

Electric-bicycles and speed-related trauma in pediatrics: Risk of internal injury and hospitalization

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ARTICLE INFO

Keywords:

Pediatric trauma
E-bicycle injury
Pediatric injury

ABSTRACT

Background: Electric bicycles (e-bikes) are becoming increasingly popular, offering higher speeds compared to traditional pedal bicycles. Despite their growing use, there is limited data on the epidemiology of e-bike related injuries in the pediatric population. Specifically, previous studies have not adequately explored the injury circumstances regarding e-bikes, particularly concerning loss of control due to speed. This study aims to assess the patterns and outcomes of e-bike injuries in children, hypothesizing that speeds higher than 20 miles per hour (MPH) result in more internal injuries necessitating hospital admission.

Methods: This retrospective cross-sectional study analyzed data from the National Electronic Injury Surveillance System, specifically targeting pediatric ages 0-18 e-bike injuries recorded between 2019 and 2023. We utilized natural language processing techniques to extract narratives from the database, identifying words related to the circumstances of injury, and distinguishing between speed-related incidents vs. non-speed-related incidents. The cohort was divided into two groups based on the identified cause: injuries due to increased speed and injuries attributed to other causes. We then conducted bivariate analyses to compare the characteristics and outcomes between these groups, focusing on the type of injury, its severity, and the need for hospital admission.

Results: A national estimate of 15,121 pediatric patients with injuries related to e-bikes (79.7% males and 71.3% adolescents aged 13-18) were identified. Injuries attributed to speed were associated with a higher incidence of head, neck, or facial injuries (49.1% vs 28.7%) compared to those resulting from other causes. A greater proportion of children with speed-related injuries sustained internal organ injuries (24.1% vs 10.4%) and were admitted to the hospital (7.3% vs 4.7%). Of those injuries specified as "internal" 96.7% were head and neck injuries compared to 3.3% other anatomic sites. Over the five-year study period, the frequency of e-bike injuries showed a sharp increase, with 4.18% occurring in 2019 and 49.8% in 2023.

Conclusion: Pediatric e-bike injuries have increased in frequency and can be severe, requiring hospitalization. The findings highlight the risks associated with speeds higher than 20 MPH on e-bikes and the need for targeted safety measures and legislation especially related to prevention of head injuries. Future research should focus on the effectiveness of safety interventions, including helmet usage and speed control features on e-bikes.

Type of study: retrospective cross-sectional study

Background

Bicycles remain amongst the most common mode of transportation,

recreation and exercise in the pediatric population. Electric bicycles (e-bikes) are increasingly popular in the United States, where e-bike sales nearly quadrupled from 2019 to 2022 [1]. On a global scale, 40.3

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<https://doi.org/10.1016/j.injury.2025.112931>

Accepted 28 November 2025

Available online 4 December 2025

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million e-bikes were predicted to be sold internationally by 2023 [2]. With the support of the United States Congress, e-bike use has been incentivized over routine motor vehicle use to decrease greenhouse gas emissions and combat climate change [3–5]. E-bikes are increasingly popular as a means of transportation when compared to traditional pedal bicycles as they enable riders to carry more weight, travel uphill and endure longer distances with less physical exertion [3,6,7]. E-bikes offer an affordable and enjoyable alternative to traditional automobile trips and do not require a license, thereby appealing to the pediatric population [8].

E-bikes can reach 30 miles per hour (MPH) or more, posing an increased risk of injury to riders and concerns for public safety [9,10]. Achieving these high speeds on e-bikes requires less physical effort than that of pedal bicycles, and pediatric riders may be less likely to wear helmets [11]. A 2015 single-center study reports higher injury severity scores (ISS) and more frequent intra-abdominal injuries in the pediatric population experiencing e-bike trauma, when compared to that of pedal bicycles [12]. A study produced by DiMaggio et al. demonstrates that electric scooter and e-bike trauma across all ages is more likely to result in internal injury and hospitalization than that of trauma related to traditional pedal bicycles [11,13]. Multiple studies report solely on electric scooter (e-scooter) injuries in children, elucidating that children are likely to experience fractures, polytrauma, traumatic brain injuries (TBI) and hospitalizations related to e-scooter trauma and lack of associated safety legislation [14–18].

