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ORIGINAL RESEARCH

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Impact of modern recreational conveyances on rates of pediatric craniofacial fractures

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Abstract

Objective: Trauma remains the leading cause of death for children over a year old. Motorized recreational conveyances (RCs) adds another potential cause of pediatric trauma. This study aims to determine the impact of adding electric motors to RCs on the severity and frequency of pediatric injuries and craniofacial fractures.

Methods: Pediatric trauma information was obtained from the National Electronic Injury Surveillance System (NEISS) database between 2012 and 2021. Demographics, injury cause, diagnoses, and incident narrative were collected. Bivariate and multivariate regression analyses were used to determine injury factors associated with serious injuries.

Results: One million five hundred ninety-six thousand five hundred fifty-nine encounters were examined; 113,905 (7.1%) were related to pediatric RCs and 5354 (5.4%) of those involved RCs with electric motors. 14.3% of injuries were related to scooters, 18.6% to skateboards, 54.2% to bicycles, and 12.9% to other RCs. There were significant differences in age, sex, race, helmet use, serious injuries, and craniofacial fractures between RC modalities. RC users were more likely to develop facial fractures (OR 2.12; 95%CI 2.01, 2.23; $p < .001$) and be involved in serious injuries (OR 1.42; 95%CI 1.38, 1.46; $p < .001$). Compared to their self-propelled counterparts, motorized scooters (OR 2.24; 95%CI 1.86, 2.69; $p < .001$) but not motorized skateboards (OR 1.01; 95%CI 0.88, 1.17; $p = 0.88$) were more likely to cause serious injuries. Helmet use was associated with fewer serious injuries (OR 0.5; 95%CI 0.46, 0.54; $p < .001$), facial fractures (OR 0.48; 95%CI 0.41, 0.55; $p < .001$), and skull fractures (OR 0.13; 95%CI 0.09, 0.17; $p < .001$).

Conclusions: The addition of electric motors to RCs significantly increases the risk of pediatric craniofacial fractures and serious injuries.

Level of Evidence: 3.

KEYWORDS
electric scooters, facial fractures, micromobility, pediatric, skull fractures

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1 | INTRODUCTION

Electric recreational conveyances have been increasingly popular since their inception in the late 2010s, as an environmentally friendly, inexpensive means of transport in urban cities.[1] They are now commonly used in the United States, Europe, Asia, and Australia.[2,3] Their diversity has also greatly increased in recent years to include both motorized and self-propelled scooters, skateboards, and bikes; as well as roller skates and wagons. Trauma remains the leading cause of death for children greater than a year old.[4] In 2019 alone, 7444 youth aged 0–19 died from unintentional injuries and resulted in a $14 billion burden of medical bills and lost income on the families.[5] Overall, the number of admissions for pediatric trauma have decreased, however, the proportion of severe injuries have increased.[6] One potential cause is the spike in the severity of injuries is the availability of electric conveyances. Although it has been well established that nonmotorized conveyances (i.e., self-propelled scooters and skateboards) can cause morbidity and mortality in pediatric patients,[7–9] with the addition of an electric motor, injuries are more severe and are more likely to require admission to a trauma center.[10] A study by Paudel et al. looking at the dynamic factors governing head injury in e-scooter injury found that there is a strong correlation between the severity of head injuries and the e-scooter speed.[11] Approaching the relationship between speed and injury slightly differently, when the top speed of e-scooters was dropped from 25 km/h to 20 km/h in Helsinki, the unadjusted odds ratio of scooter injuries fell to 0.5.[12] There are three main goals of this study: (1) identify how the addition of an electric motor to common recreational conveyances impacts the risk of sustaining craniofacial fractures; (2) perform subgroup analysis to identify the risk of craniofacial injuries with individual conveyance modalities; and (3) identify the prevalence and risk of craniofacial injuries when helmets are worn.

