least one hazard.
Clemson et al., 1996	Case-control Study of Hazards in the Home and Risk of Falls and Hip Fractures	To determine if the prevalence of various environmental hazards was greater in the homes of people with recurrent falls or a recent hip fracture than in the homes of other elderly people.	Case-control study	Community-dwelling	52 subjects with a recent hip fracture, 43 fallers (subjects with two or more falls in the past year but no hip fracture), and 157 nonfallers (subjects without hip fracture and with fewer than two falls in the past year).	Number of hazards in the homes of fallers and nonfallers. Number of falls among people with cognitive impairment and number and type of medications	The homes of fallers were no more hazardous than the homes of nonfallers. However, fallers with cognitive impairment had significantly more hazards in their homes than nonfallers with cognitive impairment. Furthermore, homes of those with recent hip fractures were more hazardous than those without.
Close et al., 1999	Prevention of Falls in the Elderly Trial (PROFET): A Randomized Controlled Trial	To assess the benefit of a structured interdisciplinary assessment of people who have fallen in terms of further falls.	Randomized controlled study	Community-dwelling	Eligible patients were aged 65 years and older, presented to an accident and emergency department with a fall.	The intervention group (n=184) underwent a detailed medical and occupational-therapy assessment (including home assessment) with referral to relevant services if indicated; those assigned to the control group (n=213) received usual care only.	The risk of falling was significantly reduced in the intervention group as was the risk of recurrent falls.

Table 1 continued

Study	Title	Focus of study	Research design	Setting	Sample	Outcome measures	Major findings
Connell and Wolf, 1997	Environmental and Behavioral Circumstances Associated With Falls at Home Among Healthy Older Adults .	To conduct an in-depth examination of the environmental and behavioral circumstances associated with falls and near-falls experienced by older adults and to evaluate the usefulness of reenactment as a method for studying falls.	Prospective study	Community-dwelling	15 community-dwelling, relatively healthy individuals, age 70 to 81 years.	Incidents were analyzed to determine patterns of interaction of individuals' personal characteristics, environmental-use behaviors, and environmental characteristics.	There is a dynamic interaction between environmental conditions and behavior involving use of the environment and its implications for falls in older people. Although some incidents involved familiar environmental and behavioral risk factors, less familiar environmental factors also were critical contributors to the incidents.
Cumming et al., 1999	Home Visits by an Occupational Therapist for Assessment and Modification of Environmental Hazards: A Randomized Trial of Falls Prevention	To determine whether occupational therapist home visits targeted at environmental hazards reduce the risk of falls.	Randomized Controlled Trial	Community-dwelling	530 subjects (mean age 77 years)	The primary study outcome was falls, ascertained over a 12-month follow-up period using a monthly falls calendar.	Home visits by occupational therapists can prevent falls among older people who are at increased risk of falling. However, the effect may not be caused by home modifications alone. Home visits by occupational therapists may also lead to changes in behavior that enable older people to live more safely in both the home and the external environment.
Cumming et al., 2001	Adherence to Occupational Therapist Recommendations for Home Modifications for Falls Prevention	This study examined adherence to home- modification recommendations made by an occupational therapist and attempted to identify predictors of adherence	Pretest-posttest design	Community-dwelling	178 people (mean age = 76.4 years)	An experienced occupational therapist visited homes to evaluate for and recommend appropriate home modifications for falls prevention. One year later, a research assistant visited these persons' homes to assess adherence.	In the 121 homes revisited after 12 months, 419 home modifications had been recommended, and 216 (52%) were met with partial or complete adherence. A major barrier to adherence to home-modification recommendations is that many older people do not believe that home modifications can reduce their risk of falling.
Day et al., 2002	Randomized Factorial Trial of Falls Prevention Among Older People Living in Their Own Homes	To test the effectiveness of, and explore interactions among three interventions to prevent falls among older people.	Randomized controlled trial	Community-dwelling	1,090 healthy elderly aged 70 years and over and living at home	Time to first fall ascertained by an 18-month falls calendar and analyzed with survival analysis techniques. Changes to targeted risk factors were assessed by using measures of quadriceps strength, balance, vision, and number of hazards in the home.	Home-hazard management, vision screening, and referral are not markedly effective in reducing falls when used alone, but add value when combined with the exercise programme.
Fleming & Pendergast, 1993	Physical Condition, Activity Pattern, and Environment As Factors in Falls by Adult Care Facility Residents	To determine the location of falls; if physical factors were involved; the residents' activity level at the time of the fall; if environmental factors were involved; and the time of the fall in an adult-care facility where the environmental hazard has been minimized.	Retrospective study	Adult-care facility	95 residents in relatively good health living in an adult-care facility	Frequencies of fall, location, time of day or night, and the precipitating factors from fall descriptions made by residents, their caregivers, or both.	Although 50% of the falls were precipitated by the environment, a large percentage of these could have been caused by physical limitations that prevented residents from safely interacting with their environment.

