



## Original Contribution

## Injuries associated with hoverboard use: A review of the National Electronic Injury Surveillance System

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## ABSTRACT

**Introduction:** Hoverboards have become popular since they became available in 2015. We seek to provide an estimate of the number of injuries in the United States for 2015 and 2016, and to evaluate differences between adult and pediatric injury complexes.

**Methods:** We performed a retrospective analysis of the National Electronic Injury Surveillance System (NEISS) from January 1, 2015 to December 31, 2016. Using the weighted design of the NEISS, a nationally representative sample could be determined.

**Results:** During the 2 year period, there were 24,650 hoverboard related injuries (95% confidence interval [CI], 17,635–31,664) in the US. The average age was 20.9 years old. There were 15,134 pediatric injuries (95%CI 9980–20,287) and 9515 adult injuries (95%CI 7185–11,845). Female patients comprised 51.2% of the sample. The upper extremity was the most common region injured [13,080 (95% CI 8848–17,311)] and fracture was the most common type of injury [10,074 (95% CI 6934–13,213)]. Hoverboard injuries increased from 2416 (95% CI 575–4245) in 2015 to 22,234 (95% CI 16,446–28,020) in 2016. Pediatric patients were more likely to be injured in the upper and lower extremity when compared to their adult cohort ( $p = 0.0031$ ). Six percent of the cohort [1575 (95% CI 665–2485)] sustained critical injuries with pediatric patients being at 1.46 times higher risk for life threatening injuries.

**Conclusion:** Emergency department (ED) visits for hoverboard related injuries appear to be increasing. Pediatric patients are more at risk for hoverboard related injuries than adults and almost 6% of ED visits involved critical injuries, highlighting that hoverboards may be more dangerous than previously recognized.

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## 1. Introduction

Self-balancing motorized scooters, commonly referred to as hoverboards, have become increasingly popular in the US since becoming commercially available in 2015 [1]. An estimated 2.5 million hoverboards have been sold since 2015, totaling almost 1 billion in sales [2]. Even with half a million hoverboards recalled in 2016 due to the malfunctioning lithium batteries [3], the hoverboard market is projected to surpass \$1.8 billion by 2021 [4]. This growth is due to an expanding youth population, increasing adoption of hoverboards for personal mobility, and recreational activities [4].

There are growing concerns of the safety of hoverboards, based on several problems identified with their use. Poorly manufactured lithium batteries can create a fire hazard and subsequent injuries due to burns

have been described [3, 5, 6]. Likewise, several small single-institution pediatric-based studies have evaluated injury complexes related to hoverboards, highlighting that falls are the most common mechanism of injury resulting in primarily orthopedic injuries [5, 7, 8, 9, 10]. Recently, guidelines for rider protection have been developed, including the use of helmets, knee pads, elbow pads, wrist guards, and shoes [11], but compliance with these guidelines remains unknown. Safety concerns prompted California to require riders be at least 16 years old and wear a helmet, while New York City banned hoverboards altogether [11]. Despite these recommendations and legislative actions, numerous videos on social media highlight individuals riding hoverboards without protective gear sustaining falls. A recent multi-community hospital emergency department (ED) based study suggested that children and adults were injured at similar rates, but pediatric patients were more likely to suffer from a fracture [12].

While there have been several small single-institution studies on the injury complex of hoverboard-injured patient, there has yet to be a national representative sample to evaluate these injuries in pediatric and

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adult populations. Since hoverboard's became commercially available in the US in 2015, we seek to provide an estimate of the number of injuries nationwide in the for 2015 and 2016 and to evaluate differences between adult and pediatric injury complexes.

## 2. Methods

We performed a retrospective analysis using data obtained from the United States Consumer Protection Safety Commission's National Electronic Injury Surveillance System (NEISS) from January 1, 2015 to December 31, 2016 regarding injuries associated with hoverboard use.

The NEISS receives reports from 101 EDs throughout the U.S. regarding injuries related to consumer products which then employs a population-based algorithm to provide the national incidence of discrete injuries [13]. Lacking a specific code for hoverboards, the NEISS database includes hoverboards in the powered scooters and skateboards code 5042 [14]. The NEISS database provides sex, age, race, injury diagnosis, body part injured, disposition, and a single sentence narrative for each reported injury. Each narrative provides a brief description of the injury, allowing injuries attributed to the use of hoverboards to be distinguished from those related to powered scooters and skateboards. Inclusion into the study requires that the patient sustained an injury from a hoverboard. Hoverboard injuries were identified and included in this study by any mention of "hoverboard," "hooverboard," "hover board," "hoover board," "hoverbaord," "hooverbaord," "hover boad," "hoverboard," or "hoverbrd" within the narrative, allowing for spelling errors and typos. Cases that did not contain any obvious spelling variation of hoverboard were excluded from the study. Likewise, patients that did not have an injury associated with a hoverboard were excluded. All patients under the age of 18 were defined as pediatric patients.