2 | MATERIALS AND METHODS

The National Electronic Injury Surveillance System (NEISS),[13] a US Consumer Product Safety Commission resource detailing emergency department (ED) visits related to consumer product, was used to retrospectively review patterns of craniofacial injuries in pediatric patients. NEISS aggregates data from a cohort of approximately 100 EDs of varying sizes and settings randomly sampled throughout the United States' 5000+ EDs. A validated algorithm weighting these departments allows extrapolation of this information to estimate nationwide incidence of injuries. The data include information about patient demographics, race, diagnosis/type of injury, site of injury, consumer products associated with the injury, and a brief narrative that describes specific details about the injury and its mechanism. It has been used to describe the risk and patterns of injuries to both adult and pediatric patients.[3,7,10,14–23] This study was reviewed by the Colorado Multiple Institution Review Board (COMIRB) and the Denver Health Sponsored Programs and Research Office (SPARO) and qualified as nonhuman subject research, thus exempting it from requiring institutional review board approval.

The most recent 10-year period (2012–2022) was searched for craniofacial injuries related to the use of "scooters" (codes 1329, 5022, 5023, 5024, and 5042), "skateboards" (codes 1333, 5025, and 5042), "skates" (codes 3216, 3217, 3255, and 3297), "bicycles" (1283, 1301, 5033, and 5040), and "moving children's toys" (codes 1327, 1328, 1330, 1398, 5021) refining our search to injuries involving the skull and face in patients less than 19 years old. Powered recreational conveyances were identified with the codes 1330, 5022, 5025, and 5042. The presence of facial fractures was determined by searching the brief narrative for mention of "mandible fracture," "jaw fracture," "sinus fracture," "maxilla fracture," "nasal bone fracture," "orbital fracture," or "facial fracture." Skull fractures were identified by searching the narrative for "occipital fracture," "frontal fracture," "parietal fracture," "temporal fracture," or "skull fracture." Patient demographic characteristics (including sex and age), injury characteristics (including injury location, injury diagnosis, and disposition), and seasonal variation were evaluated among each of the NEISS entries meeting our search criteria.

Further sub-setting of the data was performed to classify conveyance modality, severity of injury, identify mechanisms involving MVCs, and determine helmet use at the time of injury. Scooter, skateboard, and bicycle injuries were identified if the rider was using these conveyance modalities at the time of the trauma. The "other toy" cohort included traumas related to powered and unpowered wheeled child riding toys, wagons, roller skates, inline skates, and ice skates. Although there were powered other toys, because these toys are not likely used on public streets, they were not included in the electric conveyance category. A "severe injury" was classified if the patient required hospitalization, transfer to a higher level of care hospital, or if the injuries resulted in death. Any involvement of *moving* motor vehicles, including automobiles, buses, or trains classified the mechanism as an MVC, however, if the injury was the result of the subject colliding with a parked vehicle or an open door, or the result of the subject swerving to avoid collision, the mechanism was not designated as an MVC. To determine helmet use, the brief narrative was searched for any mention of the term "helmet" and a positive designation.

Univariate analysis was performed with Mann–Whitney U tests and X^2 analysis for comparison of continuous and categorical variables, and multivariate analysis with generalized linear models. Threshold for significance set at $p < .05$. All statistical calculations were performed using Python (https://www.python.org) and R statistical software (https://www.r-project.org).

3 | RESULTS

3.1 | National cases

A total of 1,898,328 cases of pediatric trauma were obtained from the NEISS database between 2012 and 2021. Of those, 128,601 (6.8%)

cases were related to children's recreational conveyance vehicles and riding toys and 6461 (0.3%) were due to powered devices. Table 1 describes the national estimates of pediatric trauma based on different conveyance modalities. There was a significant difference in the number of recreational conveyance injuries per year ($p = .006$), with an overall decline in the rate of pediatric traumas occurring between 2012 and 2021 (Figure 1A). On the other hand, there was a steep rise in powered conveyance traumas from 2012 to 2021 ($p = .006$; Figure 1B). Serious injuries had a sharp increase between 2017 and 2020, followed by a short decline (Figure 1C).

TABLE 1 Number of cases and national averages.