Table 1 continued

Study	Title	Focus of study	Research design	Setting	Sample	Outcome measures	Major findings
Gill et al., 1999	Mismatches Between the Home Environment and Physical Capabilities Among Community-Living Older Persons	To determine whether environmental hazards related to transfers, balance, and gait are any less prevalent in the homes of older persons with specific deficits in physical capabilities than they are in the homes of older persons without the same deficits	Cross-sectional study of a population-based cohort	Community-dwelling	1,088 persons, aged 72 years and older who had an environmental assessment of their homes	Assessment of physical performance to identify deficits in physical capabilities. Identification of potentially hazardous environment for participants with specific deficits in transfers, balance, or gait.	With the exception of no grab bars in the tub/shower, environmental hazards were as prevalent in the homes of participants with specific deficits in physical capabilities as they were in the homes of participants without the same deficits. In many cases, they were actually more prevalent.
Huang, 2005	Home Environmental Hazards Among Community-Dwelling Elderly in Taiwan	To determine the prevalence and variables that best predict home environmental hazards among the community-dwelling elderly in Taiwan.	Prospective cohort study	Community-dwelling	1,212 people aged 65 years and older, chosen by cluster sampling from registered households in northern Taiwan	An assessment was made of the home environments, and baseline data were collected related to demographics, mobility level, fear of falling, subject's awareness of their health status, and family support.	Environmental hazards were found in the majority of homes (60.4%) where community-dwelling elderly people lived. The bathroom was the most common site for environmental hazards. Significant predictors of potential home environmental hazards were: living in an urban area, poor awareness of one's health status, family dysfunction, fear of falling, being older, poor gait, and poor balance.
Isberner et al., 1998	Falls of Elderly Rural Home Health Clients	To develop a list of risk factors for home health nurses to use at assessment to identify clients at risk of a fall and include recommendations to reduce risk.	Retrospective case-control study	Community-dwelling living in rural homes	90 elderly clients (45 fallers and 45 controls) aged 60 or older	Logistic regression analysis incorporating intrinsic and extrinsic factors.	Logistic regression analysis revealed that previous falls, frailty, physical inactivity, balance problems, absence of handrails, and uneven floors were related to a fall in this sample.
Lowery et al., 2000	What Is the Prevalence of Environmental Hazards in the Homes of Dementia Sufferers and Are They Associated With Falls?	To examine the frequency of environmental hazards in the homes and in care environments of patients with dementia and their associations with falls.	Prospective study	Homes and residential or nursing home facilities	65 dementia patients	Number of falls in a 3- month period and the safety of the environment assessed by an occupational therapist using a home- hazard checklist.	A means of 5.4 environmental hazards were identified in patients' own homes, compared to a mean of 1.8 hazards in care environments. Despite that, there was no significant difference in the likelihood of falling in one's own home and in care environment.
Northridge et al., 1995	Home Hazards and Falls in the Elderly: the Role of Health and Functional Status	To determine whether vigorous and frail older people who identify environmental hazards in their homes have an increased risk for falls.	Cohort prospective Study	Community-dwelling	266 female and 59 male community-dwelling volunteers aged 60 to 93 years who had fallen at least once during the previous year	Composite measures of home safety and of frailty associations between baseline home safety measures and falls at home over the follow-up year were compared between vigorous and frail groups.	Falls were not strongly associated with the presence of home hazards. However, when compared with vigorous older persons living with fewer home hazards, vigorous older persons living with more home hazards were more likely to fall.