### 2.1. Statistical analyses

Patient demographics and injury characteristics were reported as mean  $\pm$  standard deviation for continuous variables, and as frequency (percent) for the categorical variables. Weighted analyses were used

to provide a nationally representative sample of hoverboard related injuries in U.S. EDs from 2015 to 2016. The standard errors of the weighted estimates were used to compute 95% confidence intervals (CIs) for the estimated number of injuries to correct for any sampling errors. Wald chi-square test was used to compare pediatric and adults hoverboard-related injuries. Association between critical injury and age group was assessed using a logistic regression analysis estimating odds ratios (ORs) and 95% CIs. All analyses were performed in SAS 9.4 (SAS Institute, Cary, NC), and all  $p$ -values less than  $\alpha = 0.05$  were considered statistically significant.

## 3. Results

During 2015 and 2016 there were 734,326 entries for the code 5042. In this dataset, there were 743 encounters for hoverboard related injuries, leading to 24,649 estimated patients nationally (95% CI 17,635–31,664). About 91.4% of these injuries were sustained in 2016, while only 8.6% were observed in 2015 (Table 2). The national mean age estimate in this population was 20.89 years old (95% CL 18.66–23.13) (Table 1). The oldest patient was 75 years old and the youngest patient was 1 year old. Over these two years, most cases involved pediatric patients (61.4%) while adults accounted for 38.6%; these two proportions are statistically different with  $p$ -value  $< 0.001$ . There was a near equal distribution of sexes, with female patients representing 51.2%. Women had less observation in our sample but had a larger national estimate due to the patient weighting that is inherent to the NEISS. While 94.8% of patients were treated and released from the ED, 3.3% of patients were admitted, and about 1.9% were observed, transferred, or left without treatment.

The most common injury was fracture (40.9%) followed by contusion/abrasion (18.1%), strain/sprain (13.9%), and internal injury (6.3%) (Fig 1). Head injuries were coded in several different ways in the NEISS under internal injury, concussion, and contusion. Other injuries present were coded as "other" (8.7%), laceration (6.4%) dislocation (0.8%), hematoma (0.5%), burns (0.3%), and anoxia (0.3%).

**Table 1**

Characteristics of individuals with hoverboard injuries (N = 743) for 2015 and 2016.

	N. observations	National estimate (95% CL)	Percentage of national estimate
Total	743	24,650 (17,635–31,664)	100%
Age, mean (SD)	17.96 (13.47)	20.89 (18.66–23.13)	–
Age group			
Pediatric	519	15,134 (9980–20,287)	61.4%
Adult	224	9515 (7185–11,845)	38.6%
Sex			
Male	375	12,026 (8183–15,868)	48.8%
Female	368	12,624 (8864–16,383)	51.2%
Race			
White	239	8830 (5815–11,844)	35.8%
Black	170	3555 (1691–5420)	14.4%
Unknown	279	10,762 (3566–17,958)	43.7%
Other	55	1503 (567–2439)	6.1%
Injury disposition			
Treated and released	701	23,357 (16,647–30,067)	94.8%
Hospitalized	28	813 (286–1340) <sup>a</sup>	3.3%
Transferred, held for obs., or left without treatment	14 <sup>a</sup>	480 (148–813) <sup>a</sup>	1.9%
Body part injured			
Lower extremity	151	5451 (3669–7234)	22.1%
Upper extremity	393	13,080 (8848–17,311)	53.1%
Head/Neck	142	3914 (2384–5444)	15.9%
Thoracoabdominal/Trunk	55	2174 (1409–2939)	8.8%
Injury type			
Fracture	302	10,074 (6934–13,213)	40.9%
Contusion/Abrasion	121	4464 (2617–6311)	18.1%
Sprain/Strain	102	3437 (2046–4828)	13.9%
Internal injury	57	1544 (640–2449)	6.3%
Concussion	27	953 (328–1579) <sup>a</sup>	3.9%

<sup>a</sup> When the number of observation is less than 20 or the national estimate is less than 1200 then the estimate is not reliable according to NEISS.

