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Research Article

Injuries Following Height Versus Ground-Level Falls: A Hospital Registry-Based Study

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Abstract

Introduction: Falls are the second leading cause of unintentional injury-related deaths worldwide, posing a significant public health concern. This study compares injury patterns between patients who fell from height and those who experienced ground-level falls.

Methods: This hospital-based registry study analyzed data from Sina Hospital in Tehran, including all patients with fall-related trauma from September 2016 to August 2022. Collected variables included demographics, fall mechanisms, length of hospital stays, intensive care unit admission, intensive care unit length of stay, mortality, Glasgow Coma Score, injured body regions, and injury types.

Results: This study included 1,484 patients, with 50.3% experiencing falls from height and 49.7% having ground-level falls. Falls from height were more common among males (80.1%) and individuals aged 18-64 years (77.1%). After adjusting for age and gender, patients who fell from height had a higher rate of moderate head injuries (1.5% vs. 0.3%), longer hospital stays (8.2 vs. 6.9 days), and more frequent injuries to the chest, spine, upper extremities, and multiple traumas compared to ground-level fallers. Forearm fractures were more prevalent among patients who fell from height (21.5% vs. 12.4%), whereas femur fractures were more common in ground-level fallers (42.6% vs. 13.2%).

Conclusion: Significant differences exist in injury patterns between falls from height and ground-level falls. Falls from height disproportionately affect males and working-age individuals, leading to a higher incidence of upper extremity injuries, forearm fractures, and multiple traumas. In contrast, ground-level falls are more common among the elderly and result in a higher incidence of lower extremity injuries, particularly femur fractures. Recognizing these differences is crucial for developing targeted prevention strategies and improving patient outcomes.

Keywords: Accidental Falls, Fall from Height, Ground-Level Fall, Trauma Centers

Introduction

According to the world health organization, falls are the second leading cause of unintentional injury mortality worldwide, accounting for 684,000 deaths annually. Over 80% of these fatalities occur in low- and middle-income countries [1]. Fall-related injuries pose a higher risk of being life-threatening compared to other types of injuries, and while mortality rates from other trauma mechanisms are declining, deaths due to falls are rising [2, 3]. Between 2005 and 2015, fall-related deaths increased by 21%, primarily due to population growth and aging [4]. Globally, falls contribute to more years lived with disability than any other trauma mechanism. From 2006 to 2016, fall-related disability-adjusted life years (DALYs) per 100,000 population rose by 14% [5].

Several studies have examined trauma patterns in Iran. A systematic review on the epidemiology of injuries in Iran found that falls were the second most common cause of injuries after road traffic accidents [6]. This finding was further supported by a study conducted in Hamedan city, Iran [7]. A population-based study reported an annual incidence rate of fall-related

injuries of 59 per 1,000 people [8]. Additionally, a national-level study in Iran found that the age-standardized mortality rate due to falls was 2.13 per 100,000 people in 2015 [9].

In the literature, falls are generally classified as falls from height and ground-level falls [10]. A fall from height occurs when a person descends from an elevated position to a lower level [2]. In contrast, a ground-level fall refers to an incident in which an individual falls from the same level as the source of injury, without any elevation involved [11]. Among elderly individuals, ground-level falls are more common than falls from heights and often result in severe injuries [12].

Several studies have examined patterns of fall-related injuries in Iran at both national and provincial levels [8, 9, 13]. However, despite an extensive search, no published studies in Iran, have compared falls from height to ground-level falls. Therefore, this study aims to analyze the injury patterns associated with different fall mechanisms.

Methods

This registry-based study utilized data from the National Trauma Registry of Iran (NTRI) and was conducted at Sina Hospital, one of NTRI's collaborating hospitals. It included patients admitted for fall-related injuries between September 17, 2016, and August 31, 2022. The study population comprised patients who remained hospitalized for more than 24 hours, those who died in the hospital, and those transferred from the ICU wards of other hospitals.