Despite the rapidly growing prevalence and use of both e-scooters and e-bikes, there is limited literature specific to the epidemiology of e-bike related injuries within the pediatric population. The injury patterns related to e-bikes in children, particularly with attention to high speeds and associated loss of e-bike control, have yet to be explored. This retrospective study aims to use data from the National Electronic Injury Surveillance System (NEISS) to assess the accident, injury circumstances and clinical outcomes of pediatric e-bike trauma. With higher top-end e-bike speeds comes the risk of losing control and the likelihood of experiencing more severe trauma, due to a heightened transfer of energy. Therefore, we hypothesize that e-bike trauma related to speeds greater than 20mph results in more internal injuries necessitating hospitalization amongst the pediatric population.

Methods

Data source

The NEISS is a nationally representative probability sample of approximately 100 hospital emergency departments, including approximately 20 pediatric emergency departments, geographically distributed throughout the US and its territories. NEISS data is collected by the Consumer Products Safety Commission (CPSC) and is used to generate national estimates of injury frequency related to specific consumer product categories and sub-categories. The data collected by emergency departments and reported to NEISS include age, race, ethnicity, gender, date of injury, injury diagnosis, anatomic region of injury, admission to the hospital, and circumstances related to injury reported as free text within a narrative field. This project was deemed exempt by the institution's Institutional Review Board, with a waiver of consent granted due to the use of a deidentified national database. The STROBE checklist was used to ensure proper reporting of methods, results, and discussion (SDC 3.)

Inclusion/exclusion criteria (see Fig. 1)

Reports of injuries that occurred during the period from 2019–2023 in individuals 2–18 years of age were extracted from NEISS using the consumer product codes for “Bicycles and Accessories (Excluding All Terrain Bicycles)” (5040) and “Mopeds or Powered Bicycles” (3215). Presence of the terms “ELECTRIC”, “ELECTRIC BIKE”, “BATTERY”,

“EBIKE”, “E-BIKE”, “E BIKE”, “E-BICYCLE”, “MOTORIZED BICYCLE” in the narrative field was used to differentiate electric-powered bicycles from gas-powered “mopeds.” Only records with statistical weights in the appropriate NEISS field were included. Statistical weights were used to generate population estimates related to the frequency of injury corresponding to demographic and clinical variables. Incomplete data for other variables related to the anatomic site or nature of injury were not used as a criterion for exclusion, as patients with partial data could still contribute to variable-specific estimates. Weighted sample estimates corresponding to groups of observations with a frequency of 20 or less, a coefficient of variation >33 %, or a confidence interval that did not include an estimate of 1200 or more were omitted from the results in this analysis due to the large range of variability in the generation of those estimates as recommended by NEISS/CPSC.

Study variables

The variables examined included: patient age (continuous variable); age categorized as <13 years, and 13–18 years; sex; race; year of injury (2019–2023), anatomic site of injury (upper extremity, lower extremity, head and neck, face, trunk, or other); injury type/diagnosis (amputation, avulsion, burn, hematoma, poisoning, hemorrhage, dental injury, avulsion, dislocation, concussion, laceration, contusion, puncture, fracture, other). These levels of the injury type variable represent the greatest degree of specificity provided by NEISS. It is not possible, for instance, to differentiate between external and internal fracture or additional injury details. All patients 18 years or younger were considered pediatric patients for the purpose of this study. Narrative text was used to determine whether the individual used a protective device (helmet) at the time of injury, but due to a large degree of missingness, we have not reported these data. Data recorded in NEISS were complete across all sampled instances except for variables tracking Hispanic ethnicity, secondary diagnosis, and injury to the second anatomic site. Hispanic ethnicity was excluded from this study due to the large proportion of missingness. All other variables were “missing” due to the context of a patient's circumstances. Additional variables were created by identifying reported patient circumstances of patient injury in the provided narrative field. The variable “Lost control due to speed” was first created using text keywords: (“LOST CONTROL”, “TOO FAST”, “COULDNT STOP”, “COULD NOT STOP”, “MPH”) hand annotation of those observations meeting these criteria was conducted to ensure appropriate categorization. Injury circumstances were also defined using narrative text that contained the keywords that included (fell off, crash into, hit by car/truck, (other vehicle names), riding with, hit by a, trick/showing off/ wheelie/other tricks). Injury circumstances were also reviewed by hand to ensure appropriate annotation. Missingness within these created variables was reported, and observations were not deleted based upon missingness within variables created using text in narrative fields. The reporting of “helmet use” data was to present the need for a discrete field dedicated to protective device use, not to present data that was representative of helmet use within e-bike riders.