Conveyance	National estimate[a] (95% CI)	Number of cases
Scooters	464,383 (356,276–572,491)	16,535
Skateboards	723,515 (496,843–950,186)	20,454
Unspecified scooter/skateboard	106,663 (79,371–133,955)	3385
Bicycles	2,044,806 (1,612,849–2,476,763)	66,281
Skating	466,061 (332,997–599,125)	15,404
Other toys	185,650 (136,212–235,086)	6542
Powered conveyances	192,562 (133,449–251,674)	6461
Unpowered conveyances	3,798,516 (2,881,099–4,715,932)	122,140

[a]National estimates based on the NEISS validated weighting of emergency departments.
Abbreviation: CI: confidence interval.

3.2 | Demographics

Overall, 1,596,559 subjects were included in the analysis; median age was 8 (IQR: 3–13), 59.6% were male, and 42.2% white. The complete demographic profile of the cohort can be found in Table 2. There were 113,905 (7.1%) injuries related to recreational conveyance use, of which patients were more likely older ($p < .001$), male ($p < .001$), White ($p < .001$), involved in a serious injury ($p < .001$), and sustained a concomitant craniofacial fracture ($p < .001$). In multivariate analysis, patients involved in recreational conveyance traumas were more likely older (OR 1.07; 95%CI 1.07, 1.07; $p < .001$), male (OR 1.3; 95%CI 1.29, 1.32; $p < .001$), white (OR 1.09; 95%CI 1.07, 1.1; $p < .001$), and sustained a serious injury (OR 1.45; 95%CI 1.41, 1.48; $p < .001$). A total of 72,205 (4.5%) traumas were considered serious; involved patients were older ($p < .001$) and the traumas were more likely to involve a motor vehicle