In the NTRI, patient data were collected by registrars through face-to-face interviews with patients or their substitute decision-makers, as well as by reviewing the medical records. The collected data were entered into a web-based database and subsequently reviewed by an observer for quality assurance [14-18]. In this study, fall injuries were classified into falls from height and ground-level falls. A fall from height was defined as a fall occurring above ground level, whereas a ground-level fall occurred at the same level. The following data were extracted from the NTRI database: fall mechanism (fall from height; ground-level fall) [10], gender, age categories (preschool [0-6]; school [7-17]; working [18-64]; elderly [≥65]), injury season (spring, summer, autumn, winter), number of traumas (injury to more than one body region classified as multiple trauma), Glasgow Coma Scale (GCS) score (categorized as mild [13-15], moderate [9-12], severe [≤8]) [19], injured body region (patients with injuries to multiple regions were considered as multiple trauma, while two injuries within the same region where considered a single trauma), diagnosis (based on ICD-10-CM[1] codes), length of stay (LOS) in the hospital, intensive care unit (ICU) admission, ICU LOS , and in-hospital mortality.

The Chi-Square test was used to assess the association between categorical and nominal variables and the fall mechanism. Bonferroni adjustment was applied for post hoc analyses following the Chi-Square test. The Independent Samples t-test was employed to compare the means of quantitative variables with a normal distribution between the two fall mechanisms. Age and sex standardization was conducted using the 'margins' command in STATA. Logistic regression models were first fitted, and adjusted probabilities were then estimated using this command. Statistical significance was set at $p<0.05$. All data analyses were performed using Stata software, version 14.0 (StataCorp, College Station, TX, USA).

Results

Baseline Characteristics

Sina Hospital recorded data on 1,484 fall injuries, with 752 (50.3%) classified as falls from height and 732 (49.7%) as ground-level falls. There was a statistically significant difference between the two fall mechanisms based on gender ($P<0.001$). The majority of individuals who fell from heights were male (80.1%), whereas more than half of those who experienced ground-level falls were female (51.8%). The fall mechanisms also showed statistically significant differences across age groups ($P<0.001$). Most injuries from falls from height (77.1%) occurred in the working age group (18-64 years), whereas the majority of ground-level fall injuries (54.5%) occurred in the elderly (≥65 years). Falls from height were most common in summer, while ground-level falls occurred most frequently in winter. However, the seasonal differences were not statistically significant ($P=0.11$) (Table 1).

1. International Classification of Diseases, Tenth Revision, Clinical Modification

Clinical Characteristics and Outcomes

After adjusting for age and gender, a higher percentage of patients in the fall from height group experienced moderate head injury (GCS score of 9-12) compared to the ground-level fall group (1.5% vs. 0.3%, *P*=0.04). The mean LOS in the hospital was also longer for the fall from height group than for ground-level fallers (8.2 vs. 6.9 days, *P*=0.02). However, there was no statistically significant difference in age- and sex-standardized mortality between the fall from height group (4.6%) and the ground-level fallers (4.7%) (*P*=0.91) (Table 2).

Table 1: Baseline characteristics by fall mechanism, N (%)

	Fall from height (N=752)	Ground-level fall (N=732)	Total (N=1484)	*P*-value [a]
Gender				
Male	602 (80.1)	353 (48.2)	955 (64.4)	<0.001
Female	150 (19.9)	379 (51.8)	529 (35.6)	
Age, years				
Preschool (0-6)	13 (1.7)	9 (1.2)	22 (1.5)	<0.001
School (7-17)	52 (6.9)	36 (4.9)	88 (6.0)	
Working (18-64)	580 (77.1) [b]	288 (39.3)	853 (58.4)	
Elderly (≥65)	107 (14.2)	399 (54.5)	498 (34.1)	
Injury season				
Spring	182 (24.2)	172 (23.5)	354 (23.9)	0.11
Summer	221 (29.4)	199 (27.2)	420 (28.3)	
Autumn	180 (23.9)	157 (21.4)	337 (22.7)	
Winter	169 (22.5)	204 (27.9)	373 (25.1)	

[a]Based-on Chi-Square test; [b]Pairwise comparisons were conducted using the Bonferroni test. Proportions that were significantly different between the two mechanisms are indicated in bold.

