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Incidence and circumstances of pediatric fall-related injuries: Which fall variables matter?☆

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ABSTRACT

Background: This study's purpose was to determine if age, fall height, fall mechanism, landing surface, and landing position are associated with injury severity and hospital outcomes among pediatric fall patients.

Methods: A retrospective review was conducted of patients aged ≤18 years who sustained fall-related injuries admitted to an American College of Surgeons verified Level 1 trauma center from January 1, 2006 through December 31, 2015.

Results: Patient age, fall mechanism, landing position, and landing surface were associated with the need for surgery. Patient age, fall mechanism, and landing position were also associated with intensive care unit admissions. Fall mechanism was the only variable associated with injury severity. No variables were associated with the need for mechanical ventilation or mortality.

Conclusions: Patient age, fall mechanism, landing surface, and landing position need to be considered with regard to injury severity and patient outcomes among pediatric fall patients.

Introduction

Unintentional falls account for most non-fatal injuries among children in the United States (U.S.), with almost 3 million fall-related emergency department visits each year.[1] From 2001 to 2014, U.S. children aged four or younger had the highest rate of non-fatal fall-related injuries as compared to all other children.[2] Although most pediatric fall-related injuries are minor, severe injuries such as fractures and head injuries can occur.[3–19] Compared to other fall-related injuries, fatalities among children are more common when the child sustains a head injury.[3–5]

The Resource for Optimal Care of the Injured Patient provided by the American College of Surgeons (ACS) Committee on Trauma (COT) recommends that fall height, along with physiological criteria, be considered during patient triage and trauma team activation.[20] According to the ACS-COT, a stable child who has fallen greater than 10 feet or two to three times their height should be triaged to a trauma center.[20] However, controversy remains with regard to the relationship of fall height and injury severity, with current literature not consistent on whether or not short distance falls can cause serious injuries.[3–19]

In addition to fall height, several other factors such as age, fall mechanism, landing surface, and landing positon have been suggested as contributing factors to fall severity.[3–19] However, most previous fall studies address fall severity in terms of frequency and type of injuries sustained and do not usually include hospital outcomes. The purpose of this study was to determine which of the fall variables mentioned above are associated with injury severity and hospital outcomes among a pediatric population.

Methods

Patient selection and treatment groupings

A retrospective review was conducted of all trauma patients aged 18 years or younger who presented with fall-related injuries

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Table 1
Demographics and injury severity of patients presenting with fall-related injuries.

Parameter[a]	Value
Number of Patients	871 (100%)
Age, years	7.1 ± 12.3
Age group	
Infant (<1 year)	87 (10.0%)
Toddler (1–2 years)	172 (19.7%)
Preschooler (3–5 years)	173 (19.9%)
School age (6–12 years)	231 (26.5%)
Teenager (13–18 years)	208 (23.9%)
Male	561 (64.4%)
Race	
Caucasian	624 (71.6%)
Black or African-American	83 (9.5%)
Other	164 (18.8%)
Injury severity score	5.7 ± 4.8
Glasgow Coma Scale score	14.5 ± 1.9
Level I trauma	37 (4.2%)
Level II trauma	562 (64.5%)

[a] Values presented as the number (%) or mean ± standard deviation.

at an American College of Surgeons-verified Level I trauma center from January 1, 2006, through December 31, 2015. Patients were selected if the primary method of injury was fall-related (Ecodes between 880.0 and 888.9).

Patient age and fall height were categorized into groups before analysis. Age was categorized as: infant (<1 year), toddler (1–2 years), preschooler (3–5 years), school age (6–12 years) and teenager (13–18 years). Fall height was categorized as falls that occurred from 1 to 2 feet, 3–6 feet, 7–10 feet, 11–15 feet, 16–20 feet, and 21 feet or greater.

Table 2
Fall details of patients presenting with fall-related injuries.

