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Injuries Sustained by Falls - A Review

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Abstract

Falls are one of the major causes of trauma in all countries and cause a typical injury pattern. It has different aetiologies in different populations. This review focuses on what is known about the major groups of falls; same-level falls, intentional high falls and unintentional high falls. There is evidence in the literature that these groups are different in many other ways than fall height and intentionality, including age, sex, pre-existing illnesses, drug abuse, injury pattern, treatment and long term outcome. There is also a lack of standards and definitions in fall research.

Keywords: Free fall; Fall from standing; Vertical deceleration; Accidental fall; Trauma; Morbidity and Mortality

Abbreviations:

MVC: Motor Vehicle Collision; MOI: Method of Injury: SLF: Same Level Falls; AHF: Accidental High Falls; IHF: Intentional High Falls; HF: Mixed High Falls; ISS: Injury Severity Score; ATD: Anthropomorphic Test Dummies; UE: Upper Extremity; DIY: Do It Yourself.

Introduction

Falls are the second greatest reason for unintentional injury in the Western world, exceeded only by motor vehicle collisions (MVCs) [1]. The "falls" mechanism of injury category encompasses many different types of events, including falls on stairs or steps; from ladders; out of buildings; into holes; from one level to another such as from playground equipment, from cliffs or furniture and falls on level ground as a result of slipping, tripping, or stumbling.

Also included are sports injuries involving falls due to slipping, tripping, or pushing and collisions due to pushing or shoving by another person.

These different methods of injury (MOI) can however be grouped in three major groups: same level falls (SLF), accidental high falls (AHF) and intentional high falls (IHF). People sustaining an AHF are termed fallers and those sustaining an IHF are called jumpers. Fall victims signify all three groups. This paper will be looking at differences and similarities between them.

The height of the fall is sometimes defined in meters and sometimes in floors. Often the height is registered in floors by ambulance personnel and then recalculated in meters. However, there is no common definition of how high a floor is. Neither is there consensus what height defines a high fall or if there should be any stratification in this group [2-6].

Who Falls?

SLFs happen to most people, but are most common for older people with impaired balance. Risk factors have been divided in categories depending on environment, medical conditions, medication, age, nutrition and lack of exercise. Repetitive falling is the greatest predictor of falling again [7].

Falls from heights can be divided into accidental and intentional falls. Accidental falls are by far the most common in rural areas [8,9] whereas in urban and western societies intentional falls are more common [3,10,11]. This is probably due to both more strict building codes in developed countries preventing many AHFs and the fact that psychiatric illness is more common in cities. IHFs are heavily associated with psychiatric disorders where schizophrenia, depression, bipolar disease and drug abuse predominate [12-14]. Most intentional falls happen with a suicidal intent and a few during a psychosis, e.g. under the conviction that one can fly or is immortal.

AHFs have a diverse demography ranging from infants to elderly people. Falls occur at work, at home and at recreational places. Faulty equipment, risk-taking behavior and absence of building regulations are common risk factors [4,9,15-17].

Alcohol is a very important risk factor in men, being involved in 58% of SLF and 27% of HF. In women it is only involved in 11% of SLF and 13% of HF. Alcohol also results in a different injury pattern, causing more injuries to the face, brain and internal organs [18]. There is a linear dose-response risk of falling compared to alcohol intake per day [19]. In suicides by IHF in Sweden, alcohol intoxication is present in 19%, which is less than in other types of suicide [13]. In a Greek study on fatal fall injuries there was 16% alcohol intoxication and 3.2% intoxication with other psychoactive drugs [20].

The majority of geriatric fall-related injuries were due to fall from the same level at home [21]. One-third of community-dwelling people older than 65 years of age fall each year, and half of them fall at least twice a year. An important health risk indicator is (orthostatic or postprandial) hypotension, which may induce cerebral hypo perfusion. Although the majority of falls remain without major consequences, 10% to 25% of falls in care homes result in bodily trauma [22].

In suggestive evidence that the physical activity program may reduce the rate of fall related fractures and hospital admissions in men [23].

Subermaniam et al., in there study showed, evaluated the effectiveness of a modular bed absence sensor device (M-BAS) in detecting bed exits among older inpatients .The sensitivity of the M-BAS was 100% with a positive predictive value of 68% and a nuisance alarm rate of 31%.

The M-BAS was able to accurately detect bed absence episodes among geriatric inpatients and alert nurses accordingly [24].

We know that, older adults are disproportionately affected by painful musculoskeletal conditions and receive more opioid analgesics than persons in other age groups, insufficient evidence is available regarding opioid harms in this age group [25].

Additional research is needed to determine whether opioid use is a marker of risk or a cause of falls, fractures, and progressive impairment among older adults with persistent pain [25].

In another article Wallander [26] showed, the risk of fractures differs substantially among patients with T2DM and an increased risk of hip fracture was primarily found in insulin-treated patients, whereas the risk of non-skeletal fall injury was consistently increased in T2DM with any diabetes medication.