Injured Body Regions

Table 3 presents the distribution of injured body regions by fall mechanism. The results show significant differences in the distribution of injuries across body regions, including the chest, abdomen, spine, upper extremities, and lower extremities (*P*<0.05). Injuries to the upper extremities were more common in falls from height than in ground-level falls (29.1% vs. 22.8%, *P*=0.006), while lower extremities injuries were more prevalent in ground-level falls than in falls from height (58.7% vs. 32.1%, *P*<0.001). Additionally, multiple traumas occurred more frequently in falls from height than in ground-level falls (11.6% vs. 3.8%, *P*<0.001) (Table 3).

ICD-10 Diagnosis

Table 4 summarizes the ICD-10 diagnoses in the two groups. A significant difference was observed in the incidence of femur and forearm fractures between the ground-level falls and falls from height (*P*<0.001). The most common injury among ground-level fallers was a femur fracture (42.6%), whereas a forearm fracture was more frequent among those who fell from height (21.5%) (Table 4).

Table 2: Age and sex standardized clinical characteristics and outcomes by mechanism of fall

	Fall from height	Ground-level fall	Total	*P*-value
GCS				
Mild (13-15) (%)	97.4	98.7	98.1	0.04[a]
Moderate (9-12) (%)	1.5[c]	0.3	0.8	
Severe (≤8) (%)	1.1	1.0	1.1	
ICU admission (%)	25.9	22.0	23.7	0.1[a]
LOS in hospital (days), mean (SD)	8.2 (0.3)	6.9 (0.3)	7.6 (0.2)	0.02[b]
LOS in ICU (days), mean (SD)	6.3 (0.9)	5.0 (0.7)	5.6 (0.5)	0.33[b]
Mortality (%)	4.6	4.7	4.7	0.91[a]

Abbreviations: GCS, Glasgow Coma Scale; ICU, Intensive Care Unit; LOS, Length of Stay; SD, Standard Deviation
[a]Based on Chi-Square test; [b]Based on Sample T-test; [c]Pairwise comparisons were conducted using the Bonferroni test. Proportions that were significantly different between the two mechanisms are indicated in bold.

Table 3: Injured body regions by mechanism of fall, N (%)

Body regions	Fall from height (N=752)	Ground-level fall (N=732)	Total (N=1484)	*P*-value[a]
Head	48 (6.4)	61 (8.4)	109 (7.4)	0.148
Face	26 (3.5)	16 (2.2)	42 (2.8)	0.14
Neck	3 (0.4)	0 (0.0)	3 (0.2)	0.087
Chest	39 (5.2)	7 (1.0)	46 (3.1)	<0.001
Abdomen	15 (2.0)	4 (0.5)	19 (1.3)	0.013
Spine	73 (9.7)	19 (2.6)	92 (6.2)	<0.001
Upper Extremity	218 (29.1)	166 (22.8)	384 (26.0)	0.006
Lower Extremity	241 (32.1)	428 (58.7)	669 (45.2)	<0.001
Multiple Trauma	87 (11.6)	28 (3.8)	115 (7.8)	<0.001

[a]Statistical analyses were conducted based on Chi-Square test

Table 4: ICD-10 diagnosis by mechanism of fall, N (%)