Statistical analysis

National estimates of pediatric two-wheeled vehicle injury were generated by applying sample weights developed by the NEISS for the years 2019–2023. Estimates of injury frequency were produced by multiplying a reported sample observation by the sample weight and summing within a given category. Descriptive statistics reporting estimated frequencies and proportions were reported for all categorical variables. Calculation of 95 % confidence intervals was completed using the following formula: “estimate \pm (1.96*estimate*Coefficient of Variation).” NEISS recommendations for national estimates require the restriction of results for groups with <20 actual cases, as the size of the sample at this level may suffer from instability. If an estimate generated is <1200, NEISS states that these estimates may also be unstable. For

this study, estimates were annotated with an “-” in those cases where the estimate met the criteria for instability. As this analysis was both exploratory and descriptive, estimates of 1200 that were contained within an estimate’s 95 % confidence interval were also included. R statistical programming language (Vienna, Austria) 4.03 was used for all analyses. In the calculation of National Estimates, rounding errors are introduced, and that explains why percentages that should logically sum to 100 % do not always do so.

Results

The study cohort consisted of 437 e-bike patients that were estimated to represent 15,121 pediatric patients with injuries related to e-bikes between 2019 and 2023 (Table 1). Patients were predominantly male (79.7 % male vs 20.2 % female) and adolescents ages 13–18 years (71.3 % aged 13–18 vs 28.6 % <13, Table 1). Of those e-bike injuries attributed to loss of control, an even higher proportion were noted to be male (94.7 % male vs 5.22 % female). Injuries related to loss of control encompassed 13.2 % of all injuries, and 86.6 % were not classified as related to loss of control. Most injuries occurred at the level of the extremities (61.0 %), and of these extremity injuries, 63.8 % were within the non-speed related group (Table 2). Injuries attributed to loss of control of e-bike were observed with a higher incidence of head, neck and facial injuries (49.1 % vs 28.7 %, Table 2) compared to e-bike injuries resulting from other causes. Pediatric patients sustaining e-bike speed-related trauma were likely to experience injuries classified as fracture, concussion, or internal injury (55.5 %) when compared to those patients with injuries that were not related to loss control (41.2 %, Table 1). Pediatric patients who sustained injuries due to loss of control were less likely to be helmeted than those whose injuries were unrelated to loss of control (7.89 % vs 19.3 %), however, 88.3 % of total patients reviewed for e-bike injuries had no helmet status recorded, indicating that helmet status is unknown (Table 1). Over the 5-year study period, from 2019–2023, the frequency of e-bike injuries showed a sharp increase with 4.18 % occurring in 2019 and 49.8 % in 2023.

Discussion

This national study demonstrates the increasing frequency of e-bike injuries amongst the pediatric population from 2019 to 2023. Of the incidences of e-bike injuries among children reported in the NEISS database during the study period, just 4.18 % occurred in 2019, rising to 49.8 % in 2023. This sharp increase in e-bike related injuries in children in the United States coincides with increased usage of e-bikes, supported by state and federal incentives and increasing accessibility and appeal of e-bikes to a young population [3–5].