Parameter[a]	Value
Number of Patients	871 (100%)
Fall height	
1–2 feet	13/178 (7.3%)
3–6 feet	75/178 (42.1%)
7–10 feet	50/178 (28.1%)
11–15 feet	23/178 (12.9%)
16 –20feet	13/178 (7.3%)
21 feet or greater	4/178 (2.2%)
Fall mechanism	
Playground	130/610 (21.3%)
Furniture	111/610 (18.2%)
Stairs	74/610 (12.1%)
Standing	71/610 (11.6%)
Collision	70/610 (11.5%)
Dropped by caregiver	40/610 (6.6%)
Tree	36/610 (5.9%)
Balcony/roof/window	36/610 (5.9%)
Skateboard	23/610 (3.8%)
Shopping cart	19/610 (3.1%)
Landing surface	
Concrete	88/230 (38.3%)
Ground	82/230 (35.7%)
Hardwood/tiled floor	22/230 (9.6%)
Furniture	14/230 (6.1%)
Glass/sharp object	11/230 (4.8%)
Ice	9/230 (3.9%)
Carpet	4/230 (1.7%)
Landing position	
Head (face/neck)	141/230 (61.3%)
Extremity/hip	67/230 (29.1%)
Trunk (chest/back)	18/230 (7.8%)
Feet	4/230 (1.7%)

[a] Values presented as the number (%).

Table 3
Injury characteristics of patients presenting with fall-related injuries.

Parameter[a]	Value
Number of Patients	871 (100%)
Head injuries	
Concussion	246 (28.2%)
Skull fracture	102 (11.7%)
Loss of consciousness	69 (7.9%)
Subdural hemorrhage	40 (4.6%)
Facial fracture	23 (2.6%)
Subarachnoid hemorrhage	17 (2.0%)
Extradural hemorrhage	15 (1.7%)
Neurologic deficit	12 (1.4%)
Spinal cord injury	12 (1.4%)
Soft tissue injury	393 (45.1%)
Upper extremity fractures or dislocations	191 (21.9%)
Lower extremity fractures or dislocations	100 (11.5%)
Spine fracture	18 (2.1%)
Pelvic fracture	3 (0.3%)
Thoracic injuries	
Lung contusion	5 (0.6%)
Rib fracture	5 (0.6%)
Hemothorax	4 (0.5%)
Pneumothorax	3 (0.3%)
Abdominal injuries	
Spleen	8 (0.9%)
Liver	6 (0.7%)
Renal	4 (0.5%)
Hollow viscous	2 (0.2%)

[a] Values presented as the number (%).

Data collection

Data collected from the trauma registry included: demographics (age, gender, race), Injury Severity Score (ISS), Glasgow Coma Scale (GCS), injury details, hospital outcomes (intensive care unit [ICU] admit and length of stay, mechanical ventilation utilization, operative management, hospital length of stay), disposition at discharge, and mortality. Information regarding falls was provided by a witness to the fall, first responders, or by the patient. Fall variables extracted from the patients' electronic medical records included fall mechanism, height, landing surface, and landing position.

Table 4
Hospitalization details and disposition of patients presenting with fall-related injuries.

Parameter[a]	Value
Number of Patients	871 (100%)
Intensive care unit (ICU) admission	304 (34.9%)
ICU length of stay, days	0.6 ± 1.6
Mechanical ventilation	26 (3.0%)
Mechanical ventilation days	0.1 ± 1.1
Hospital length of stay, days	1.7 ± 2.5
Surgery	247 (28.4%)
Orthopedic	206 (23.7%)
General	26 (3.0%)
Neurosurgery	15 (1.7%)
Blood transfusion	5 (0.6%)
Permanent disability	9 (1.0%)
Disposition	
Home	853 (97.9%)
Rehabilitation/acute care	8 (0.9%)
Other (against medical advice/mental health)	5 (0.6%)
Mortality	5 (0.6%)

[a] Values presented as the number (%) or mean ± standard deviation.

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Table 5
Injury severity and hospital outcomes of patients presenting with fall-related injuries by age group.