Table 1 continued

Study	Title	Focus of study	Research design	Setting	Sample	Outcome measures	Major findings
Plautz et al., 1996	Modifying the environment: A Community-based Injury-reduction Program for Elderly Residents	To test the hypothesis that providing minor home safety modifications would reduce rates of falls, scalds, and burns.	A one-group, pretest-posttest design	Community-dwelling	141 participants aged 60 and older.	Number of falls during the six-month periods before and after the intervention. The intervention used 10 person-hours of unskilled labor and $93 worth of materials on average and included home safety assessments and modifications.	Reported falls were reduced by 60% after the intervention, from 0.81 to 0.33 falls per person-year. This community-based program to reduce hazards in the home environments of senior citizens was feasible, well accepted, and probably effective in preventing falls
Sattin et al., 1998	Home Environmental Hazards and the Risk of Fall Injury Events Among Community-Dwelling Older Persons	To determine if home environmental hazards increase the risk of fall injury events among community-dwelling older persons.	Case-control study	Community-dwelling	270 persons aged 65 years and older who sought treatment at six area hospitals for injuries resulting from falls within the dwelling unit and 691 controls, frequency matched for sex and age, selected randomly from health care files	The home environment of each person, assessed directly by interviewers using a standardized instrument	Environmental hazards were present in nearly all dwelling units. After adjusting for important confounding factors, most of these hazards were not associated with an increased risk of fall injury events among most older persons. Increasing numbers of tripping hazards or total hazards in the dwelling unit did not increase the risk of fall injury events, nor was there an increasing trend in risk.
Speechley and Tinetti, 1991	Falls and Injuries in Frail and Vigorous Community Elderly Persons	To identify the prevalence, circumstances, and sequelae of falls across the functional spectrum of elderly persons	Prospective study	Community-dwelling	337 elderly individuals aged 75 and over living in a private residence or housing units	Incident falls and surrounding circumstances	Environmental hazards were more likely to be associated with falls in vigorous than frail individuals. Frail elderly person almost always fell at home and during routine non-displacement daily activities. Vigorous subjects tended to fall while away from home, on stairs, in the presence of environmental hazards, or during displacing activities.
Stevens, Holman, Bennet and de Klerk, 2001	Preventing Falls in Older People: Outcome Evaluation of a Randomized Controlled Trial	To evaluate the outcome of an intervention to reduce hazards in the home on the rate of falls among seniors.	Randomized controlled trial with follow-up of subjects for 1 year.	Community-dwelling	1,737 elderly people age 70 and older.	Reported number of falls. The falls were then assigned to one of three overlapping categories: all falls, falls inside the home, and falls involving environmental hazards in the home.	The intervention was not associated with any significant reduction in falls or fall-related injuries. The study provides evidence that a one-time intervention program of education, hazard assessment, and home modification to reduce fall hazards in the homes of healthy older people is not an effective strategy for the prevention of falls in seniors.
Stevens, Holman, and Bennett, 2001	Preventing Falls in Older People: Impact of an Intervention to Reduce Environmental Hazards in the Home	To evaluate the impact of an intervention to reduce fall hazards in the homes of older people.	Randomized controlled trial	Community-dwelling	570 elderly people age 70 and older.	Hazard prevalence was assessed at baseline in all homes and 11 months later in a random sample of 51 homes. Action taken in response to the intervention was assessed by a self-completed postal questionnaire completed 11 months after the intervention.	The intervention resulted in a small reduction in the mean number of hazards per house, with many study subjects taking action but removing only a few hazards.

Table 1 continued

Study	Title	Focus of study	Research design	Setting	Sample	Outcome measures	Major findings
Studenski et al., 1994	Predicting Falls: The Role of Mobility and Nonphysical Factors	To test a four-domain predictive model of recurrent falls developed for this study. In this model, attitudinal, social, and environmental factors are proposed to influence fall risk only in persons with impaired mobility.	Prospective cohort study	Veterans Affairs Ambulatory Care Service	306 male veterans aged 70 or older	The primary outcome was recurrent falls. Subjects were further assessed in their homes for mobility in more detail, attitude toward risk, social supports, and environmental status.	People with limited mobility are at greater risk than people with either high or very low mobility. For these people, a 10-point increase in environment score was associated with a 23% rise in fall risk.
Thompson, 1996	Preventing Falls in the Elderly at Home: A Community-Based Program	To analyze the effectiveness of an ongoing program for reducing the risk of falls in the elderly in their homes.	Pretest-posttest design	Community-dwelling	305 Healthy older adults	Number of falls in the 12 months before and after home modifications.	The total number of falls decreased from 121 to 45 --a 63% reduction. There was a significant decrease in falls in the 61–65, 66–70, 71–75 and 81–85 years age groups. The risk of falling in the elderly can be lowered by more than a half by simple modifications to the home. Behavioural change, as well as environmental change, is important to the success of falls-prevention programs.
Tinetti et al., 1988	Risk Factors for Falls Among Elderly Persons Living in the Community	To identify the risk factors associated with falling in a representative sample of elderly persons.	Prospective study	Community-dwelling	336 subjects (mean age = 78.3 ± 5.1 years)	Falls and their circumstances were identified during bimonthly telephone calls during one year of follow-up.	Although the number of environmental hazards was not significantly associated with falling, there were trends toward both increased and decreased risks in individual rooms.
van Bemmel et al., 2005	In an Observational Study Elderly Patients Had an Increased Risk of Falling Due to Home Hazards	To explore the relationship between home hazards and the incidence of falls in the oldest old population.	Prospective population-based study	Community-dwelling	599 elderly residents aged 85 and over.	The incidence of falling in the first year, home hazards, and physical impairment.	Participants without preceding falls (n=246) had a 4-fold risk for falls in the presence of six or seven home hazards compared with those without home hazards. Participants with preceding falls (n=234) had no increased risk of falls with increasing numbers of home hazards, although they had a higher risk to fall.
van Doorn et al., 2003	Dementia As a Risk Factor for Falls and Fall Injuries Among Nursing Home Residents	To compare rates of falling between nursing home residents with and without dementia and to examine dementia as an independent risk factor for falls and fall injuries	Prospective cohort study	Nursing homes	2,015 newly admitted nursing home patients	During 2 years, fall data (incident of falls and injurious falls) in patients with and without dementia.	Nursing home residents with dementia were nearly twice as likely to fall as those without dementia.
Vetter et al., 1992	Can health visitors prevent fractures in elderly people?	To assess whether intervention by a health visitor could reduce the number of fractures, over a four year period.	Randomized, controlled trial	Community-dwelling	674 patients aged 70 and over on the practice records; 350 were assigned to the intervention group, 324 as controls.	The approach was four-pronged for the intervention group: assessment and correction of nutritional deficiencies, assessment and referral for medical conditions, assessment and correction of environmental hazards in the home, and assessment and improvement of fitness. The intervention continued for four years.	The incidence of fractures was 5% (16/350) in the intervention group and 4% (14/324) in the control group (difference not significant). A health visitor visiting a group of people aged 70 and over and using simple preventive measures had no effect on the incidence of fractures.