**Table 2**  
Comparison of ED visits between 2015 and 2016 for hoverboard related injuries.

Year	N. observations	Estimate	National estimate (95% CL)
2015	64	2416	575–4256
2016	679	22,234	16,446–28,020

During 2016, it is estimated that 22,234 injuries were related to hoverboard use (95% CL 16,446–28,020), while in 2015 it was lower, at 2416 injuries (95% CL 575–4256). During 2015 and 2016, there were an estimated 15,134 (95% CL 9980–20,287) pediatric patients and 9515 (95% CL 7185–11,845) adult patients with hoverboard related injuries.

The predominant anatomic region injured was the upper extremity (53.1%) followed by the lower extremity at 22.1% and head and neck injuries at 15.9% (Fig 2). Most upper extremity injuries involved the lower arm (16.2%), wrist (16.3%), and elbow (7.9%). For supraclavicular injuries, we found that 93% involved head and facial injuries. There was no remarkable distribution among the lower extremity injuries between the leg, shin, or foot.

### 3.1. Pediatric vs adults anatomic injury location

There were significant differences between the distribution of body regions injured when comparing injuries in pediatric and adult patients ( $p = 0.003$ ). The proportions of thoracoabdominal injuries were significantly higher in adults (15.6%) than in pediatrics (4.6%) ( $p = 0.02$ ). Furthermore, adults are almost 4.3 times (95%CI = 2.04–8.90) more likely to experience an injury to the thoracoabdominal region compared to the pediatric cohort (Fig 3). There was no statistically significant association between pediatric and adults in terms of sex, race, and injury disposition.

### 3.2. Pediatric vs adult fracture analysis

From 2015 to 2016, in the NEISS database, there were 77 cases of fractures in adults and 225 cases of fractures in the pediatric cohort (Table 3). These injuries represent an estimated 3257 (95% CL 2301–4213) and 6817 (95% CL (4351–9283)) fracture related injury in the national sample, respectively. Although the proportion of pediatric fracture-related injury (45.0%) was higher than that of the adults (34.2%), the difference was not statistically significant ( $p = 0.65$ ).

### 3.3. Critical injuries in adult and pediatric patients

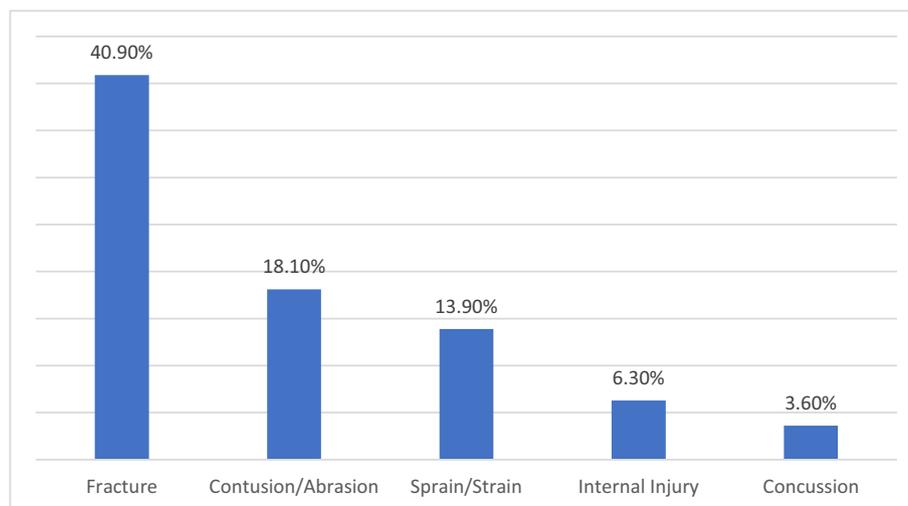
We compared the difference between adults and pediatric patients regarding critical injuries. We defined a critical injury within the NEISS database as an internal injury or anoxia. In 2015 and 2016, there were an estimated total of 1575 (95% CI 665–2485) critical injuries with 1094 (295–1893) or 7.23% among all pediatric injuries, and 481 (150–812) or 5.05% among all adult injuries. The results showed no statistically significant association between age groups and critical injury ( $p = 0.37$ ), even though the nominal odds ratio demonstrated that pediatric patients were at a 1.46 times higher risk for life threatening injuries (OR = 1.464, 95% CI = 0.63–3.36), but this association is not statistically significant.