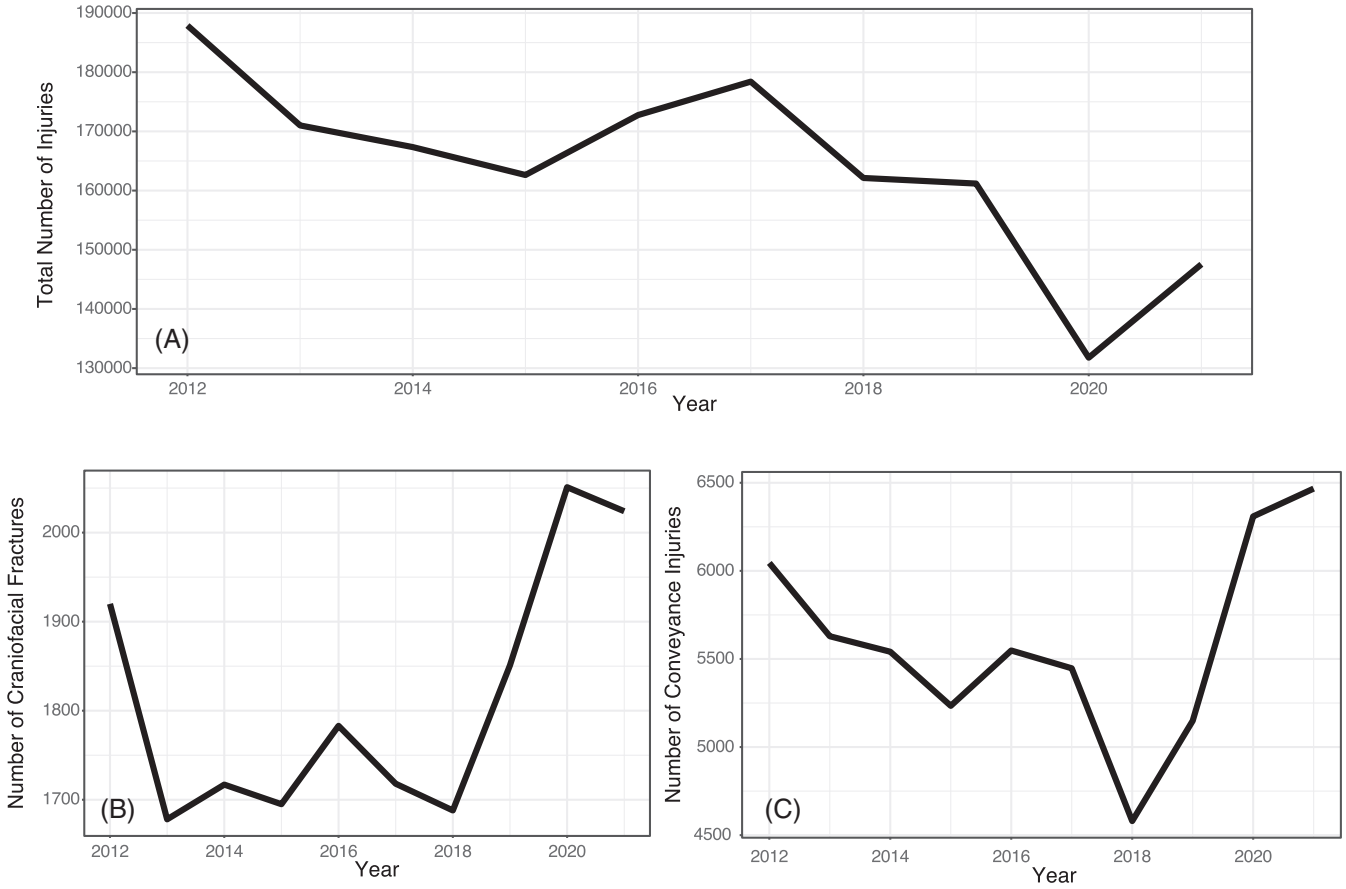

FIGURE 1 Changes in injury rates by year. (A) Total number of injuries based on year. (B) Total number of craniofacial fractures based on year. This includes all skull and facial fractures. (C) Total number of injuries when recreational conveyances were involved.

TABLE 2 Demographic table.

Variable	Overall $N = 1{,}596{,}559$[a]	Any conveyance $N = 113{,}905$[a]	Powered conveyance $N = 5{,}354$[a]
Age (years)	8.0 (3.0, 13.0)	10.0 (7.0, 13.0)[b]	10.0 (7.0, 12.0)[b]
Male gender	952,029 (60%)	75,556 (66%)[b]	2875 (54%)[b]
White race	636,201 (40%)	47,669 (42%)[b]	2040 (38%)[b]
Serious injury	72,205 (4.5%)	6950 (6.1%)[b]	389 (7.3%)[b]
Craniofacial fracture	17,480 (1.1%)	2037 (1.8%)[b]	94 (1.8%)
Helmet use	17,489 (61%)	4884 (37%)[b]	137 (30%)[b]

[a]Median (IQR); *n* (%).
[b]Statistically significant.

TABLE 3 Bivariate and multivariate analysis of serious injuries.

Variable	Bivariate[a]	Multivariate[a,b]
Age	0.99 (0.99, 1.00)	1.06 (1.04, 1.08)[c]
Male	1.36 (1.32, 1.4)[c]	1.01 (0.84, 1.22)
White	1.32 (1.28, 1.36)[c]	1.31 (1.12, 1.54)[c]
Helmet use	0.34 (0.3, 0.39)[c]	0.81 (0.68, 0.96)[c]
Conveyance	1.76 (1.69, 1.84)[c]	0.68 (0.07, 6.32)
Electric motorization	1.04 (0.88, 1.24)	0.96 (0.66, 1.4)
Craniofacial fracture	10.19 (9.87, 10.52)[c]	7.63 (6.49, 8.96)[c]

[a]Odds ratio (95% confidence interval).
[b]craniofacial_fracture ~ age + male + White + helmet_use + conveyance + power_status + serious_injury.
[c]Statistically significant.

($p < .001$). In a multivariate analysis, age, male gender, helmet use, conveyance involvement in the trauma, and craniofacial fractures remained significant predictors of the serious injuries (Table 3).

