# Falls: Epidemiology, Pathophysiology, and Relationship to Fracture

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**Current Osteoporosis Reports** 2008, **6:**149–154
Current Medicine Group LLC ISSN 1544-1873
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Falls are common in the elderly, and frequently result in injury and disability. Most falls result from an interaction between individual characteristics that increase an individual's propensity to fall and acute mediating risk factors that provide the opportunity to fall. Predisposing risk factors include age-associated changes in strength and balance, comorbidities such as osteoarthritis, visual impairment and dementia, psychotropic medications, and certain types of footwear. Fewer studies have focused on acute precipitating factors, but environmental and situational factors are clearly important to fall risk. Approximately 30% of falls result in an injury that requires medical attention, with fractures occurring in approximately 10%. In addition to the risk factors for falls, the fall descent, fall impact, and bone strength are all important determinants of whether a fall will result in a fracture. In recent years, numerous studies have been directed toward the development of effective fall and fall-related fracture prevention interventions.

## Introduction

Falls are one of the most common health concerns facing elderly persons today. About one third of community-dwelling adults over the age of 65 and nearly one half of institutionalized persons or persons over the age of 80 will fall each year [1]. Almost half of those who fall in 1 year will experience a repeat fall within the next year [1]. Although most falls result in no injury, 31% of falls result in an injury requiring medical attention or restriction of activities for at least 1 day [2]. Most of these are minor soft tissue injuries, but 10% to 15% of falls result in fracture, and 5% of those result in more serious soft tissue injury or head trauma [3]. Women are 50% more likely to report a fall-related injury than men [2]. Among nursing home residents, the incidence of major soft tissue injury or fracture related to a fall is twice that found in community-dwelling elders [4].

Falls may have other important consequences, even among elders without a fall-related injury. Falls are associated with greater functional decline, social withdrawal, anxiety and depression, and an increased use of medical services [5]. Fear of falling is common among the elderly who have, and fear of falling has been associated with impaired mobility and decreased functional status [6]. As a result, older adults who have fallen are at greater risk of becoming institutionalized regardless of whether they have experienced an injurious fall [5].

The total cost of fall-related injuries to the US health care system is substantial. Almost 8% of persons over the age of 70 will seek medical care in the emergency room secondary to a fall-related injury, and about one third of these persons will be admitted to the hospital [7,8]. In 2000, the US health care system spent $19 billion on the direct medical costs of fall-related injuries [9]. Hip fractures, which are commonly associated with falls, cost the US health care system more than $8.7 billion per year alone [10].

Although fall-related injuries are not a common cause of death in the elderly, accidental falls are the leading cause of unintentional injury deaths in those over 65 years of age [11]. Death related to falls increases with advancing age and greater number of comorbidities [7]. Certain fall-related injuries, such as hip fractures, are associated with a high mortality within the first 6 months, particularly in men [12].

## Pathophysiology of Falls

Most falls are not the result of a single cause, but rather multiple interactions between an individual with a propensity to fall and acute mediating factors.

### Individual characteristics associated with falls

In older adults, the incidence of falls increases steadily with advancing age [1]. Not only are chronic medical conditions, such as cognitive impairment and arthritis, more common in older adults, but physiologic changes of normal aging are also believed to increase the risk of falls [13].

Prospective cohort studies have identified several comorbidities as predisposing risk factors for falls. Parkinson's disease may increase the risk of falls through a number of mechanisms, including increased rigidity of the lower musculature, bradykinesia, orthostasis, and in some cases, cognitive impairment [14]. Stroke is another neurologic condition that has been consistently associated with falls. One study of 124 females with a history of stroke suggested that visual spatial problems, impairment in balance through loss of peripheral sensation or cerebellar function, and residual dizziness were all strongly associated with recurrent falls in women with a history of stroke [15]. Motor weakness in this group was less predictive of falls. Dementia, regardless of etiology, is a strong predictor of falls, in part due to poor safety awareness [1]. Osteoarthritis is another chronic medical condition associated with an increased risk of falls [16]. Osteoarthritis of the hip or knee may increase falls by impairing one's ability to maneuver around objects. Postural stability may also be influenced if there is a tendency to avoid full weight-bearing on the affected limb. As one might expect, the risk of falling increases as the number of comorbidities increase [17].