ICD-10 diagnosis of injury[a]	Fall from height	Ground-level fall	Total	*P*-value[b]
Head				
Fracture of skull and facial bones	37 (4.9)	19 (2.6)	56 (3.8)	0.02
Intracranial injury	29 (3.9)	31 (4.2)	60 (4.0)	0.71
Other and unspecified injuries of head	12 (1.6)	17 (2.3)	29 (2.0)	0.31
Thorax				
Superficial injury of thorax	21 (2.8)	4 (0.5)	25 (1.7)	0.001
Fracture of rib(s), sternum and thoracic spine	26 (3.5)	7 (1.0)	33 (2.2)	0.001
Injury of other and unspecified intra-thoracic organs	29 (3.9)	3 (0.4)	32 (2.2)	<0.001
Abdomen, lower back, lumbar spine, pelvis and external genitals				
Fracture of lumbar spine and pelvis	91 (12.1)	23 (3.1)	114 (7.7)	<0.001
Other and unspecified injuries of abdomen, lower back, pelvis and external genitals	9 (1.2)	7 (1.0)	16 (1.1)	0.65
Shoulder and upper arm				
Fracture of shoulder and upper arm	52 (6.9)	41 (5.6)	93 (6.3)	0.30
Elbow and forearm				
Open wound of elbow and forearm	9 (1.2)	6 (0.8)	15 (1.0)	0.47
Fracture of forearm	162 (21.5)	91 (12.4)	253 (17.0)	<0.001
Wrist, hand and fingers				
Open wound of wrist, hand and fingers	6 (0.8)	6 (0.8)	12 (0.8)	0.96
Fracture at wrist and hand level	35 (4.7)	17 (2.3)	52 (3.5)	0.015
Hip and thigh				
Fracture of femur	99 (13.2)	312 (42.6)	411(27.7)	<0.001
Knee and lower leg				
Open wound of knee and lower leg	8 (1.1)	4 (0.5)	12 (0.8)	0.27
Fracture of lower leg, including ankle	102 (13.6)	64 (8.7)	166(11.2)	0.003
Ankle and foot				
Fracture of foot and toe, except ankle	52 (6.9)	10 (1.4)	62 (4.2)	<0.001
Multiple body regions				
Fractures involving multiple body regions	35 (4.7)	5 (0.7)	40 (2.7)	<0.001
Unspecified multiple injuries	39 (5.2)	4 (0.5)	43 (2.9)	<0.001

[a]Diagnosis codes that were reported more than 10 times are listed, and 74 patients had missing data for diagnosis variable (More than one diagnosis code may be reported for a patient); [b]Statistical analyses were conducted based on Chi-Square test.

Discussion

In this study, injury patterns were analyzed based on baseline and clinical characteristics, injured body regions, and injury types across two fall mechanisms. To our knowledge, this is the first study comparing injury patterns between falls from height and ground-level falls in Iran.

The findings indicate that falls from height were more common among males and the working-age group, whereas ground-level falls were more prevalent among the elderly. Patients who fell from height had a higher incidence of upper extremity injuries, forearm fractures, and multiple traumas. In contrast, ground-level fallers experienced more lower extremity injuries and femur fractures.

After adjusting for age and sex, the results demonstrated a higher percentage of injuries with a GCS score of 9-12 in falls from height compared to ground-level falls. In a retrospective cross-sectional study, patients in the non-ground-level fall group exhibited significantly lower GCS scores [20]. This study also found that falls from height were associated with a greater incidence of

multiple injuries than ground-level falls. These findings align with previous research [2, 21, 22], which suggests that the higher energy transfer to the body during a fall from height leads to more severe injuries compared to ground-level falls [10, 23]. Furthermore, the length of hospital stay was longer in the fall from height group, likely due to the higher prevalence of multiple traumas in this group.