Patients affected by e-bike related injuries during this study period were predominantly adolescents, aged 13–18. The legal age for operating a motor vehicle in most US states is 16, however, all but six US states have no license requirement for operating an e-bike [19]. The lack of legislation requiring licensure for e-bike operators likely contributes to the appeal of e-bikes as a means of transportation among adolescents – e-bikes are available to those not yet old enough to legally drive. Furthermore, the data generated by this study suggests that males are predominantly affected. Multiple established studies demonstrate that males are more likely to experience trauma-related injuries than females [20–23]. Several theories exist related to the propensity of males to be involved in trauma-related injuries when compared to females, including that of reduced perception of risk, limited use of protective equipment, and the lesser likelihood of supervision during risky behavior [21,22,24]. The gender disparities in trauma observed in childhood extend well into adolescence, as male patients aged 15–19 years are 2.5 as likely to experience unintentional trauma than females [24]. The likelihood of adolescent males amongst pediatric patients experiencing e-bike related trauma as demonstrated by this study is aligned with these findings.

E-bikes are different from traditional bicycles as they can reach speeds up to 30 mph without increasing one’s maximum perceived exertion [9,10]. The data produced by this study reports traveling at speeds greater than 20 mph did result in loss of e-bike control and collision, and loss of control of an e-bike resulted in traumatic injuries that are more likely to include head neck and face injury and fracture or concussion or internal injury. A 2015 single-center study produced by Capua et al. similarly found that e-bike trauma is more likely to result in injuries with greater injury severity scores (ISS) on presentation [12]. Capua et al. also found that the incidence of intra-abdominal injury in adult e-bike trauma patients is higher than that of traditional pedal bicycles. DiMaggio et al. also substantiated that e-bike injuries are more likely to result in hospitalization and internal injuries [13]. Patients achieving high speeds on e-bikes are more likely to experience forceful energy transfer upon collision, resulting in these internal injuries that require hospitalization.

Our study’s findings expand on this existing literature, as we note that pediatric patients in particular sustain a myriad of injury patterns related to e-bikes (see Fig. 2). The distribution of general injury type among pediatric e-bike riders include contusions, fractures, lacerations, internal injuries, strains, concussions and amputations. Our study finds, however, that when accounting for e-bike injuries related to speeds greater than 20mph, internal organ injuries are most often sustained. Many of these injuries specified as internal are classified not as intra-abdominal injuries, but rather as injuries affecting the head and neck.

The data on helmet usage was limited by the high degree of missingness (88.3 %). However, our analysis did suggest that there may be less helmet usage amongst those riders involved in loss of control collisions. Perhaps patients more likely to engage in risky behavior related to higher speeds are also less likely to mitigate that risk by donning protective equipment. Multiple prior studies have suggested that an increase in traumatic brain injuries (TBI) related to e-scooter injuries in children can be attributed to a lack of safety legislation [14–18]. California state legislation at present requires helmet use for all bicycle riders ages 17 and under. It is well established that helmets reduce head injuries, though the missingness of helmet reports in this NEISS dataset reminds us that often patients’ helmet status is not documented, or unknown [25,26]. Perhaps moving forward, more stringent policy regarding both documentation of helmet status and penalties for riding without helmets could be enforced for the safety of this population. Furthermore, provisional penalties exist for racing, though specific to identifiable speeds do not exist [26]. More research should be done to evaluate the effects of legislation limiting e-bike speeds.

There are limitations to this study. The dataset produced by the queried NEISS database is not a national registry, but rather a sample probability. Some of the estimates produced by the NEISS database may therefore be inaccurate. The internal injury variable examined reveals subsets, such as that of injuries of the head and neck, that were most common among the study subjects experienced speed-related e-bike trauma. The NEISS database, however, does not reveal the types of head and neck injuries these patients experienced. Some categories, such as helmet use, are not well captured and exhibit significant missingness. While the trends are stated, this missingness could likely contribute to bias in results. The NEISS database also only captures patients that were presented to emergency departments, indicating that a proportion of affected pediatric patients are left out of the dataset should they have presented elsewhere.

Conclusion

E-bike injuries amongst the pediatric population have increased in frequency over time and can be severe, requiring hospitalization. The findings of this study highlight the risks of e-bike loss of control, and the associated likelihood of sustaining internal injuries to the head and neck. Such findings elucidate the need for future focus on the effectiveness of safety interventions in pediatric patients, including helmet use, penalties

Table 1
Demographics and Characteristics of E-bike Injuries.