Physiologic changes of normal aging may increase the risk of falls. For example, with normal aging there is diminished input from the visual, proprioceptive, and vestibular systems, which may result in alterations of balance. Older adults may also have impaired balance recovery due to an age-related decline in the ability to rapidly and efficiently contract the muscles of the lower extremities [18]. Changes in blood pressure regulation may also increase the risk of falls in the elderly. Baroreflex sensitivity and vascular compliance diminish with normal aging. As a result, older persons are at risk of orthostasis during periods of decreased cardiac preload and tachycardia [19]. Age-related changes in total body water and in the renin-angiotensin system contribute to impairments in blood pressure regulation. Consequently, stressors producing transient drops in blood pressure may lead to falls through impaired postural control or cerebral hypoperfusion in association with syncope [20]. Aging also results in decreased muscle mass, although it is less clear how this translates into strength.

Physical examination findings, including an inability to rise from a chair without using one's arms, poor depth perception, and poor contrast sensitivity, have all been associated with an increased risk of falls [21]. Balance problems and lower extremity weakness have been associated with a two- to fourfold increased risk of falls in community-dwelling elders [1].

Medications may be one of the most common and potentially reversible risk factors for falls in the elderly. Psychotropic medications (eg, benzodiazepines, antidepressants, sedative hypnotics, anticonvulsants, and neuroleptics) have been strongly associated with an increased risk of falls in several studies [4,22]. The risk of falls with tricyclic antidepressants versus the newer selective serotonin-reuptake inhibitors appears to be similar [23]. Conflicting evidence exists over whether the risk of falls differs with short- and long-acting benzodiazepines [22,24]. In the nursing home, starting a benzodiazepine or antipsychotic drug is associated with more than a 10-fold increased risk of falls within the 48 hours after starting the medication [25]. The risk of falls is greater in persons taking more than one psychotropic medication or more than three to four medications of any kind [22]. Although cardiac medications, including vasodilators, are commonly believed to be associated with an increased risk of falls, results from a large meta-analysis did not find an association between nitrates or centrally acting antihypertensives and falls [26]. The only cardiac medications that were associated with falls were diuretics, type IA antiarrhythmic drugs (eg, procainamide), and digoxin.

Hypoglycemic agents have been implicated as a risk factor for falls in a few retrospective studies [27]. It is unclear whether these agents cause falls during periods of hypoglycemia, or whether these medications are simply surrogate markers for persons with diabetic neuropathy, a predisposing risk factor for falls. A recent retrospective cohort study suggested that these drugs may increase the risk of falls through hypoglycemia as it was found that persons with lower hemoglobin $A_{1c}$, a marker of better diabetic control, had an increased risk of falls [28]. Prospective studies are needed to determine if an independent association between hypoglycemic agents and falls exists.

Footwear may also be a predisposing risk factor for falls. A small laboratory study testing balance in 25 older men using various shoe types found that shoes with thin, hard soles were associated with the best balance [29]. However, a nested case-control study of 327 men and women who had fallen and 327 age- and sex-matched controls found that wearing athletic shoes was associated with the lowest risk of falling, and that shoes with increased heel height and decreased surface area between the sole and the floor were associated with a higher risk of falls [30].

**Acute mediating risk factors for falls**

Individual characteristics associated with falls have been well investigated in the literature; however, these traditional risk factors are limited in their ability to predict an individual's acute risk of falling given that many persons with predisposing risk factors do not routinely fall each time they ambulate. Instead, clinical observation and expert opinion suggest that there is often an acute mediating factor that causes a fall [31]. Fewer studies have focused on the importance of acute mediating factors.

Environmental hazards, including wet floors, poor lighting, and improper bed height, may increase the risk of falls in the nursing home setting [32]. Home hazard assessments, which modify the environment, have been successful in reducing the incidence of falls [33]. This indirectly suggests the importance of environmental hazards as risk factors for falls.