in the homes of participants with deficits. However, some mismatches between the home environment and physical capabilities were found. For example, low-lying chairs were more prevalent in homes of people having difficulty in transferring and obstructed pathways were more prevalent in homes of people having gait problems (Gill et al.).

In trying to link falls with environmental hazards, the authors of the current study assumed that the homes of fallers are less safe than the homes of nonfallers. However, Clemson, Cumming, and Roland (1996) found that, after assessing 252 subjects, the homes of fallers were no more hazardous than the homes of nonfallers. The fairly frail older adult population participating in that study was identified by the authors as one of the reasons for the lack of association between falls and the environment. They argued that intrinsic factors, not the environment, caused most falls among this population. Unfortunately, the researchers did not acquire measures such as balance, strength, reaction time, vision, and the number of medications to find out if there were differences between faller and nonfallers that would substantiate their argument.

In the study by Gill et al. (1999), a trained research nurse using a standard instrument completed a room-by-room assessment for 13 potential trip or slip hazards in the homes of 1,088 men and women over 72. The assessment was made at baseline and one year later. Falls were ascertained monthly for 3 years using a fall calendar and follow-up phone calls. The results showed no consistent association between the 13 trip or slip hazards and nonsyncopal falls, even after participants were categorized by impairments in vision, balance/gait, and cognition. Likewise, Sattin, Rodriguez, DeVito, and Wingo (1998) showed that most of the hazards found in the homes of 270 fallers and 691 control individuals age 65 and over were not associated with an increased risk of fall injuries. Just as in previous studies, Tinetti et al. (1988) found that the number of environmental hazards was not significantly associated with falling after a 1-year follow-up of 336 individuals over the age of 75.

Last, a study of a sample of 761 subjects 70 years old and over living in a rural township in New Zealand by Campbell et al. (1990) showed that the great majority of 507 falls occurred over normal household objects in an uncluttered environment. Therefore, there was no evidence that inspection of homes and installation of safety features would have prevented most of the falls.

On the other hand, Fleming and Pendergast (1993) found that 50% of falls surveyed in a safe adult care facility with which the residents were very familiar were precipitated by environmental hazards. The study also pointed out that most of the falls occurred in the residents' own rooms. This may be due to the fact that much of the residents' time is spent there.

The results from all these studies suggest that changing the environment to reduce the number of hazards in older persons' homes may not reduce the risk for fall in this population. One limitation of all the studies mentioned was that researchers only measured the number of environmental hazards before the intervention. However, there was the possibility that the number of hazards increased during the follow-up period.

The effect of environmental hazards on frail versus vigorous older adults

Popular perception might assume that very frail older women are the victims of falls. However, studies have shown that environmental hazards were more likely to be associated with falls in vigorous rather than frail individuals. Speechley and Tinetti (1991), in an effort to identify the prevalence, circumstances, and sequelae of falls, found that a frail older person almost always fell at home and during routine non-displacement daily activities, such as standing or turning. However, vigorous subjects, even though they had relatively fewer falls than frail subjects, tended to fall while away from home, on stairs (27% vs. 6%), in the presence of environmental hazards (53% vs. 29%), or during displacing activities, such as walking or climbing (53% vs. 31%). Another study by Northridge, Nevitt, Kelsey, and Link (1995) to determine whether vigorous and frail older people who identify environmental hazards in their homes have an increased risk for falls found that falls were not strongly associated with the presence of home hazards. However, when compared with vigorous older persons who were living with fewer home hazards, vigorous older persons living with more home hazards were more likely to fall.

Furthermore, Fleming and Pendergast (1993) found that despite the changes in the physical environment of adult care facilities involved in their study, a large number of falls were reported; those who fell were mostly older adults in relatively good health for their age. Another study by Studenski et al. (1994) found that people with limited mobility were at greater risk of falling than people with either high or very low mobility. For these people, a 10-point increase in environment score (which ranged from 0 to over 100, with increasing scores representing increased environmental hazards) was associated with a 23% rise in fall risk.