Parameter[a]	Injury Severity Score[b]	Intensive Care Unit Admission[c]	Mechanical Ventilation	Surgery[c]	Mortality
Number of Patients	871 (100%)	304 (34.9%)	26 (3.0%)	247 (28.4%)	5 (0.6%)
Age group					
Infant (<1 year)	5.3 ± 4.5	53 (60.9%)	0 (0.0%)	2 (2.3%)	0 (0.0%)
Toddler (1–2 years)	5.3 ± 4.8	72 (41.9%)	6 (3.5%)	33 (19.2%)	2 (1.2%)
Preschooler (3–5 years)	5.3 ± 4.5	54 (31.2%)	5 (2.9%)	59 (34.1%)	3 (1.7%)
School age (6–12 years)	6.2 ± 4.7	71 (30.0%)	5 (2.2%)	90 (39.0%)	0 (0.0%)
Teenager (13–18 years)	6.2 ± 5.4	54 (26.0%)	10 (4.8%)	63 (30.3%)	0 (0.0%)

[a] Values presented as the number (%) or mean ± standard deviation.
[b] Non-parametric test used due to skewed distribution.
[c] Statistically significant difference between subjects.

Table 6
Injury severity and hospital outcomes of patients presenting with fall-related injuries by fall height.

Parameter[a,b]	Injury Severity Score[c]	Intensive Care Unit Admission	Mechanical Ventilation	Surgery	Mortality
Number of Patients	871 (100%)	304 (34.9%)	26 (3.0%)	247 (28.4%)	5 (0.6%)
Height					
1–2 feet	5.4 ± 4.2	5 (38.5%)	0 (0.0%)	3 (23.1%)	0 (0.0%)
3–6 feet	5.2 ± 4.6	29 (38.7%)	1 (1.3%)	19 (25.3%)	0 (0.0%)
7–10 feet	6.2 ± 7.2	18 (36.0%)	3 (6.0%)	6 (12.0%)	1 (2.0%)
11–15 feet	7.8 ± 9.6	7 (30.4%)	1 (4.3%)	4 (17.4%)	1 (4.3%)
16–20 feet	7.0 ± 5.1	5 (38.5%)	1 (7.7%)	3 (23.1%)	0 (0.0%)
21 feet or greater	6.0 ± 3.9	0 (0.0%)	0 (0.0%)	1 (25.0%)	0 (0.0%)

[a] Values presented as the number (%) or mean ± standard deviation.
[b] No statistically significant difference between subjects.
[c] Non-parametric test used due to skewed distributions.

Statistical analysis

Descriptive analyses were presented as frequencies, with percentages for categorical variables and means with standard deviations for continuous variables. Variables used as markers of injury severity included average ISS, ICU admissions, need for operating room, mechanical ventilation requirements, and mortality. To determine the association of these variables with patient age and fall characteristics (mechanism, height, landing surface, and landing position) comparisons were conducted using Chi-square analysis for categorical data and ANOVA for continuous data. Fisher's exact correction was used for comparisons with expected counts less than five in any cell, and nonparametric tests were used for skewed distributions.

All tests were two-sided, and a P value of ≤ 0.05 was considered significant. All statistical analyses were conducted using SPSS release 19.0 (IBM Corp., Armonk, New York). This study was approved for implementation by the Institutional Review Board of Ascension Via Christi Hospital Wichita, Inc. and the University of Kansas School of Medicine – Wichita's Human Subjects Committee.

Results

Among the 871 patients included in the study, most were Caucasian (71.6%, n = 624) and male (64.4%, n = 561) (Table 1). Slightly more than one-fourth of patients were school-aged children (26.5%, n = 231), and 10% (n = 87) were infants. Most patients sustained mild injuries with an average ISS of 5.7 ± 4.8 and GCS of 14.5 ± 1.9.

Among the 20.4% (n = 178) of patient records with a documented fall height, fall height ranged from 1 to 60 feet with most occurring between 3 and 6 feet (42.1%, n = 75) (Table 2). Fall mechanism was documented for 70.0% (n = 610) of patients. Falls from playground equipment (21.3%, n = 130) or furniture (18.2%, n = 111) were the most prevalent. Among the few records that documented landing surface (26.4%, n = 230) and landing position

Table 7
Injury severity and hospital outcomes of patients presenting with fall-related injuries by fall mechanism.