We also performed a logistic regression, adjusting for race, gender and anatomic location of the injury to test for association between age group and critical injury. Again, the adjusted results were not statistically significant. However, we found that Caucasian pediatric patients are 18.75 times (95% CI 2.34–15.19) more likely to experience critical hoverboard injuries compared to Asian pediatric patients. No other significant differences were found among pediatric patients across other races. When we looked at the overall data for the two age groups, it appeared that Caucasian patients are 2.65 times (95% CI 1.11–6.30) more likely to experience critical hoverboard injuries compared to African American patients.

## 4. Discussion

Our study is the first to utilize a national sample to evaluate and characterize the extent of hoverboard related injuries in over 24,000 pediatric and adult patients seen in US EDs. We found, in this national sample, that there were more ED visits for pediatric patients when compared to the adult cohort (61.4% vs 38.6%,  $p$ -value < 0.001) highlighting that children are at a higher risk for injury. In our sample, hoverboard related injuries appear to be rising tenfold, from 2416 in 2015 to 22,234 in 2016. In 2016, there were 60 patients per day presenting to a U.S. ED with a hoverboard related injury.

Hoverboards were introduced to the market in the US in 2015, and became one of the most popular gifts for Christmas that year. This dramatic rise in popularity and availability lead to increased sales, which accounts for the difference in the number of injuries between 2015 and 2016. To the best of our knowledge, there does not appear to be a change in the structural design making them more dangerous. Instead, the volume of people with access to hoverboards has increased dramatically.



**Fig. 1.** Percentage of hoverboard injuries by injury type with the national estimates and confidence intervals.

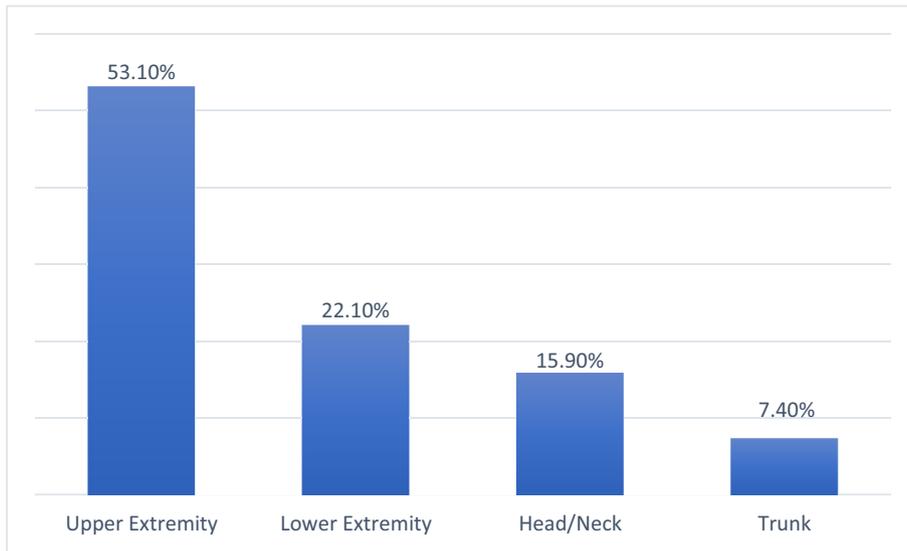


Fig. 2. Percentage of hoverboard injuries by body location with the national estimates and confidence intervals.

Our study is congruent with a previous review of hoverboard injuries in the Canadian Hospitals Injury Reporting and Prevention Program (CHIRPP). It found that patients younger than 19-year-old were more likely to be injured than adults [8]. Similarly, we found that 61% of our injuries were under the age 18. A limitation in their review was that the CHIRPP database is skewed toward pediatric surveillance, with 11 pediatric hospitals in their registry and only six general hospitals [8]. This finding contrasts with a recent multi-community ED based study that found a near equal distribution of adults (51.8%) and pediatric (48.2%) patients [12].

With hoverboard related injuries, the upper extremity is most at risk to be injured. According to a pediatric radiology review, hoverboard injuries place pediatric patients at increased risk of upper extremity fractures [15]. These findings are similar to the CHIRPP study, that found that 70% of their injuries involved the upper extremity [8]. The trend toward upper extremity injuries is again shown in our national representative study, with 53% of injuries involving the upper extremity. While our study has a lower overall proportion of upper extremity injuries compared to most prior pediatric studies, it is consistent with a mixed sample of adult and pediatric patients from a community based population [12].