In our study, most patients who fell from height were male (80.1%), consistent with findings from other studies [2, 10, 12, 24, 25]. A cross-sectional observational study conducted in Sri Lanka also reported a higher occurrence of falls from height among males [12]. Similarly, a retrospective study in South India over 24 months noted a male predominance (74%) in fall from height cases [2]. Another retrospective study in Turkey found that 63.5% of patients who fell from height were male [24]. Additionally, a registry-based descriptive study conducted in Japan indicated that falls from height were more common among males [10]. This gender difference in fall patterns is likely due to variations in risk-taking behavior, as males are more likely to engage in hazardous occupations [25]. In our study, a larger proportion of ground-level fall patients were female, which aligns with findings from other studies [10, 12]. A cross-sectional observational study in Sri Lanka found that approximately 62.5% of ground-level fallers were female [12]. Similarly, a registry-based descriptive study in Japan showed that most ground-level fall patients were female, particularly among the elderly population [10]. This finding may be explained by greater involvement of female in activities such as cleaning, which increases the likelihood of ground-level falls.

Ground-level falls are the most common cause of injuries among elderly individuals. This finding is consistent with the results of the present study and aligns with observations from various other studies. A retrospective observational study in India also demonstrated that ground-level falls are a frequent cause of injury in the elderly population [26]. In our study, falls from height primarily affected individuals in the working-age group. This finding is supported by a study by Mekkodathil et al., which examined the epidemiological and clinical characteristics of fall-related injuries in Qatar and found a higher occurrence of falls from height among the working-age population [27].

Similar to previous studies, the extremities were the most commonly injured body regions in fall-related trauma [28, 29]. A descriptive study at a Level-I trauma center in Saudi Arabia reported that fractures of the lower and upper limbs were the most common injuries [28]. Likewise, a hospital-based study in the United Arab Emirates found that the lower and upper extremities were the most frequently injured body regions [29]. In our study, upper extremity injuries were more prevalent in falls from height, while lower extremity injuries were more common among ground-level falls. This finding aligns with prior research. A retrospective study in India revealed that most patients who fell from height sustained lower limbs injuries [2]. Similarly, a retrospective cross-sectional study in Greece demonstrated that accidental high falls predominantly results in upper limb fractures [30]. Additionally, a retrospective study in Turkey found that upper extremity injuries were more common than lower extremity injuries in falls from height [24]. A registry-based descriptive study in Japan, focusing on the elderly population, reported that lower extremity injuries were more frequent in ground-level falls [10]

We found that hip and thigh injuries were the most common fall-related injuries, followed by elbow and forearm injuries. Femur fractures were more frequent among ground-level fallers than those who fell from height, likely due to factors such as age-related complications and osteoporosis. Studies have shown that even in ground-level falls, osteoporosis increases the risk of femur fractures [31]. In contrast, forearm fractures were more common among patients who fell from height than ground-level fallers. Forearm fractures can result from both high- and low-energy traumas, and research suggests that falls from height are one of the leading causes of these fractures [32].

Conclusion

Baseline and clinical characteristics, injured body regions, and injury types differed between the two fall mechanisms. Falls from height were more common among males and individuals in the working-age group. Patients who fell from heights had more moderate GCS scores and longer hospital stays compared to those who fell from ground-level. They also experienced more upper extremity injuries, forearm fractures and multiple injuries. In contrast, ground-level falls were more frequent among elderly individuals, and were associated

with a higher incidence of lower extremity injuries and femur fractures. Understanding this injury patterns can provide valuable insights for prevention strategies and reducing severe consequences.

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Conflict of Interest Disclosures

The authors declare no conflicts of interest related to this study.

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Declaration of Generative AI and AI-assisted technologies

Not cleared.

Authors' Contributions

P.H conceptualization, methodology, data curation, writing – original draft, writing – review & editing

V.B methodology, formal analysis, writing – review & editing

M.Z supervision, project administration

V.RM methodology, study consultation, writing – review & editing

P.S conceptualization, project administration, supervision, writing – review & editing

All Authors read and approved the final manuscript.

Ethical Statement

This study, conducted by Tehran University of Medical Sciences, was approved by the research ethics committee (Approval ID: IR.TUMS.SINAHOSPITAL.REC.1399.090). Verbal informed consent was obtained from all patients or their substitute decision-makers before participation.

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