Environmental hazards and fractures

A few studies have also investigated the association between environmental hazards and fractures. For example, a study by Vetter, Lewis, and Ford (1992) to assess whether intervention by a health visitor could reduce the number of fractures over a four-year period showed that the incidence of fractures was 5% in the intervention group and 4% (14/324) in the control group (difference not significant). The lack of any significant difference of effect between intervention and control groups was quite surprising because the multifactorial approach involved not only assessment and correction of environ-

mental hazards in the home but also correction of nutritional deficiencies, referral for medical conditions, and improvement of fitness. Another study by Clemson et al. (1996) showed that homes of those people with recent hip fractures were more hazardous than those people without. Individuals who had experienced a hip fracture had an average of 6.3 hazards in their homes, while those individuals without a hip fracture had an average of 4.6 hazards. However, the authors were concerned that these findings might be due to biased assessment of hazards in the homes of hip-fracture patients since the occupational therapists assessing the homes were not "blinded" to whether the subject had a hip fracture.

Interaction between behavioural and environmental factors

Individual health, mobility, and environmental factors have been linked, in some way, to risk of falls in the older adult population. However, few studies have tried to understand the effect of behavioural factors (e.g., risk taking) in individuals' risk for falls. For example, Connell and Wolf (1997) conducted an in-depth examination of the environmental and behavioral circumstances associated with falls in a small group of community-dwelling fallers aged 70 to 81 years. They found that there was a dynamic interaction between environmental conditions and behavior involving use of the environment. The authors argued that most environmental falls can be attributed to poor judgment and not to environmental characteristics.

Another study by van Bemmel, Vandenbroucke, Westendorp, and Gussekloo (2005) showed that participants without preceding falls had a 4-fold risk for falls in the presence of six or seven home hazards compared with those people without home hazards. However, participants with preceding falls had no increased risk of falls with increasing numbers of home hazards, although they had a higher risk of falling. Even though fear of falling was not measured in the study, it is possible that the difference may be due to behavioural differences between recurrent fallers (more cautious) and nonfallers (less cautious). Finally, Hornbrook, Wingfield, Stevens, Hollis, and Greenlick (1991) asked fallers to describe the events leading up to their falls and to give their perspective of the causes of their falls. The answers were quite surprising. Risk-taking behaviours—such as not being careful or alert, not looking where one was going, and being in a hurry—were cited in 63% of the falls. Of those falls, 50% involved behavioural plus environmental factors. Furthermore, most fallers reported that their falls could have been prevented and that their future prevention techniques included increasing caution or reducing high-risk behaviour. However, only 3% of fallers indicated that they planned to make changes to their environment.

Efficacy of home-modification interventions

A small number of studies have demonstrated effective home-modification interventions. Some of these studies used a multifactorial approach, including modification of the environment, while others focused primarily on the reduction of environmental hazards.

Single intervention

Of the studies that used only modification of the environment as the intervention, the study by Plautz, Beck, Selmar, and Radetsky (1996) and that of Thompson (1996) showed the best results. After a six-month follow-up, Plautz et al. reported falls were reduced by 60% after the intervention, from 0.81 to 0.33 falls per person-year. The intervention consisted of 10 person-hours of unskilled labor and $93 worth of materials on average and included home safety assessments and modifications in the homes of 141 participants. The most common work accomplished was the installation of fixed grab bars in the bathroom. The authors argue that the community-based program to reduce hazards in the home environments of senior citizens was feasible, well accepted, and probably effective in preventing falls. In Thompson's study, the total number of falls decreased from 121 falls recorded in the 12 months prior to intervention to 45 falls 12 months after the intervention, which is a 63% reduction. The intervention included a free home safety inspection and simple home modifications, such as grab-rails, nonslip floor surfaces, and others. However, the authors recognized that the reduction in falls might have been the result not only of environmental changes but also of behavioural changes. Cumming et al. (1999) also recognized the same factors in their study to determine whether occupational therapist home visits targeted at environmental hazards reduce the risk of falls.

Certain factors may predetermine participants' intentions for home modification. For example, a recent study identified three groups that are more likely to express their intentions for modifications: those people who believed home modifications were beneficial; those ones who believed home modifications could prevent falls, and those who had taken action in the past to change their home environments (Yuen & Carter, 2006).

Multifactorial interventions

Several studies have successfully used a multifactorial approach, including modification of the environment as intervention, to decrease the risk of falls and improve quality of life (Clemenson et al., 2004; Close et al., 1999; Day et al., 2002; Gitlin et al., 2006; Stevens, Holman, Bennett, & de Klerk, 2001; Tinetti et al., 1994). One of these (Close et al.) showed the efficacy of a structured interdisciplinary approach to the management and prevention of falls in older people. In this study, 141 older adults in the intervention

group received a complete medical assessment with modification of risk factors for falls if possible, a home environment modification, and an educational session about safety within the home. The 163 older adults in the control group received only usual care. The results show that the risk of falling was significantly reduced in the intervention group, as was the risk of recurrent falls after a one-year follow-up.