Thaler et al., in new study of 400 female patients aged 70 years or older who were consecutively admitted to the Trauma Center, after a fall and who required hospital admission. In conclusion, the results provide further evidence that PPI use may increase risk of falls and fractures in older women and highlight the need for clinicians to reassess the original indication and the need for continuation of PPIs on a regular basis [27].

In another study the rate of psychotropic drug use in general and their anticholinergic burden are similar in acutely admitted elderly patients with or without hip fractures [28]. However, higher usage rate of anxiolytics found in the patients with hip fractures may indicate that this is a risk factor for hip fractures related to falls in elderly patients living in the community [28].

Fall risk for older adults is a multi-factorial public health problem as 90% of geriatric injuries are caused by traumatic falls. It is estimated 33% of adults >65 years incurred a fall in 2011, with 30% resulting in moderate injury.

While much has been written about overall risk to trauma patients on oral anticoagulant (OAC) therapy, less has been reported on outcomes in the elderly trauma population.

Risks of anticoagulation in elderly trauma patients are complex. While OAC use is a predictor of 30-day mortality after fall, the injuries sustained are markedly different between the elderly who die and those who do not. As a result there is a greater need for healthcare providers to identify preventable and non-preventable risks factors indicative of falls in the anti-coagulated elderly patient.

How do people fall?

When the center of gravity of the body is moved outside of the supporting area made up by the feet, a fall is initiated. This can be caused by e.g. a gust of wind or by the normal sway of the body. Usually we try to compensate, shifting our area of support back under the center of gravity by moving the feet. This ability is slowly lost with age and thus the balance-provoking stimulus needed to cause a fall is reduced. Other falls occur because of changes in the supporting material, or by an uncontrollable shift of the supportive area, e.g. when a ladder breaks or when we slip on ice. While this applies to SLFs and AHFs, the mechanism in intentional high falls is slightly different. The center of gravity is then wilfully placed outside the supportive area.

What about a fall causes significant injury?

The bodily damage caused by a fall is due to the absorbed energy at impact. This energy relates to the kinetic energy, E_k, of the moving body right before impact, explained by equation 1:

$$E=mv2 \quad (1)$$

where m is the body mass and v is the speed of the body. The speed is closely related to the height of the fall, but is also affected by the air friction, or air drag. The higher the fall, the greater the effect of air drag up to 32 floors where the drag force equals the gravitational force [29]. Falls from these heights are very rarely survivable [30]. Mass is also central and is believed to be one of the reasons why children can survive higher falls than adults [12].

The stopping distance, i.e. the penetration of the falling object into the landing material, is the other great determinant of injury. The shorter the distance, i.e. the more un-yielding the landing material, the greater is the deceleration. This affects the impact force, which is explained in equation 2:

$$F=m^{*}\Delta v \quad (2)$$

The body's ability to absorb energy without significant injury depends on the landing position, neuromuscular reflexes dampening the impact by lowering the peak deceleration [15] and the energy absorbing properties of different tissues. Younger and stronger bones can absorb more energy before breaking, and while this is the major determinant of injury in SLFs it also affects high falls. Studies made on anthropomorphic test dummies (ATD) have given important insights in injury mechanisms [28]. Models don't always match reality as shown

by a Canadian study where more children got injured playing on playgrounds with specially designed impact dampening ground material than on normal sand [31]. The injury severity score by fall from different floor heights is given in Table 1.

Table 1: Average injury severity score and mortality due to fall from different floor heights.

Floor	Height (m)	Vmax (m/s)	E_k (J)	$g_{concrete}$	g_{soft}	Avg ISS [11]	Mortality [11]
1	3.67	8.5	2518	734	85	12	0%
2	7.34	12.0	5035	1468	120	14	4%
3	11.01	14.7	7553	2202	147	18	0%
4	14.68	17.0	10070	2936	170	28	12%
5	18.35	19.0	12588	3670	190	29	27%
6	22.02	20.8	15106	4404	208	33	50%
1 floor=15 ft=3.67 m; Mass=70 kg; Stopping distance (d) in concrete=0.005 m; d on soft ground=0.1 m							

What injuries are most common after a fall?

Most studies have a specific sub-population or MOI in focus leading to great difficulties in comparing outcome data between studies. Not all falls result in significant injury, but studies show that 40-70% of fallers seeking medical attention in the ED (emergency department) have sustained injuries. One study on mixed falls concludes mortality to be 1 per 220 ED visits or 1500 falls [32]. The injuries most commonly associated with falls are:

Extremity skeletal injuries (ranging from 20% in SLFs [33] to 77% in high falls [9] where hip and upper extremity (UE) injuries predominate in SLFs and other lower extremity (LE) injuries are more common in high falls.

Spine injuries are very common (ranging from 13% in mixed falls [9] to 36% in high falls [4,6]. Lumbar spine injuries are completely predominating. Spine injuries are not confined to high falls, but can happen from even below 2 m [6].

Head injuries are more common in children, likely due to them having relatively larger heads, shifting the center of gravity cranially. Jumpers more often land on their feet than fallers and thus injuries to the lower extremities are more common, but the higher the fall, the greater is the chance of landing on the head. 20-45% of falls from 2-10 m resulted in head injury. Several studies have detailed reports on head injuries with ranges of 0.7-5.8% of epidural hematoma, 0.9-6.0% of subdural hematoma, 1.5-7.0% of subarachnoid hematoma and 0.4-3.7% of intracerebral hematoma [8,10,16,34].

