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Injury epidemiology of inflatable amusement devices: a level I trauma center experience

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Abstract

Objectives The incidence of pediatric injuries involving inflatable amusement devices (IADs) has increased. This study aimed to evaluate the epidemiology of these injuries treated at a level 1 trauma center. We hypothesized that there would be a yearly increase in injuries across the study period.

Methods After Institutional Review Board (IRB) approval, a retrospective chart review was conducted of pediatric patients (< 18 years-old) treated at Loma Linda University Children's Hospital (LLUCH) for IAD-related injury between January 1, 2014, and June 30, 2024.

Results Forty-nine patients were treated. An average of 4.4 patients were treated for IAD-related injuries each year. A positive relationship between injury rate and year was not observed in the cohort ($p = 0.102$). The median injury severity score (ISS) was 4. Forty-three patients suffered one or more bone fractures (88%) and 35 required surgical intervention (71%).

Conclusions Our cohort did not show a significant increase in the incidence of pediatric IAD-related injuries over time. The injury burden in our study was high, with 71% of patients treated surgically. This might be due to the high proportion (78%) of patients transferred from outside institutions for definitive treatment.

Keywords Pediatric trauma, Inflatable amusement device, Bounce house

Introduction

Over the last two decades, pediatric injuries due to inflatable amusement devices (IADs) have increased substantially. These structures include devices such as bounce houses, slides, and ball pits. A report from 2022 estimated that a total of 159,569 pediatric injuries involving IADs in the US occurred between 2000 and 2019 [1]. Additional reports cite a yearly average of 5.3 injuries per 100,000 children in the US, with the annual rate increasing 15-fold from 1995 to 2010 [2, 3].

Few publications describe the epidemiology of IAD-related pediatric trauma at the hospital level. Of these, only one reports injuries specific to a level 1 trauma center [4]. Additional reports are needed to support safe practices, promote parental education, and guide regulatory standards. The purpose of this study was to evaluate the rates of IAD-related injuries in our region. We aimed to determine if there was an increasing rate of injury treated at a level I trauma center over the past ten years and to generate safety recommendations based on injury patterns. We hypothesized that a yearly increase in

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IAD-related injuries would be apparent across the study period.

Materials and methods

After IRB approval (#5240520), a retrospective chart review of the pediatric trauma database was conducted on patients under 18-years-old presenting to LLUCH with IAD-related injury between January 1, 2014, and June 30, 2024. Patient charts were screened for cause of injury keywords including 'bounce house', 'inflatable house', 'bouncy house', bouncer', and 'bouncer with slide'.

Data including demographics, type of IAD, injury details, hospital management and disposition were collected to analyze temporal trends, patient attributes and injury severity. Temporal trends were assessed by looking at the ten-year period between January 01, 2014, and December 31, 2023, to enable annual and seasonal comparison. All other demographics were abstracted from the entire 10.5-year study window.

Regression analysis was used to test the hypothesis that a yearly increase in IAD-related injury would be observed. Chi-Squared and Mann Whitney tests were used to analyze differences in surgery rate and injury severity by age group. Data analysis was performed using JASP (version 0.19.1.0) and Microsoft Excel (Excel 2024). P values less than 0.05 were considered statistically significant.

Results

Patient demographics

A total of 53 patients were screened into the initial patient pool. Of these, 49 patients fit the full criteria for the study; the remaining four patients did not have injuries directly related to the IADs defined in the methods. Of the 49 patients seen at LLUCH for IAD-related injuries from January 1, 2014, to June 30, 2024, 57% (28/49) of the patients were male. The greatest number of injuries occurred in three-year-old children (9), followed by eight-year-old children (7). 55% (27/49) of patients injured were six years old and under. Of these patients, 21 (77.8%) were treated surgically. Of the 22 patients aged seven and older, 14 (63.6%) required surgery. Post hoc chi-squared analysis did not reveal a significant difference between these two frequencies ($p = 0.276$). The age distribution of patients with IAD-related injury is given in Fig. 1.