Parameter[a]	Injury Severity Score[b,c]	Intensive Care Unit Admission[c]	Mechanical Ventilation	Surgery[c]	Mortality
Number of Patients	871 (100%)	304 (34.9%)	26 (3.0%)	247 (28.4%)	5 (0.6%)
Fall mechanism					
Playground	4.9 ± 3.1	22 (16.9%)	0 (0.0%)	60 (46.2%)	0 (0.0%)
Furniture	5.4 ± 4.2	44 (39.6%)	5 (4.5%)	32 (28.8%)	2 (1.8%)
Stairs	4.5 ± 4.3	23 (31.1%)	3 (4.1%)	9 (12.2%)	1 (1.4%)
Standing	5.9 ± 4.2	34 (47.9%)	2 (4.2%)	10 (14.1%)	0 (0.0%)
Collision	5.4 ± 3.9	17 (24.3%)	0 (0.0%)	23 (32.9%)	0 (0.0%)
Dropped by caregiver	5.8 ± 3.4	24 (60.0%)	1 (2.5%)	1 (2.5%)	0 (0.0%)
Tree	7.5 ± 8.4	11 (30.6%)	3 (8.3%)	11 (30.6%)	1 (2.8%)
Balcony/roof/window	5.6 ± 5.6	13 (36.1%)	0 (0.0%)	5 (13.9%)	0 (0.0%)
Skateboard	9.5 ± 7.7	7 (30.4%)	2 (8.7%)	10 (43.5%)	0 (0.0%)
Shopping cart	5.2 ± 3.5	11 (57.9%)	0 (0.0%)	2 (10.5%)	0 (0.0%)

[a] Values presented as the number (%) or mean ± standard deviation.
[b] Non-parametric test used due to skewed distributions.
[c] Statistically significant difference between subjects.

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(26.4%, n = 230), most involved a concrete landing surface (38.3%, n = 88) and landing on the head (61.3%, n = 141).

Injury details are presented in Table 3. Common head injuries included concussions (28.2%, n = 246) and skull fractures (11.7%, n = 102). Extracranial injuries were most likely to be soft tissue injuries (45.1%, n = 393) such as contusions, lacerations, or abrasions. Extremity injuries were also common with 21.9% (n = 191) of patients sustaining upper extremity injuries, and 11.5% (n = 100) lower extremity injuries. Injuries to the thoracic (1.9%, n = 17) and abdominal (2.2%, n = 20) regions were rare.

Thirty-four percent of patients (n = 304) were admitted to the ICU, and 3.0% (n = 26) required mechanical ventilation (Table 4). In addition, 28.4% (n = 247) of patient underwent a surgical procedure, with 23.7% (n = 206) of the total population requiring an orthopedic surgery. Most patients were discharged after 1–2 days, and almost all went home (97.9%, n = 853). One percent of patients (n = 9) suffered a permanent disability, and 0.6% (n = 5) died. Among the five deaths, all were caused by a head injury, and all patients were five years or younger.

Compared to other age groups, infants were significantly more likely to be admitted to the ICU (60.9%, n = 53, $P < 0.001$), and school-aged children required the most surgeries (39%, n = 90, $P < 0.001$) (Table 5). There were no significant differences in ISS, the need for mechanical ventilation, or mortality by age group. No differences were also noted between the different fall heights (1–60 feet) with regard to ISS and hospital outcomes (Table 6).

Differences by fall mechanism were noted regarding ISS, ICU admission, and the need for surgery (Table 7). Patients who experienced skateboard falls had the highest ISS (9.5 ± 7.7, $P = 0.000$), whereas patients who experienced a fall from stairs had the lowest ISS (4.5 ± 4.3, $P = 0.000$). Compared to other fall mechanisms, children who were dropped were more likely to be admitted to the ICU (60.0%, n = 24, $P < 0.001$), and those who experienced playground falls were more likely to need surgery (46.2%, n = 60, $P < 0.001$). There were no differences regarding mechanical ventilation requirements or mortality by fall mechanism.