A few studies have looked at the impact of situational hazards on the risk of falls. For example, an increased patient-to-nurse ratio has been associated with falls in the hospital and nursing home settings [34,35]. High turnover of care assistants and nurses has also been adversely associated with patient care outcomes, including falls, in the nursing home setting [36]. In these situations, falls may result from a decreased ability of the staff to recognize an individual's functional abilities and/or offer appropriate assistance.

Additionally, relocation to a new environment may be a risk factor for falls. Friedman et al. [37] found that the incidence of falls doubled among a cohort of nursing home residents who moved to a newer facility. It is unclear, however, whether the increased fall rate was due to environmental hazards, such as an unfamiliar bathroom, or due to institutional factors, such as changes in staff.

Acute intrinsic hazards may result in falls as well. For example, sleep disturbances are associated with an increased fall risk independent of sedating medications [38]. Acute illnesses, such as fever and dehydration, can also potentially result in falls mediated through delirium, orthostasis, and medication use.

## Relationship of Falls to Fracture

Similar to falls, fractures associated with falls are multifactorial in origin. In addition to the traditional risk factors for falls, the nature of the fall descent, impact of the fall, and bone strength are all important determinants of whether a fracture will occur.

### Risk factors for falls associated with fractures

Few studies attempt to distinguish risk factors for injurious falls from noninjurious falls [3,39]. In community-dwelling elders, cognitive impairment, multiple comorbidities, gait and balance abnormalities, and a history of fracture have all been associated with serious fall injuries, whereas decreased grip strength has been associated with minor injury [3,39]. One prospective study looking specifically at risk factors for fall-associated fractures in community-dwelling individuals found that the fear of falling, lower extremity weakness, and poor visual acuity were predictive of fractures, whereas limited social participation actually protected against fall-associated fractures [40].

Fractures may also be influenced by the timing and location of a fall. Among community dwellers, injurious falls are more likely to occur in the early morning or at night [41]. Most hip fractures are associated with a fall within the home [42]. Fall-related injuries in the institutionalized setting depend on the resident's ambulation status [43]. Nonambulatory residents are more likely to experience injurious falls while using equipment or in the act of transferring (eg, from a bed to a wheelchair). Ambulatory nursing home residents are at greatest risk of injurious falls during the night.

### Factors involved in fall descent

Certain internal characteristics place fallers at a higher risk for injury during fall descent. For example, impaired reaction time and decreased grip strength have been associated with falls resulting in minor injury [39]. Taller height may also increase the risk of injury during a fall as height is predictive of hip fracture independent of bone mineral density (BMD) in women [21]. This may be explained by the greater distance that taller women fall before striking the ground, allowing for greater force on fall impact, or because taller persons have longer hip axis length, an independent predictor of hip fractures [44].

The type of injury sustained is also related to the direction of the fall. Persons experiencing a hip fracture are more likely to report falling sideways, whereas wrist fractures are more strongly associated with trying to break a forward or backward fall with an outstretched arm [44].

### Factors involved with fall impact

Despite the observation that lateral falls are more closely associated with hip fractures, a study of simulated falls showed that a fall directly on the buttocks was associated with a larger force of impact on the greater trochanter than lateral or posterolateral falls [45]. This suggests that the decreased risk of fracture observed with falls directly on the buttocks may relate to the greater amount of posterior soft tissue, which can absorb some of the impact [46]. Other observational studies confirm the importance of soft tissue as a mitigating factor in fractures associated with a fall. For example, older adults with a femoral neck fracture have decreased skinfold thickness compared with age-matched controls [47]. Additionally, higher body mass index has been shown to be protective of hip fracture, although some of this relationship is explained by increased BMD [48]. Weight loss has also been shown to be predictive of hip fracture in several studies, irrespective of baseline weight [21]. Although this may be partially explained by a decrease in BMD seen with unintentional and intentional weight loss [21], the loss of soft tissue protection also may contribute to the increased risk of fracture.