Characteristic	Individual Frequencies <i>n</i> = 437	All Patients National Estimates <i>n</i> = 15,121	95 % CI	Individual Frequencies <i>n</i> = 379	Injury Attributed to Features Other Than Speed Control National Estimate <i>n</i> = 13,124	95 % CI	Frequency <i>n</i> = 58	Loss Control Due to Speed National Estimate <i>n</i> = 1998	95 % CI
Age(0–18)									
Age <13	274	4333 (28.6 %)	2670–5995	235	3905 (29.7 %)	2728–5082	–	–	–
Age Greater than or equal to 13	163	10,789 (71.3 %)	7874–13,704	144	9218 (70.2 %)	6392–12,044	41	1571 (78.6 %)	1089–2052
Sex									
Male	340	12,056 (79.7 %)	8451–15,662	290	10,170 (77.4 %)	7083–13,257	50	1886 (94.7 %)	1366–2406
Female	96	3057 (20.2 %)	2050–4065	89	2953 (22.5 %)	2015–3891	–	–	–
Anatomic Site of Injury									
Head Neck Face	148	4753 (31.4 %)	3222–6286	121	3771 (28.7 %)	2520–5022	27	982 (49.1 %)	700–1264
Injury Type (Comparing Proportion of Internal Injury)									
Amputation	–	–	–	–	–	NA	–	–	–
Avulsion	–	–	–	–	–	NA	–	–	–
Burn Thermal	–	–	–	–	–	NA	–	–	–
Contusion	–	–	–	–	–	NA	–	–	–
Concussion	95	3593 (23.7 %)	2583–4602	81	3024 (23.0 %)	2156–3892	–	–	–
Crushing	–	–	–	–	–	NA	–	–	–
Dental Injury	–	–	–	–	–	NA	–	–	–
Dislocation	–	–	–	–	–	NA	–	–	–
Foreign Body	–	–	–	–	–	NA	–	–	–
Fracture	118	3939 (26.0 %)	2686–5192	104	3383 (25.7 %)	2283–4483	–	–	–
Hematoma	–	–	–	–	–	NA	–	–	–
Hemorrhage	–	–	–	–	–	NA	–	–	–
Internal Injury	54	1855 (12.2 %)	1282–2428	42	1373 (10.4 %)	929–1816	–	–	–
Laceration	63	2172 (14.3 %)	1525–2820	54	1932 (14.7 %)	1374–2489	–	–	–
Other	47	1731 (11.4 %)	1226–2236	43	1674 (12.7 %)	1207–2140	–	–	–
Poisoning	–	–	–	–	–	NA	–	–	–
Strain	–	–	–	–	–	NA	–	–	–
Injury Type									
Fracture/ Concussion/ Internal Injury	188	6240(41.2 %)	4257–8223	159	5122(39.0 %)	3451–6793	29	1118(55.5 %)	806–1429
All Other Types	249	8881(58.7 %)	6240–11,523	220	8001(60.9 %)	5641–10,351	–	–	–
Disposition (Comparing proportion of admitted)									
Treated & Released	386	13,806 (91.3 %)	9691–17,922	338	12,008 (91.5 %)	8396–15,621	48	1798 (90.0 %)	1293–2303
Admitted	40	–	–	–	–	–	–	–	–
Reported Wearing a Helmet(Bias in Missingness)									
Yes	42	1421 (9.39 %)	985–1857	–	–	NA	–	–	–
No	–	–	–	30	1035 (7.88 %)	724–1346	–	–	–
Unknown	376	13,356 (88.3 %)	9351–17,362	336	11,904 (90.7 %)	8317–15,490	40	1452 (72.7 %)	1031–1873

**N/A: redacted to comply with NEISS recommendations of removal of unstable estimates.

Table 2
Distribution of E-bike Injuries 2019-2023.