3.3 | Electric conveyances

There were 5354 (5.4%) traumas involving electric recreational conveyances, 29.4% were scooter-related and 70.5% were skateboard/hoverboard-related traumas. In the study period, there was a 700% increase in electric conveyance injuries between 2012 and 2021 (Figure 2). Compared to self-propelled riders, electric conveyance users were more likely female (46% vs. 30%; $p < .001$), less likely white (42% vs. 44%), and less likely to wear helmets (30% vs. 37%; $p < .001$). Compared to electric skateboarders, electric scooter users were younger (8 years vs. 13 years; $p < .001$), less likely male (67% vs. 72%; $p < .001$), less likely to be involved in a serious injury (5.2% vs. 6.3%; $p < .001$), but more likely to wear helmets (34% vs. 29%; $p < .001$) and be involved in motor vehicle collisions (2.9% vs. 2.0%; $p < .001$).

3.4 | Helmet use

Overall, 36.9% of the recreational conveyance trauma patients and 29.9% of the electric modality users wore helmets ($p = .003$). Subsetting electric recreational conveyance modalities, 29.7% of electric scooter users, 30.5% of electric skateboard users, and 38.8% of electric bike users wore helmets. Helmet wearing was associated with better outcomes following the trauma; 8.2% suffered serious injuries versus 15% of those without helmet use ($p < .001$). After controlling for age, gender, and race, skateboarders were the least likely to wear helmets (OR 0.09; 95%CI 0.08, 0.1; $p < .001$), followed by scooter users (OR 0.11; 95%CI 0.1, 0.12; $p < .001$) and bicyclists (OR 0.13; 95%CI 0.12, 0.14; $p < .001$).

Children wearing helmets were older ($p < .001$), more likely male ($p < .001$), and more likely white ($p < .001$). Patients utilizing electric conveyances were less likely to wear helmets ($p = .04$). Although only trending toward significant, children involved in trauma related to motorized scooters were less likely to wear a helmet (16.5% vs. 20.0%, $p = .11$; Table 4). The use of helmets resulted in a significant decrease in orbital, nasal, maxilla, mandible, skull, and overall craniofacial fractures when helmets were worn (Table 4).

4 | DISCUSSION

An estimated 3,991,078 cases of pediatric conveyance traumas occurred within the last decade, and of these, 192,562 involved electrically powered modalities. In this study, we identified that the addition of an electric motor significantly increased the risk of children being involved in a serious injury after controlling for age, sex, and race. While scooters and skateboards with electric motors may provide a convenient and efficient means of transportation for many adults, they have similarly become increasingly popular among children.[10,24,25] The rise of dockless, rental-based electric scooters has been directly associated with a rise in ED visits for traumatic injuries on these products.[1,3,26] We found that since 2012, there has been a 553% increase in electric motor recreational conveyance injuries (Figure 2). Electric scooters also place a significant financial burden on the health care system, with an average cost of $95,710 per encounter.[27] Previous studies evaluating pediatric injuries related to recreational conveyances such as skateboard, hoverboards, and scooters have focused on electric versus self-propelled subtypes[9,10] or comparisons between classes of conveyances[28–32] Among pediatric traumas related to recreational conveyances, craniofacial injuries are a common location of injury associated with significant morbidity. To date,