Day et al. (2002) tested the effectiveness of and explored interactions among three interventions to prevent falls among older people by dividing subjects over 70 years old into multiple groups. Each group was given at least one intervention (exercise program, home-hazard management, and vision management), and one group received no intervention until after the study. The results showed that the combined effect of all three interventions produced an estimated 14% reduction in annual fall rate, the largest outcome observed. However, the results for the single and dual intervention groups indicate that the exercise program made the major contribution. In contrast, the results from the home-hazard management group showed no significant reduction in annual fall rate. In another study, Stevens, Holman, Bennett, and de Klerk (2001) assessed the effect of a one-time intervention program of education, hazard assessment, and home modification to reduce fall hazards that was administered in the homes of 570 healthy older people. After a one-year follow-up, findings indicated no significant reduction in falls or fall-related injuries in the intervention group when compared with the 1,167 healthy elderly individuals in the control group. In summary, results from these studies show that a multifactorial approach to falls management may help individuals cope better with their physical environment.

Although some of these studies look at the location of the modified environment [e.g., the study by Plautz et al. (1996) on grab bars in bathrooms], in general there is a lack of comparative studies examining falls in the modified areas versus nonmodified areas of the home. This is a critically neglected area of research since modifying the home environment will not reduce the risks for falls in parts of the home that were not modified,in public spaces (e.g., dimly lit restaurants, broken sidewalks), or in other people's homes.

Adherence to home-modification interventions

Intervention programs with the objective of home-hazard modification face several obstacles. Older adult individuals are usually emotionally attached to their environments, and most do not acknowledge the need for interventions to prevent falls. In a study to evaluate the impact of an intervention to reduce fall hazards in the homes of 570 older individuals (Stevens, Holman, & Bennett, 2001), the intervention resulted in a small reduction in the mean number of hazards per house, with many study subjects taking action but removing only a few hazards. In another study that examined adherence to home-modification recommendations made by an occupational therapist (Cumming et al., 2001), the researchers found that of the 419 home modifications that had been recommended in the 121 homes, only 216 (52%) were met with partial or complete adherence when revisited after 12 months. The study also found that the only significant predictors of adherence were a belief that home modifications can prevent falls and having help from relatives at home.

The role of physical environment in falls among people with cognitive impairment

The risk for falls increases greatly in people with cognitive impairment and dementia. Based on prospective studies, it is estimated that the annual incidence of falls among individuals with dementia is between 70% and 85%—which is twice that of the cognitively intact population (van Doorn et al., 2003). Not only are individuals with cognitive impairment more prone to falling, but they are also more prone to sustaining a serious injury due to the fall (Shaw, 2002). The incidence of hip fractures is approximately 4% in people with cognitive impairment and 2% for the population without cognitive impairment (Shaw). Dementia can increase the risk of falling mainly by impairing judgment and limiting the ability to recognize and avoid hazards. Other factors include gait problems, postural instability, visual-spatial perception, and psychotropic medication (Strubel, Jacquot, & Martin-Hunyadi, 2001). Consequently, special attention has to be paid when designing or assessing the physical environment of people having these conditions.

Even though long-term care environments suggest safety, the number of falls is much higher in that environment when compared to home environments (Speechley & Tinetti, 1991). Therefore, it is easy to assume that care facilities are not as safe as they should be. However, in a study to examine the frequency of environmental hazards in the homes and care environments of 65 dementia patients, Lowery, Buri, and Ballard (2000) found that patients' own homes had a significantly larger number of environmental hazards when compared to care environments, 5.4 and 1.8 hazards respectively. Nevertheless, this study indicated that there was no significant difference in the likelihood of falling between home and care environments. The researchers stated that there is no support for a significant association between environmental hazards and falls based on these results.

In another study comparing fallers and nonfallers (both groups having cognitive impairment), Clemson et al. (1996) showed that fallers with cognitive impairment had significantly more hazards than nonfallers with cognitive impairment, suggesting that home hazards might increase the risk of falls in this group. Findings from a study by van Doorn et al. (2003) indicated that nursing home residents with dementia were nearly twice as likely to fall compared to

those without dementia. The study pointed out that the presence of an Alzheimer care unit in the facility or a better environmental score on the Therapeutic Environmental Screening Survey for Nursing Homes (TESS-NH) were related to an increased risk for falls. The relationship of these two variables indicates that dementia is an independent risk factor for falling even in safer environments.

Discussion

A conceptual framework

The "multifactorial falls risk" is a proposed conceptual framework (Figure 1) based on previous studies showing that an individual's risk for falls can be determined by the interaction of three main factors: mobility, behaviour, and physical environment (Clemson et al., 2004; Connell and Wolf, 1997; Hornbrook et al., 1991; Studenski et al., 1994).