We found significant differences between body regions when stratified by age. Prior data has shown increased proportions of upper extremity injuries in children [12]. In our sample, pediatric patients are more likely to injure their upper (57.6% vs 45.8%) and lower extremities (22.9% vs 20.8%), whereas adults were more likely to injure their core (15.6% vs 4.6%). We found no difference in head/neck injuries (17.6% for adults vs 14.8% for children), when stratified by age. We attribute this difference between adults and pediatric patients from the change in the center of gravity, neuromuscular coordination, and skeletal immaturity in pediatric patients.

Similar to previous studies [12], our national sample showed that pediatric patients had a higher fracture percentage compared to adults; 45% compared to 34.2%, with almost twice the number of fractures in pediatric patients compared to adults (6817 vs 3257). Unfortunately, this difference was not statistically significant ( $p = 0.6524$ ).

An earlier study demonstrated a low injury severity score with hoverboard injuries [12] consistent with the injuries described in prior work [7, 8, 15]. While most the injuries in our database were consistent with these prior studies, we found an estimated 1575 patients with internal injuries or anoxic injuries via the NEISS. These potentially life threatening injuries occurred in 6% of patients who presented to the

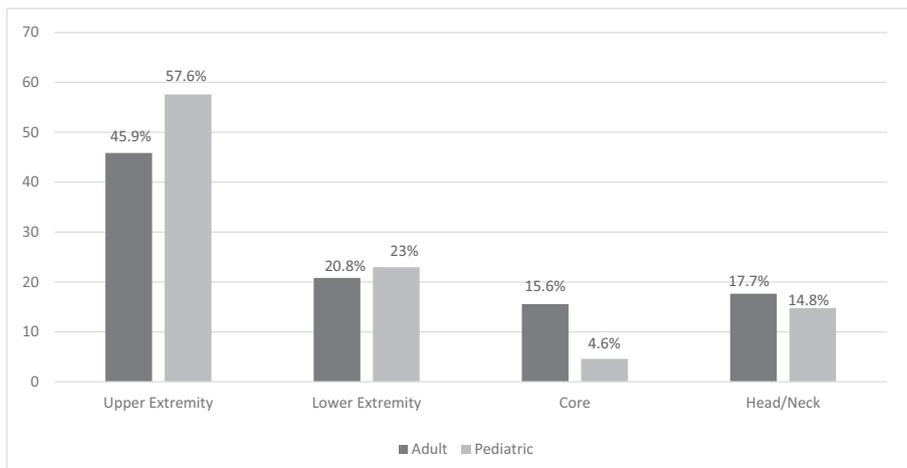


Fig. 3. Percent of hoverboard injuries by region and age group.

**Table 3**  
Comparison of pediatric and adult hoverboard-related injuries, 2015–2016.

	Pediatric		Adult		p-Value <sup>b</sup>
	N = 519	%	N = 224	%	
National estimate	15,134 (9980–20,287)	38.6	9515 (7185–11,845)	61.4	
Sex					
Male	7970 (4816–11,125)	52.7	4055 (2853–5258)	42.6	0.0875
Female	7164 (4623–9704)	47.3	5460 (3904–7017)	57.4	
Race					0.9475
White	5181 (3370–6991)	34.2	3649 (2058–5240)	38.4	
Black	2215 (860–3571)	14.6	1340 (540–2139)	14.1	
Unknown	5181 (3370–6991)	45.1	3944 (1580–6308)	41.4	
Other	920 (336–1505) <sup>a</sup>	6.1	583 (79–1086) <sup>a</sup>	6.1	
Injury disposition					0.6145
Treated and released	14,322 (9380–19,263)	94.6	9035 (6784–11,287)	95.0	
Hospitalized	568 (87–1049) <sup>a</sup>	3.8	245 (0–500) <sup>a</sup>	2.6	
Transferred, held for observation, or left without treatment	244 (0–521) <sup>a</sup>	1.6	236 (52–420) <sup>a</sup>	2.5	
Body part injured					0.0031 <sup>b</sup>
Lower extremity	3473 (2055–4890)	23.0	1979 (1219–2738)	20.8	
Upper extremity	8717 (5653–11,782)	57.6	4362 (2734–5991)	45.9	
Supraclavicular	2235 (1040–3430)	14.8	1679 (1014–2345)	17.7	
Thoracoabdominal/Trunk	693 (183–1204) <sup>a</sup>	4.6	1481 (980–1982)	15.6	
Injury type					0.6524
Fracture	6817 (4351–9283)	45.0	3257 (2301–4213)	34.2	
Contusion/Abrasion	2413 (1290–3537)	16.0	2051 (1116–2986)	21.6	
Sprain/Strain	2032 (1164–2900)	13.4	1404 (610–2199)	14.8	
Internal injury	1078 (281–1875) <sup>a</sup>	7.1	466 (144–789) <sup>a</sup>	4.9	
Concussion	443 (107–779) <sup>a</sup>	2.9	510 (2–1018) <sup>a</sup>	5.4	

<sup>a</sup> When the number of observation is less than 20 or the national estimate is less than 1200 then the estimate is not reliable according to NEISS.