Temporal trends

For the ten-year period analyzed from January 1, 2014, to December 31, 2023, there was a mean of 4.4 (SD 1.02) patients treated for IAD-related injuries per year. The yearly distribution is illustrated in Fig. 2, with no apparent relation between injury rate and year identified in this cohort. The best fit line equation for the overall trend is $y = -0.194x + 5.467$. Linear regression analysis yielded a p-value of 0.102 for the slope, therefore the null hypothesis was not rejected. Analysis produced an R value of 0.546, and an R^2 value of 0.298, indicating poor predictive power. The Q-Q plot data points were relatively

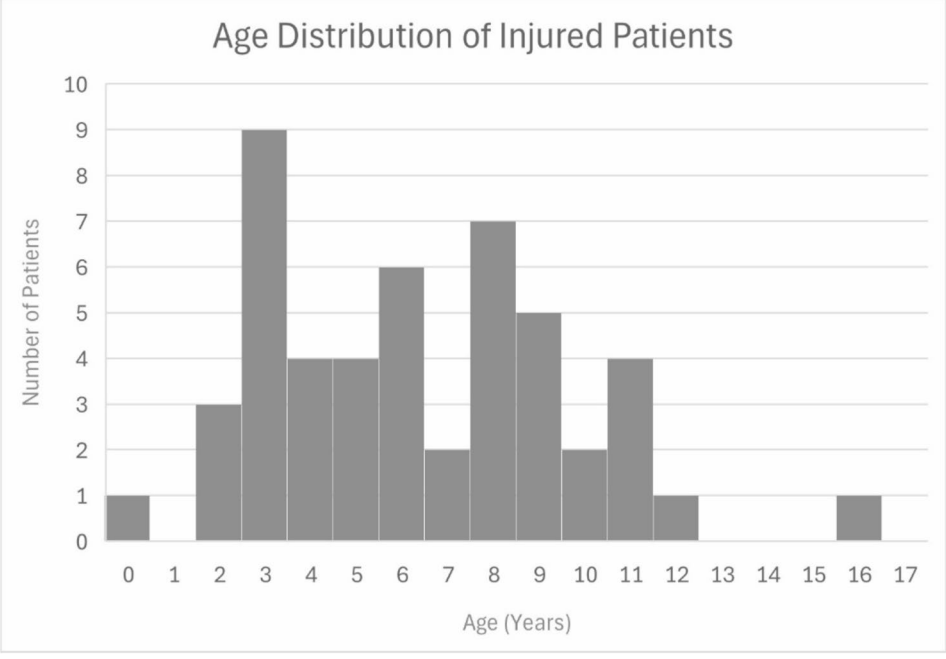

Fig. 1 Age distribution of injured patients treated at LLUCH between January 1, 2014, and June 30, 2024

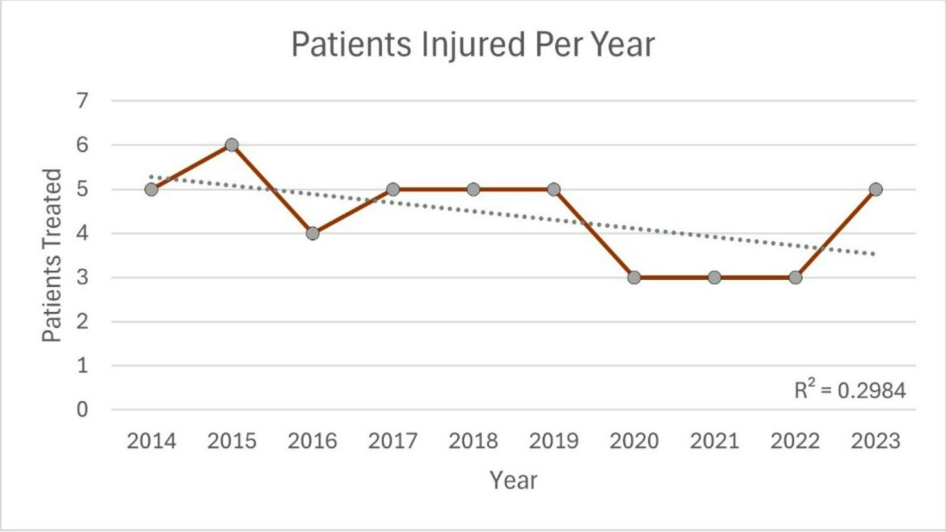

Fig. 2 Distribution of injuries per year treated at LLUCH between January 1, 2014, and December 31, 2023