Distribution of Ebike Injuries 2019-2023			
Characteristic	All Patients	Non Speed Related	Speed Related
Anatomic Site of Injury			
Head Neck Face	4753 (31.4 %)	3771 (28.7 %)	982 (49.1 %)
Upper and Lower Extremity	9238 (61.0 %)	8377 (63.8 %)	861 (43.0 %)
Trunk	980 (6.48 %)	847 (6.45 %)	N/A
Other	N/A	N/A	N/A

*N/A: redacted to comply with NEISS recommendations of removal of unstable estimates.

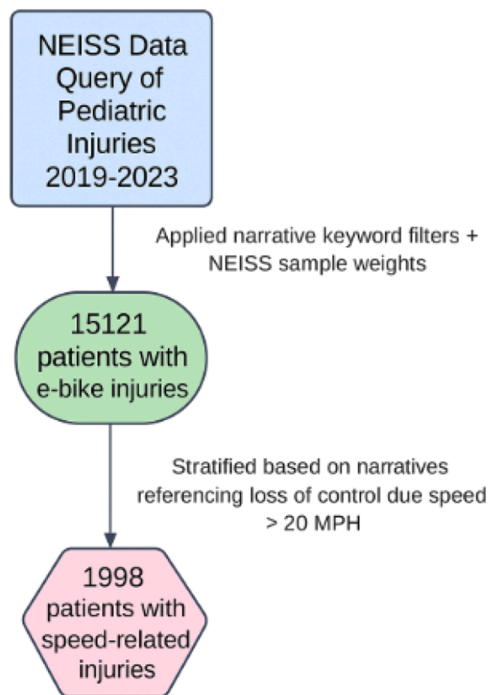


Fig. 1. Inclusion and exclusion criteria flow chart.

for speeding and mandates related to speed-control features on e-bikes.

Financial support statement

This research did not receive any specific grant from funding agencies in the public, commercial or not-for-profit sectors.

The authors have no competing interests to declare. All JTACS Disclosure forms have been supplied and are provided as supplemental digital content.

Ethics approval

Ethical approval for this study was obtained from Children’s Hospital of Orange County in-house (CHOC IH) IRB, #240,337.

Informed consent

Informed consent for patient information to be published in this article was not obtained as was exempt in the setting of retroactive, de-identified patient data analysis without any direct patient intervention.

Distribution of Type of Injury Observed in E-bike Riders

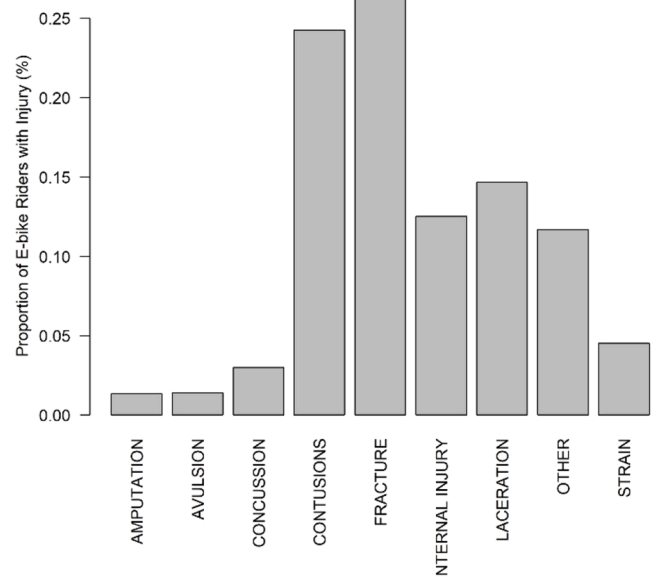


Fig. 2. Distribution of type of injury observed in E-bike riders.

Animal welfare

This research did not involve the use of animals.

CRedit authorship contribution statement

Zoe E. Flyer: Writing – original draft. **Andreina Giron:** Writing – review & editing. **John Schomberg:** Formal analysis, Data curation. **Mary Maginas:** Data curation. **Jeffrey Nahmias:** Writing – review & editing, Conceptualization. **Yigit S. Guner:** Writing – review & editing. **Romeo Ignacio:** Writing – review & editing, Conceptualization. **Troy Reyna:** Writing – review & editing. **David Gibbs:** Writing – review & editing. **Laura F. Goodman:** Writing – review & editing, Supervision, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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