Type of landing surface was only associated with the need for surgery; those who landed on glass or a sharp object (72.7%, n = 8, $P = 0.000$) were more likely to need surgery as compared to the other landing surfaces (Table 8). Landing position, however, was associated with both ICU admission and the need for surgery (Table 9). Children who landed on their head required ICU admission the most (49.6%, n = 70, $P < 0.001$), and those who landed on an extremity/hip required the most surgeries (76.1%, n = 51, $P < 0.001$). There were no other significant differences in injury severity or patient outcome by landing position.

Comments

To our knowledge, this is the first study that has specifically evaluated ISS and hospital outcomes among pediatric fall patients. Previous literature has suggested that type and severity of fall-related injuries are influenced by various factors, most notably fall height.[3–19] A study by Harris et al. evaluated injuries associated with pediatric window falls demonstrating that children who fell ≥3 stories (≥24.1 feet) were more likely to sustain a fracture, to be hospitalized, or to die when compared to children who had fallen from lower heights.[4] However, other studies also indicate that severe injuries can occur at fall heights of less than 10 feet.[5–12] In comparison, the current study suggests there was no association between fall height (1–60 feet) with regard to ISS or patient hospital outcomes.

In addition to fall height, an association has been reported between the age of the child who fell and injury severity.[3,4,9-11-13,19] In the current study, patients of different age groups experienced similar ISS, despite differences in ICU admissions and the need for surgery. ICU admission was more common among infants, and school-aged children required the most surgeries as compared to the other age groups. These differences may be attributable to differences in age-related injury patterns and fall characteristics.[3,9–11,13,19] For example, Ibrahim et al. noted that infants are significantly more likely to be admitted for low height falls and

Table 8
Injury severity and hospital outcomes of patients presenting with fall-related injuries by landing surface.

Parameter[a]	Injury Severity Score[b]	Intensive Care Unit Admission	Mechanical Ventilation	Surgery[c]	Mortality
Number of Patients	871 (100%)	304 (34.9%)	26 (3.0%)	247 (28.4%)	5 (0.6%)
Landing surface					
Concrete	7.7 ± 7.1	36 (40.9%)	6 (6.8%)	23 (26.1%)	1 (1.1%)
Ground	5.9 ± 5.1	25 (30.5%)	1 (1.2%)	24 (29.3%)	0 (0.0%)
Hardwood/tiled floor	5.8 ± 4.8	13 (59.1%)	1 (4.5%)	1 (4.5%)	0 (0.0%)
Glass/sharp object	8.2 ± 5.7	3 (27.3%)	0 (0.0%)	8 (72.7%)	0 (0.0%)
Furniture	7.1 ± 4.2	8 (57.1%)	2 (14.3%)	3 (21.4%)	1 (7.1%)
Ice	5.1 ± 2.4	2 (22.2%)	0 (0.0%)	3 (33.3%)	0 (0.0%)
Carpet	9.5 ± 6.6	2 (50.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)

[a] Values presented as the number (%) or mean ± standard deviation.
[b] Non-parametric test used due to skewed distributions.
[c] Statistically significant difference between subject.

Table 9
Injury severity and hospital outcomes of patients presenting with fall-related injuries by landing position.

Parameter[a]	Injury Severity Score[b]	Intensive Care Unit Admission[c]	Mechanical Ventilation	Surgery[c]	Mortality
Number of Patients	871 (100%)	304 (34.9%)	26 (3.0%)	247 (28.4%)	5 (0.6%)
Landing position					
Head (face/neck)	5.9 ± 5.8	70 (49.6%)	9 (6.4%)	9 (6.4%)	3 (2.1%)
Extremity/hip	5.5 ± 2.9	3 (4.5%)	0 (0.0%)	51 (76.1%)	0 (0.0%)
Trunk (chest/back)	7.0 ± 8.3	7 (38.9%)	0 (0.0%)	4 (22.2%)	0 (0.0%)
Feet	7.3 ± 3.6	1 (25.0%)	0 (0.0%)	2 (50.0%)	0 (0.0%)

[a] Values presented as the Number (%) or mean ± standard deviation.
[b] Non-parametric test used due to skewed distributions.
[c] Statistically significant difference between subjects.