Table 1 Summary of injury attributes and severity

Injury severity score				
1–5	6–10	11–15	≥ 16	
37 (76%)	8 (16%)	1 (2%)	3 (6%)	
Injury type				
Bone Fracture	Dislocation	Cervical Strain	Head Trauma	
43 (88%)	2 (4%)	4 (8%)	9 (18%)	
Injured body region				
Head	Neck	Superior limb	Trunk	Inferior Limb
9 (18%)	3 (6%)	30 (61%)	2 (4%)	8 (16%)
Injury mechanism				
Fall	Crush	Collision	Airborne bouncer	Unknown
37 (76%)	8 (16%)	2 (4%)	1 (2%)	1 (2%)

consistent with the best fit line. However, the partial regression plot showed inconsistent spread around the best fit line, suggesting unequal data variance. The highest number of patient encounters occurred in March (6), and the least number occurred in July (1).

Injury attributes and severity

The median Injury Severity Score (ISS) was 4, with a range of 1 to 26. Patients aged six and under had an average ISS of 5.6, whereas patients ages 7–17 had an average ISS of 7.1; post hoc analysis of ISS between these age groups did not show statistical significance ($p = 0.569$). 88% of patients suffered one or more bone fractures ($n = 43$); of these, displaced supracondylar fracture of the humerus was the most common single diagnosis. The most common mechanism of injury included fall from within or out of the IAD (75%; 37/49), followed by crush injuries involving two or more participants (8/49). 18% (9/49) of patients suffered head trauma. Of these patients, five sustained an intracranial hemorrhage and/or hematoma. A summary of injuries treated between January 1, 2014, and June 30, 2024, is given in Table 1; injury type and injured body region are listed as counts per cohort and are not mutually exclusive. Fracture counts per bone occurring in the same timeframe are detailed in Fig. 3.

Hospital course

Most patients stayed at the hospital for one day or less (77%; 38/49), required surgical intervention (71%; 35/49), and were discharged home (98%; 48/49) with temporary disability and expectations for full recovery (92%; 45/49). Of the 35 patients requiring surgical intervention, 91% (32) received open or closed reduction with skeletal fixation for limb fractures. Of the 21 patients aged six and under requiring surgery, 20 received orthopedic surgery and one received neurosurgical intervention only. Of the 14 patients aged 7–17, 11 required orthopedic surgery only, one required ENT surgery only, one required neurosurgery only, and one required both neurosurgery and dental surgery. The hospital course summary for patients treated between January 1, 2014, and June 30, 2024, is given in Table 2. Surgical interventions are included in