During a fall the impact surface may also influence the fracture risk. Nevitt et al. [39] showed that falls on stairs or steps are more likely to result in injury. One observational study in 34 nursing homes found that the force of impact as measured by transducers was lower on carpeted floors compared with other types of flooring [49]. Not surprisingly, the incidence of hip fractures experienced on carpeted floors was lower than on other types of flooring in this study. Decreasing surface stiffness through installation of foam mats in playgrounds or in nursing homes may attenuate the initial force experienced during a fall. This may decrease the risk of fractures from standing height or less, but it is unlikely to prevent fractures associated with falls from greater heights [50]. However, there is some suggestion that fall rates may be higher on carpeted floors

compared with other floor surfaces. In the only randomized trial examining the effect of floor surface on fall rates in 54 rehabilitation participants, a strong trend was noted toward an increased risk of falls on carpeted floors compared with vinyl flooring (RR, 8.3; 95% CI, 0.95–73) [51].

Hip protectors have been tried as an intervention to decrease the risk of fracture by attenuating force at the hip in association with a fall. Although these devices have been enthusiastically adopted, two systematic reviews of hip protectors have concluded that no evidence exists that hip protectors are effective in reducing hip fractures [52,53]. In subgroup analyses, it was suggested that hip protectors may be effective in nursing home residents [52,53]. These results should be interpreted with caution given that the individual studies frequently used cluster randomization (ie, nursing home ward) to assign the intervention. This may introduce bias if the staff or residents selected to participate in the "treatment" units differ from study participants in the control units [54]. Additionally, adherence to hip protectors was low in most studies, which many have concluded explains the lack of efficacy. More recently, however, a multi-institutional study that randomized individual nursing home residents to a right- or left-sided hip protector confirmed the null findings, with no reduction in hip fractures found on the protected hip [55•].

### Characteristics of bone associated with fracture

Fractures associated with falls occur when the force applied to a bone is greater than the overall bone strength. The bone's strength is a function of bone mineralization, geometry, and microarchitecture. Areal BMD measured by dual-energy x-ray absorptiometry is a measure of the overall size and mineralization of bone that has been shown to be predictive of fractures at several skeletal sites [56]. Although BMD is an important determinant of fall-associated fractures, BMD alone explains less than one half of all nonvertebral fractures [57].

Calcium and vitamin D supplementation have been associated with an increase in BMD [58], and supplementation with higher doses of vitamin D has been associated with a decreased risk of vertebral and nonvertebral fractures [59]. In addition to the protective effect on bone, adequate vitamin D supplementation (> 600 IU/d) has been associated with a decreased risk of falls among nursing home residents and community-dwelling adults [60,61]. Although the exact mechanism is unknown, vitamin D may reduce the risk of falls by increasing muscle strength and decreasing body sway [62].

Bone geometry may be additive to BMD and falls in assessing fracture risk. Most studies support longer hip axis length and increasing femoral neck/shaft angle as independent predictors of hip fracture [63,64]. Conflicting data exist on whether other anthropometric measures, such as femoral neck shaft width, are associated with an increased risk of hip fracture [63,64].

Microarchitectural changes in trabecular number, size, and distribution have been shown to predict bone fragility independent of BMD [65]. Cadaveric studies of distal forearm microarchitecture in humans confirm that women have decreased trabecular thickness when compared with men, again probably contributing to the increased incidence of wrist fractures found among older women [66]. Although changes in microarchitecture and mineralization of bone likely explain some of the rising incidence of wrist fractures seen among older women, it is also clear that the increased incidence of falls contributes to the occurrence.

## Conclusions

Falls are common in the elderly, and frequently result in injury, disability, and institutionalization. Most falls result from an interaction between individual characteristics that increase an individual's propensity to fall and acute mediating risk factors that provide the opportunity to fall. Predisposing risk factors include older age, dementia, comorbidities, use of psychotropic medications, and wearing certain types of footwear. Fewer studies have focused on acute mediating factors, but environmental and situational factors are clearly important to the risk of falls. Fractures associated with falls are multifactorial in origin. In addition to the traditional risk factors for falls, the fall descent, fall impact, and bone strength are all important determinants of whether a fracture will occur as a result of an event. Future studies should consider whether fall prevention measures are effective in reducing fractures.

## Disclosures

No potential conflicts of interest relevant to this article were reported.

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