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sustain more frequent skull fractures than toddlers.[9]

In the current study, fall mechanism was the only variable associated with injury severity; those who fell from stairs had the lowest ISS, and those who fell from a skateboard had the highest ISS. Contributing factors to the higher injury severity of skateboard falls might include a higher fall velocity due to forward motion, the likelihood of impact with a concrete surface, and lack of protective equipment use. A lower ISS among stair falls could be explained by lower momentum generated during the fall and landing on a carpeted surface.[18]

Fall mechanism was also associated with ICU admit and the need for surgery. Children who were dropped were more likely to be admitted to the ICU, and children who fell from playground equipment were more likely to have surgery as compared to other fall mechanisms. Although, we did not break down fall mechanism by age it would be interesting to see how many children who were dropped were in fact infants and whether the high number of ICU admits among this group is related more to patient age than fall mechanism. Previous pediatric fall studies that addressed fall mechanism focused on differences in injury patterns, noting that different falls can result in different types of injuries.[9,13–15,19] In Pomerantz et al.'s study of furniture and stairway falls, for example, children who fell downstairs had more frequent head injuries when compared to children who fell from furniture.[15]

Previous studies have also suggested that the type of landing surface involved in a fall can affect injury severity, with harder and less elastic surfaces resulting in more serious injuries than soft surfaces.[3,4,8,16,19] For instance, Hughes et al. noted an increased likelihood of a skull fracture/intracranial injury when a child landed on a wood surface versus a carpeted surface.[19] However, the current study suggests that landing surface is not associated with injury severity. This is consistent with studies by Thompson et al. and Johnson et al. which demonstrated that impact surface was not associated with injury severity.[17,18]

Along with landing surface, landing position during a fall has been suggested as a possible determining factor in injury patterns and injury severity.[3,17,19] For instance, the American Academy of Pediatrics noted fall-related fatalities among children occur when children sustain head injuries, mainly caused by the child striking the head during the fall.[3] In contrast, landing feet first in short distance falls has been associated with a lower risk of head injuries.[16] In the current study, no differences were found concerning landing surfaces and injury severity.

Most patients in the current study were school-aged children who experienced falls less than 6 feet. Although most injuries were not severe, severe injuries, as determined by ISS and hospital outcomes, still occurred. Our findings suggest that fall mechanism was associated with ISS and, age, landing surface, and landing position were associated with hospital outcomes. Fall height was not found to be associated with ISS or hospital outcomes, which contradicts what several previous studies have demonstrated.[3,4,13–19] With these findings, additional prospective multicenter studies should be carried out to determine whether fall height should still be used as criteria for trauma team activation and whether additional factors need to be considered.

This study had several limitations. First, our findings are limited to a single trauma center and by the retrospective study design. Despite these limitations, our findings do contribute to the current childhood fall literature by suggesting that other fall variables, and not just fall height, need to be addressed when considering injury severity and patient outcomes. A second limitation is the lack of documented fall details such as landing surface and landing positions recorded in patients' charts. In addition, fall heights were only estimates and not actual measures, which could cause an over or underestimation of the actual fall distances. Findings may also underestimate the actual number of fall-related injuries among our study population since children who were treated and released in the emergency department or treated elsewhere were not included.

Conclusions

Research suggests that fall height is associated with injury severity; greater fall height is attributed to more severe injuries and higher rates of mortality. However, findings from this study suggest that fall heights of 1–60 feet are not associated with injury severity or hospital outcomes. Other factors that need to be considered regarding injury severity and patient outcomes include patient age, fall mechanism, landing surface, and landing position.

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