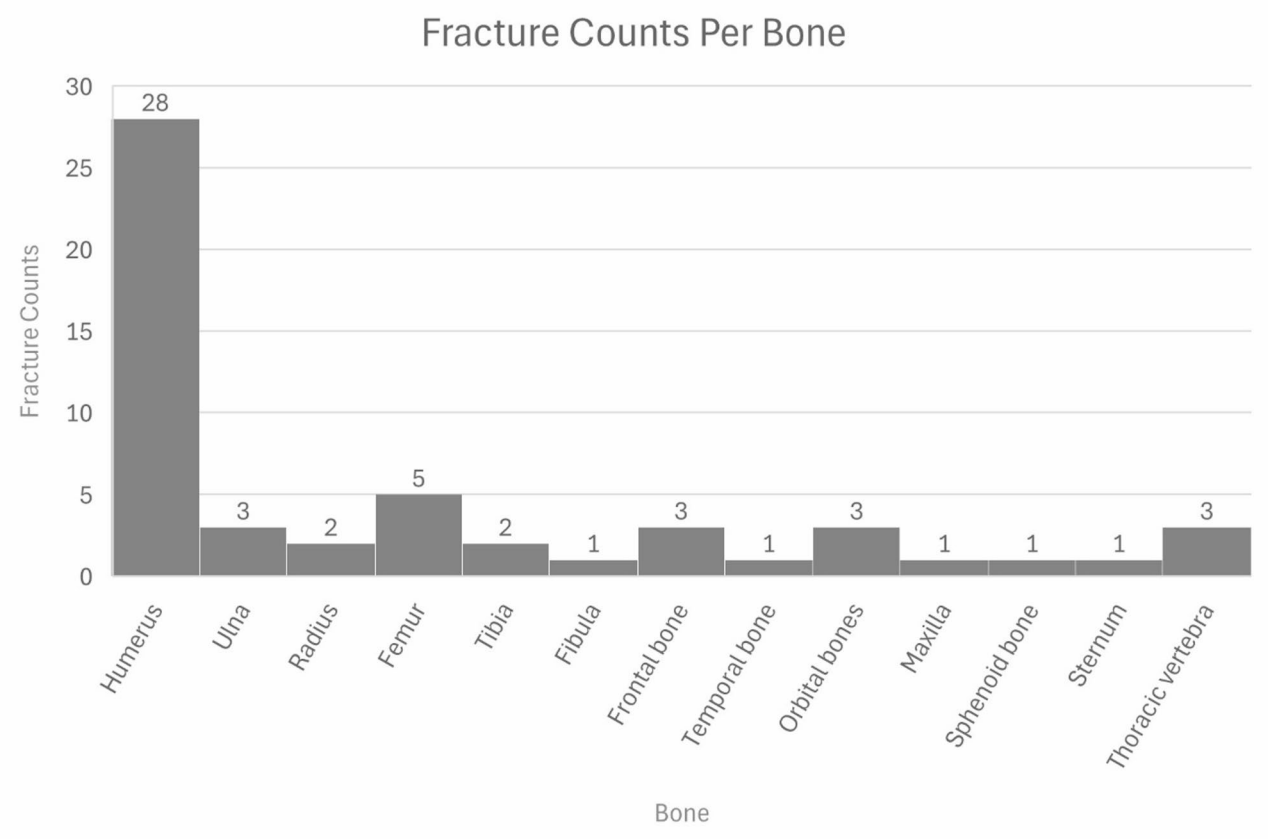

Fig. 3 Fracture counts per bone in patients treated at LLUCH between January 1, 2014, and June 30, 2024

Table 2 Hospital course summary

Length of stay					
≤ 1 day	2 days	3 days	4 days	6 days	24 days
38 (78%)	5 (10%)	2 (4%)	2 (4%)	1 (2%)	1 (2%)
Surgical intervention					
Orthopedic surgery	Neurologic surgery		Otolaryngologic surgery		Dental surgery
31 (63%)	3 (6%)		1 (2%)		1 (2%)
Disability at discharge					
Previous level of function		Temporary disability, expected full recovery		Moderate disability, expected ability for self-care	
3 (6%)		45 (92%)		1 (2%)	
Rate of transfer from outside institutions					
Transfer patients			Non-transfer patients		
38 (78%)			11 (22%)		

the table as procedure counts per 49 patients; surgical procedures are not mutually exclusive.

Discussion

We hypothesized that there would be a positive temporal trend, with IAD-related injuries increasing each year based on patterns noted in other publications. We did not reject the null hypothesis given the results of linear regression analysis. Ferro et al. reported an increasing occurrence of inflatable bounce-related injuries seen at an Italian pediatric emergency department during the years 2002-2013 [5]. Analysis of yearly averages showed a dramatic increase in cases during the study period, with rates of injury at 1.4/1000 in 2002 and 24.4/1000 in 2013. McFaull et al. noted a sharp increase in IAD-related pediatric injuries treated at emergency departments in Canada, with a six-fold increase between 2000 and 2009 [6]. Thompson et al. noted a similar increase in injuries in the US, with a 15-fold injury rate increase between 1995 and 2010 [3]. Our finding of a stable injury rate between the

years 2014–2023 does not conflict with these studies and is consistent with a recent publication exploring the epidemiology of inflatable jumping amusement-related injury in the US over a 20-year time range. Vukcevich et al. noted an increasing trend in injury rates between 2000 and 2015 but discovered that this trend did not clearly continue from 2015 to 2019 [1]. Given these findings, we conclude that while IAD-related injury rates increased substantially from 1995 to 2015, we did not find local evidence to suggest that injury rates have increased from 2015 to 2023.

A clear monthly or seasonal pattern of injury was not apparent from our data. This contrasts with other reports featuring higher injury counts in the spring and summer. Corominas et al. analyzed inflatable play structure injuries presenting to a hospital in Spain and found an increased rate of injury from May to December, and a decreased rate from December to March [2]. Similarly, Thompson et al. found that most inflatable bouncer-related injuries occurring in the United States fell between the months of April and October with a peak in June [3]. Our observation may be explained by the unique weather patterns of Southern California, where the climate is rather mild year-round (mean max temperature of 78 degrees Fahrenheit annually; mean rainfall of 12.72 inches annually) [7]. Regional considerations are important as the use of IADs in high temperatures carries risk for heat-related illness [8]. No heat-related injuries were identified in our cohort.