<sup>b</sup> Statistically significant based on a Wald Chi-Square test.

ED with hoverboard related injuries. Separately, 16% of the injuries recorded in the NEISS database were head/neck injuries. Prior studies have indicated low helmet use with hoverboards [5, 12]. This finding of potentially serious hoverboard related injuries highlights the need for a better understanding of appropriate training and safety equipment.

Hoverboards became notorious due to their propensity to catch on fire from the faulty power supplies but only one observed patient was found in the NEISS database with a burn that required an ER visit. While the hoverboard's risk of ignition is a significant public safety issue, it appears that it has not translated into injuries requiring visits to the emergency departments as burns were not found in large numbers in our national sample.

The NEISS has previously been utilized to evaluate hoverboard related injuries. Siracuse et al. [16] evaluated injuries between 2011 and 2015 secondary to hoverboards, segways, powered scooters, and powered skateboards [15,16]. They found that there were over 47,000 injuries during this period related to these motorized-wheeled devices [15,16]. Likewise, they found that in 2015 there was a dramatic 208% rise in hoverboard and powered scooter related injuries [15,16]. In 2015, the hoverboard was introduced into the market and in our analysis, there were only 2416 injuries that were directly related to hoverboards during this time frame. Their estimate of 47,000 hoverboard related injuries is falsely elevated as it includes non-hoverboard devices in their analysis. We independently reviewed the NEISS database between 2011 and 2014 and did not find any patients with injuries attributed to a hoverboard. In fact, the word hoverboard was not used in the dataset that was coded 5042 before 2015. Our study is a unique NEISS analysis as we only selected observations from the sample that are attributed to a hoverboard, and excluded all other cases. Our analysis represents the most robust national analysis to date on hoverboard related injuries across all ages.

## 5. Limitations

NEISS lacks a specific code for hoverboard, providing for the possibility that some injuries were not properly reported. Only injuries with a

narrative mentioning hoverboard or spelling variations of hoverboard were included in this study therefore number of injuries may be falsely lower and underestimated in our national prevalence of hoverboard injuries.

Additionally, there are issues with the NEISS diagnosis codes. Specifically, concussions are difficult to quantify because these are coded as concussion, internal injury, and contusion. Therefore, it is likely that the number of concussions reported is lower than the actual value and we cannot accurately ascertain the actual number of concussion.

From the NEISS, we found that the most common race in our sample is “unknown” with 37.5% of the observations. This makes the actual percentages for other races difficult to determine in an accurate manner.

We defined a critical injury as an internal organ injury or anoxia in our data analysis. The NEISS defines an “internal organ injury” as injuries to the brain, abdominal organs, and thoracic organs that are not due to aspiration or ingestion. The handbook cites examples of cardiac contusion, liver lacerations, and splenic hemorrhage but they also code tympanic membrane perforation as an internal injury [14]. Therefore, our analysis is limited for critical injuries, as the internal injury may vary from benign to potentially life threatening.

Finally, there is always a danger when extrapolating data. While the NEISS database is used for this purpose, there is the possibility that the actual number and type of injuries are higher or lower than the estimated values. This limitation would be true for any study that uses the NEISS database to estimate national trends. Similarly, the NEISS's estimate is not valid when there are less than 20 observations or 1200 patients in the national estimate.

## 6. Conclusion

Between 2015 and 2016, hoverboard related injuries increased 10-fold in the United States owing to their increased availability and popularity. Children are at high risk for hoverboard related injuries as they represent the majority of our patient population. While there were more fractures in our pediatric cohort than adults, this did not reach statistical significance. In our national sample, fractures were the most common injury, but almost 6% of ED visits involved life threatening

injuries, highlighting the fact that hoverboards may be more dangerous than previously recognized.

### Prior presentations

Mid Atlantic Regional Society of Academic Emergency Medicine, Baltimore, MD 2018.

Society of Academic Emergency Medicine, Indianapolis, IN May 2018.

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None

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