In SLFs, brain injury is also common. Brain and spine injury was seen in 25% of same level fallers in one study, hence it was more common than fractures [26].

Thoracic injuries are more common in high falls, the commonest specific injuries being rib fractures, lung contusion, pneumothorax and hemothorax [10]. In very high falls cardiac and aortic rupture are common [3].

Abdominal injuries in fall victims surviving long enough to reach the hospital are uncommon (2.0-9.0%), especially as an isolated injury and from falls below 7 m [5,6,8,9]. Retroperitoneal hemorrhage has been reported as a culprit in hemodynamically unstable patients, but intraabdominal injuries are much more common [6]. Many can be treated conservatively [35].

Many pre-existing conditions can aggravate the injuries sustained by a fall e.g. warfarin treatment for hypercoagulability [36] or beta-blockers impairing the response to hypovolemia [29].

Mortality in falls obviously depends on the height of the fall but there is no safe height and there are reports of survival after extremely high falls [37]. The 50% mortality threshold is passed between 4 and 5 floors [11]. Young fall victims tend to die shortly after the fall or survive, while old people often die in complications during the first weeks [11,30]. Mortality in SLF is mainly due to complications and co-morbidities [38]. In one study on high falls 63% of mortalities were suicides [10]. Head and/or thoracic injuries is almost exclusively involved [8–10,16].

How are fall victims treated?

Falls make up for 7-8% of ambulance calls and 70% of dispatches are to a home or residential institution [33]. As much as 40% of fallers are not brought to the ED and studies are being made on which patients that are better handled by the primary care than in the ED setting [32].

Orthopedic surgery is the dominating form of surgery in fall victims and makes up 71-77% of operations in two studies on mixed high falls [6,10]. Its relative dominance is even greater in SLF. 13% was abdominal, 5% neuro, 3% thoracic and 1% vascular surgery [6].

The hospital length of stay (LOS) and intensive care unit LOS increases with height of fall [6], age [9,30], co-morbidities [38] and is also greater for at-home fallers (as opposed to at-work fallers), probably because of them being older [5].

What is the long-term outlook after a fall?

In 40% of events leading to elders being moved to a residential institution, a fall is a predisposing factor. Fear of falling is a factor that can impair patient's quality of life and even accelerate functional decline. In fallers and jumpers, avoidance

of high places might be healthy, but in SLF:ers this fear can be a bigger handicap than the actual physical injuries [39].

We have been unable to find reliable data on long-term outcome specific for fallers. There are studies on senior (65+) severe trauma patients suggesting that while 98% are living independently before the accident, only 63% do so 3 years afterwards [40].

Are there any important cultural differences?

In SLF both demography and injury pattern are similar in different cultures [41]. The treatment is obviously dependent on economical resources, but can also differ between hospitals with similar economic backgrounds [1].

Medical care after same level falls has an ever-increasing importance because of the increasing number of old people in our community. Even though fall injuries (mainly SLFs) demanding health care have more than doubled, the average length of stay has dropped by more than half, resulting in the total number of hospital days decreasing [41].

In high falls there are great cultural differences. In two Turkish studies the most common faller was a child playing on the flat roof, falling down 2-4 levels [8,16]. In an Indian study falls from trees were common, mainly affecting men and boys [38]. An American study found that falls from hunting tree stands were both common and dangerous [4]. Two Australian studies found that falls from ladders were increasing, especially among non-workers, and hypothesized that the current popularity of DIY (do it yourself) home renovation is the culprit [2]. In several studies on urban falls IHF is very common [10,11].

However, our point of view is that there is no indication that falls from similar heights, with similar intent/non-intent, by patients of similar age and onto similar ground materials would result in differing injury patterns in different cultures or ethnic groups.

Conclusions

Unquestionably, advanced age and pre-existent medical conditions contribute significantly to the increased morbidity and mortality following falls. Falls during recreational and work related circumstances are more common in males, whereas women fall more often at home. Very young fallers are more commonly male, while women are the most common older fallers. Deaths from accidental falls are far more common than from intentional falls and both sexes are equally at risk. As is true for most causes of trauma, prevention of fall injuries has considerable potential for cost savings and the lessening of morbidity and mortality.

We believe that there is a need for a standard definition of falling, including stratification in for example same level falls (SLF), low falls (<1 story/3m), high falls (>1 story/3m) and very high falls (>10 m). Height is the most important prognostic factor in falling and could be used to make an adequate prioritation, prognosis and to provide adequate hospital reimbursement.

Authors' Contributions

Erik Altgärde has been involved in the conception, literature review and drafting of the manuscript. Hans Granhed and Levent Akyürek has reviewed the article and provided important insights and suggestions. Pazooki David initiated the project and has guided the design and literature review, and has drafted important parts of the manuscript.

Competing Interests

The authors declare that they have no competing interests.

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