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Falls: Epidemiology, Pathophysiology, and Relationship to Fracture

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Abstract

Falls are common in the elderly, and frequently result in injury, disability, and institutionalization. Although the causes of falls are complex, 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, age-associated comorbidities such as osteoarthritis, visual impairment and dementia, psychotropic medications, and certain footwear. Fewer studies have focused on acute precipitating factors, but environmental and situational factors are clearly important to the risk of falls.

Approximately 30% of falls result in an injury that requires medical attention and with fractures occurring in approximately 10% of falls. Fractures associated with falls are multi-factorial 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. In recent years, numerous studies have been directed toward the development of effective fall and fall-related fracture prevention interventions.

Introduction and Epidemiology

Falls are one of the most common health concerns facing elderly persons today. About one-third of community-dwellers 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 fallers will experience a repeat fall within the next year.¹ While most falls result in no injury, 31% of falls result in an injury requiring medical attention or restriction of activities for at least one day.² Most of these are minor soft tissue injuries, but 10-15% of falls result in fracture, and 5% of falls result in more serious soft tissue injury or head trauma.³ Women are 50% more likely to report a fall-related injury compared to 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 elderly.⁴

Falls may have other important consequences, even among elders without a fall-related injury. Falls are associated with greater functional decline, social withdraw, anxiety and depression, and an increased use of medical services.⁵ Fear of falling is common among elderly fallers, 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 U.S. 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 U.S. 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 U.S. health care system over \$8.7 billion/ 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 aged over 65 years.¹¹ Death related to falls increases with advancing age and greater number of co-morbidities.⁷ Certain fall-related injuries, such as hip fractures, are associated with a high mortality within the first six months, particularly in men.¹²

Pathophysiology of Falls

The majority of falls are not the result of a single cause, but instead due to 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 associated with falls, 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 a number of co-morbidities 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 neurological 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, irregardless 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 co-morbidities 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 exam 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 2-4× increased risk of falls in community dwellers.¹

Medications may be one of the most common and potentially reversible risk factors for falls in the elderly. Psychotropic medications (benzodiazepines, antidepressants, sedative hypnotics, anticonvulsants, and neuroleptics) have been strongly associated with an increased risk of falls in a number of studies.^{4, 22} The risk of falls with tricyclic antidepressants versus the newer selective serotonin-reuptake inhibitors (SSRI) 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 is associated with more than a ten times increased risk of falls within the 48-hours following the medication start.²⁵ The risk of falls is greater in persons taking more than one psychotropic medication or more than 3-4 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 anti-hypertensives and falls.²⁶ In fact, the only cardiac medications that were associated with falls were diuretics, type Ia anti-arrhythmic drugs (e.g. 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 found that persons with lower HgbA1C, 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 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 men and women found athletic shoes were associated with the lowest risk of falling, and 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 both 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. found that the incidence of falls doubled among a cohort of nursing home residents who moved

to a newer facility.³⁷ 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 multi-factorial 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 non-injurious falls, but the literature suggests that the risk factors are similar.^{3, 39} In community dwelling elderly, cognitive impairment, multiple co-morbidities, gait and balance abnormalities, and a history of fracture have all been associated with serious fall injuries, while 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 The majority of hip fractures are associated with a fall within the home.⁴² Fall related injuries in the institutionalized setting depend on the ambulation status of the resident.⁴³ Nonambulatory residents are more likely to experience injurious falls while using equipment or transferring. 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 of 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 forward or backwards falls 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 skin fold thickness compared to age matched controls.⁴⁷ Additionally higher body mass index (BMI) 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 both unintentional and intentional weight loss,²¹ the loss of soft tissue protection may contribute to the increased risk of fracture as well.

During a fall the surface of impact may also influence the risk of fracture. Nevitt et al. showed that falls on stairs or steps are more likely to result in injury.³⁹ 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 falls rates might be higher on carpeted floors compared to other floor surfaces. In the only randomized trial examining the effect of floor surface on fall rates in 54 rehabilitation participants, there was a strong trend towards an increased risk of falls on carpeted floors compared to vinyl flooring (relative risk 8.3, 95% confidence interval 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 there is no evidence 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 (i.e. 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 strength of a bone is a function of bone mineralization, geometry, and micro-architecture. Areal BMD by DXA is a measure of the overall size and mineralization of bone that has been shown to be predictive of fractures at a number of skeletal sites.⁵⁶ While BMD is an important determinant of fall-associated fractures, BMD alone explains less than one-half of all non-vertebral fractures.⁵⁷

Both 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 non-vertebral fractures.⁵⁹ In addition to the protective effect on bone, adequate vitamin D supplementation (>600 IU/day) has been associated with a decreased risk of falls among nursing home residents and community-dwellers.^{60, 61} While 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 exists 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 to men, again probably contributing to the increased incidence of wrist fractures found among older women.⁶⁶ While 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, co-morbidities, psychotropic medications, and certain 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 multi-factorial 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.

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Annotated References

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- Kiel DP, Magaziner J, Zimmerman S, et al. Efficacy of a hip protector to prevent hip fracture in nursing home residents: the HIP PRO randomized controlled trial. *Jama* Jul 25;2007 298(4):413–422. [PubMed: 17652295] This article presents data from an important multi-institutional study of hip protectors that randomized individual nursing home residents to a right or left sided-hip protector. This important study confirmed the null findings of previous hip protector investigations as reduction in hip fractures was found on the protected hip.