In this conceptual framework, mobility refers to the ability of a person to perform movements. Mobility limitations may arise from the natural aging process, including muscle weakness, slower reaction time, gait changes, and postural changes or may be precipitated by different pathologies, such as Parkinson's disease, stroke, arthritis, or musculoskeletal injuries. Therefore, elderly people with high mobility are the ones able to perform a variety of movements over a large range of motion in a reasonable speed with minimal effort. Conversely, elderly people with low mobility are the ones performing slow and less coordinated movements over a small range of motion requiring potentially greater effort.

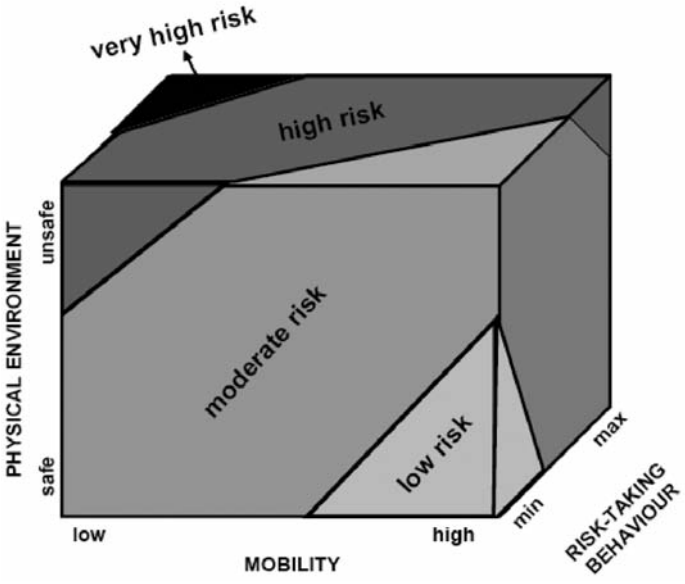
Risk-taking behaviour, in the context of this conceptual framework, is defined as behaviours that would increase the likelihood of adverse physical consequences, in this case a fall. Risk-taking behaviour can be influenced by culture, attitudes, emotions, coercion, medication, levels of attention, fears, environment, perception of physical abilities, and many other factors. Hence, older adults with a minimum level of risk-taking behaviour in a specific situation are more cautious and less likely to take risks, while individuals with a maximum level of risk-taking behaviour are willing to take risks consciously or unconsciously. In other words, risk-taking behaviour can also be understood as activities that challenge dynamic balance. In this conceptual framework, risk-taking behaviour is not defined in absolute terms, but rather in the context of the physical health (e.g., frailty), mental status (e.g., cognitive decline), and psychological aspects (e.g., risk-taking behavior) of a particular individual. The individual context determines the level of risk; therefore, the term is highly individual-specific and relative.

Unsafe physical environment may include poorly designed stairs, uneven ground, slippery surfaces, tripping hazards, lack of illumination, and absence of grab bars, among other hazards and will have multiple environmental hazards. Conversely, a safe environment will have no or minimal environmental hazards and provide prosthetic aspects (i.e., providing support to compensate for physical or cognitive decline, e.g., grab bars in the bathroom) that respond to the physical and cognitive status of the individual. This type of environment will support individuals with varying levels of mobility.

The multifactorial falls risk (Figure 1) is a three-dimensional framework with mobility (ranging from low to high) in the x-axis, risk-taking behaviour (ranging from min to max) in the y-axis, and physical environment (ranging from safe to unsafe) in the z-axis. In general, as mobility decreases, risk-taking behaviour increases, and physical environments become unsafe, the risk for falls increases from low risk to very high risk. Therefore, if an older adult has high mobility, minimum risk-taking behaviour (very cautious), and is in a safe physical environment, she or he will be at low risk for having a fall. If an older adult has low mobility, maximum risk-taking behaviour (very reckless), and is in an unsafe place that has multiple environmental hazards, then she or he will be at very high risk for having a fall. Also, based on this model, a person with limited mobility is already at a moderate risk for falls independent of behaviour and environment. The same can be suggested for individuals with maximum risk-taking behaviour and very unsafe environments, despite good mobility.

Last, even though the conceptual framework is based only on three factors, it can actually suggest risk for falls for any individual independent of other factors. This aspect of the framework is due to the fact that most pathologies or conditions, be they physical or psychological, have the potential to affect someone's mobility, risk-taking behaviour,

Figure 1
Multifactorial falls risk conceptual framework utilizing mobility, risk-taking behaviour, and physical environment



or both. If a condition does not affect mobility, behaviour, or the environment, then it will not influence someone's risk for falls. For example, individuals with dementia are at a greater risk for falls because of their impaired judgment and limited ability to recognize and avoid hazards. Therefore, having cognitive impairment changes the behaviour and may make individuals with dementia less able to be careful. As another example, some types of medications have been shown to increase risk for falls (Cumming, 1998; Neutel, Perry, & Maxwell, 2002); however, all medications that can be linked to falls affect mobility, risk-taking behaviour, or both.