The increased male proportion identified in our cohort is consistent with other publications [1–3], and children ages six and younger suffered a disproportionate number of injuries (55%; 27/49). This is similar to findings by Vukcevich et al. showing that patients between the ages of two and six represent a disproportionately high number of injuries (47.2%; estimated 75,346/159,569), with children in this age range more likely to suffer a fall from an inflatable play structure than older children [1]. Surgical intervention was more likely to be indicated in our cohort in patients aged six and younger; however, this observation was not statistically significant.

Our study yielded a high proportion of patients suffering serious injuries, with 88% (43/49) of patients presenting with bone fracture(s) and 71% (35/49) of patients requiring orthopedic, neurosurgical, otolaryngologic, and/or dental surgical interventions. These figures are substantially higher than those reported in other case series and nation-wide studies in the US and Canada [1, 3, 4, 6]. LLUCH is a level I pediatric trauma center, and a major referral center for a significant geographic region of southern California. The high proportion of serious injuries may be explained in part by the high number of patients in the cohort that were transferred from outside institutions to LLUCH for definitive care (78%; 38/49), allowing less serious injuries to be appropriately treated by community hospitals.

Table 3 Recommendations for safe use of inflatable amusement devices (IADs)

- Always ensure adult supervision with IAD use.
- Always anchor the IAD per device guidelines, regardless of fair-weather conditions.
- Never use IADs in adverse weather conditions.
- Avoid use of IADs by children younger than six-years-old.
- Avoid mixing IAD user ages and weights.
- Keep the number of IAD co-users to a minimum.
- Avoid situations conducive to falls (e.g., climbing, unsafe use of slide, failing to close bounce house entrances).
- Avoid placement of IADs over concrete.
- Seek immediate medical attention for all concerning fall mechanisms.

Our patients suffered primarily from upper extremity injuries with supracondylar humerus fracture being the most frequent. Corominas et al., Avoian et al., and Ferro et al. reported similar trends, with supracondylar humerus fracture rates between 17.5% and 35.8% in their cohorts [2, 4, 5].

In an analysis of wind-related bounce house incidents over a 21-year period, Knox et al. found a total of 132 incidents worldwide featuring 479 injuries and at least 28 fatalities [9]. In our study, the patient with the most extensive injuries occurred after the inflatable bouncer became airborne and crashed into a nearby structure. Injuries in this situation included skull fractures associated with intracranial hemorrhage, facial fractures and chest wall trauma. Treatment involved a month-long admission and eventual discharge to an acute rehabilitation facility. The analysis by Knox et al. and this patient encounter highlight the importance of staking inflatable bouncers down effectively even on temperate days. In their analysis of weather associated with wind-related incidents, Knox et al. found that severe weather phenomena are largely missing from these events, and that most accidents occurred on days of seemingly fair weather [9].

The United States Consumer Product Safety Commission (CPSC) has published guidelines for residential and commercial use of inflatable amusement rides that are intended to complement instructions for specific products. These guidelines are available online as an open-access document [10]. Recommendations for the safe use of inflatable amusement devices are proposed by multiple publications and are summarized in Table 3 with our experience [2, 4, 9, 11–13].

There are limitations to this retrospective chart review. Because this study featured data from a single institution that functions as a trauma referral center, our findings may not fully capture all regional IAD-related injury trends. It is possible that injury incidence in the region is higher than observed, and that a number of lesser injuries were treated at local facilities, not needing a tertiary center for management.

Conclusion

The incidence of inflatable amusement device-related injuries has increased and remains elevated. Injury rates were relatively stable at our level I trauma center from 2014 to 2023. We discovered a high rate of serious injury, with most of our patients requiring surgical intervention. Careful adherence to safety recommendations and close guardian supervision will mitigate these dangers in children.

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J.L., J.A., and J.M. wrote the main mansucript text. J.L. prepared all figures and tables. A.M., A.R., B.F., J.M., M.K., and D.M. provided substantial edits. All authors reviewed the manuscript.

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Data is provided within the manuscript.

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Not applicable.

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