A limitation of this model is the difficulty in determining risk-taking behaviour. While mobility and physical environments are much easier to quantify and do not change rapidly (except in extreme events), risk-taking behaviour may change depending on the individual or social circumstances. For example, people with dementia who are not in an agitated state may be at a lower risk for falls than people with dementia who are more agitated in the same physical environment. In summary, the multifactorial falls risk framework may enhance our understanding of the complex interaction between different factors related to falls. In addition, it can also guide practitioners in clinical reasoning as they consider the appropriateness of various interventions to reduce the risk of falls.

Future research directions

Most of the research related to falls and the physical environment has focused on the effect of environmental hazards on falls risk. Future studies should investigate not only the negative impact that the environment has on falls but also the positive impact. Therefore, creating environmental "protectors" may be as important as removing environmental hazards. Examples of environment protectors that have been shown to lower risk for falls are grab bars and handrails (Isberner et al., 1998). Other examples of environmental protectors that have not been investigated are furniture placement, compliant floors (i.e., floor with low stiffness to reduce impact forces of falls), automatic light switches, and innovative bathroom design. Still other environmental aspects that may have a bearing on reducing the risk of falls include visual linkage between different spaces, reduction and elimination of glare from floors and other sources, appropriate flooring in different parts of the house, and so forth.

Research in institutional environments may show that, as the multifactorial falls risk model predicts, an environment that positively stimulates the users may improve their behaviour and consequently decrease their chances of having a fall. This is particularly true for individuals with cognitive impairment. Also, measurement of risk-taking behaviours is a highly relevant, yet overlooked area. Intervention studies could incorporate risk-taking behaviours as an area for measurement and development of responsive programs for behavioural management and environmental modifications. For example, an occupational therapist could assess falls efficacy (confidence in one's ability to perform in specific situations without falling) and the associated physical environments, and a clinical judgment could be made as to the individuals' risk-taking behaviour. It should be also noted that there could be affective precipitators to falls (e.g., lack of acknowledgement of risk) as well as activity-based or behavioural precipitators (e.g., climbing stairs for an individual who is at-risk for falls). Furthermore, given the centrality of occupation to occupational therapy, it is important to identify the occupation at the time of the fall. However, we found a lack of attention to occupation in the falls literature.

Environmental hazard checklists are used often by occupational therapists and other health care practitioners. However, an environmental feature may be considered a hazard for some individuals but not for others, depending on physical and mental capabilities. With a few exceptions (e.g., Iwarsson and Slaug, 2001), most of the environmental assessment tools do not take into account the individual characteristics in assessing the relative risk level of the physical environmental aspects. Environmental hazards checklist should be completed with the user in mind in order to ensure that not only all environmental hazards on the checklist will be reported but also the environmental protectors that the individual uses and the hazards not included in the checklist.

Home attachment and familiarity with the environment in relation to falls is another area that lacks research. While some researchers may hypothesize that the greater the familiarity with the environment, the lower the risk of falls, other may suggest just the opposite, that individuals in an unfamiliar environment will tend to be more careful and, based on the multifactorial falls risk model, be at a lower risk for falls. Also, studies examining the role of physical environment need to carefully assess the micro-environmental features of the location of falls in order to be able to link discrete environmental features with risk of falls.

Another area that needs research is related to assistive devices and the physical environment. An important issue in this area is to investigate the effect of environmental hazards on individuals using assistive devices such as walkers, canes, and wheelchairs. One may hypothesize that furniture placement and stability are important factors in environments where individuals do not use assistive devices for mobility; however the same factors may increase the risk for falling in individuals who do use assistive devices for mobility. As a final area for future research, it would be appropriate to explore environmental interventions for people with dementia living at home and in long-term care facilities taking into account varying risk-taking behaviors among this population. Likewise, it would be worth

exploring any variations and related processes in effects of environmental adaptations on falls between people with cognitive impairment and cognitively intact individuals.

Conclusion

Researchers have yet to establish a strong link between environmental hazards and risk for falls. Very little is known about the mechanism by which the physical environment contributes to falls. It is significant that the major inference from the studies reviewed is that falls arise from the complex interaction between the present state of an individual and the physical environment. However, it is still not possible to conclusively state if environmental modifications alone will decrease or change risk of falls. Therefore, it is critical that intervention programs take into account the multifactorial dimensions of falls. The person's physical and cognitive abilities, behavioural patterns, and the physical environment need to be examined in an integrated way in order to develop meaningful and effective interventions. It is reasonable to conclude that environmental changes offer a promising approach to falls prevention, especially if combined with other types of falls-prevention interventions, such as exercise programs and education. More interdisciplinary research needs to examine the interrelationships among the relevant issues and variables for a more comprehensive and deeper understanding of this complex area of theory and practice.

Key messages

- Physical and cognitive abilities, behavioural patterns, and the physical environment need to be examined in an integrated way in order to develop meaningful and effective falls prevention interventions.
- A conceptual framework "multifactorial falls risk" is proposed and suggests that an individual's risk for falls can be determined by the interaction of three main factors: mobility, behaviour, and physical environment.

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