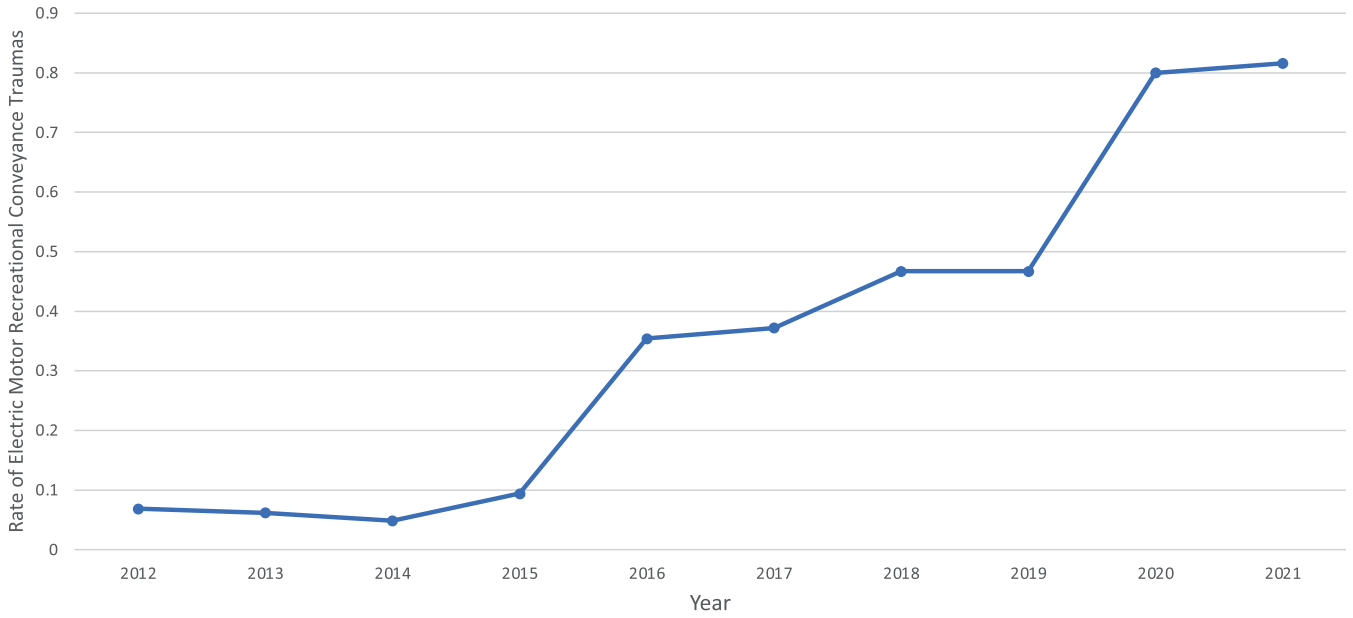

FIGURE 2 Rate of electric motor recreational conveyance injuries in the last 10 years. The rate of pediatric injuries involving electrically motorized recreational conveyances based on year.

TABLE 4 Helmet use attributes.

	Helmet use	
Variable	**Yes, $N = 17{,}489$[a]**	**No, $N = 11{,}174$[a]**
Age (years)[b]	12.0 (10.0, 15.0)	12.0 (8.0, 14.0)
Male[b]	14,713 (84%)	8322 (74%)
White[b]	8841 (51%)	4508 (40%)
Serious injury[b]	1435 (8.2%)	1702 (15%)
Motorized conveyance[b]	137 (3.0%)	321 (4.0%)
Any facial fracture[b]	332 (1.9%)	441 (3.9%)
Any skull fracture[b]	56 (0.3%)	280 (2.5%)

[a]Median (IQR); *n* (%).
[b]Statistically significant.

this is the only study that combines multiple recreational conveyances with electric motors in the pediatric population to compare the incidence of serious injuries.

The median age (10 years) of patients seeking care for craniofacial injuries correlates with a developmental stage associated with a decreased likelihood of close adult supervision, a limited degree of self-assessment of strength and coordination, and immature reflexes in responding to dynamic and static surrounding dangers. The significant increase in craniofacial injuries after 2018 also closely follows the 2017 introduction of dockless electric scooters as an affordable and convenient means of transportation in urban areas. Pediatric patients have a higher center of gravity and may be more susceptible to craniofacial injury when a scooter suddenly stops. Finally, the increased frequencies of craniofacial injuries in spring and summer seasons can be linked to warmer weather when more outdoor activities are more common.

Analysis of conveyance type importantly identifies scooters and skateboards as the most common products associated with craniofacial injuries. Electric scooters specifically were more likely to be utilized by older patients and were associated with more serious injuries, consistent with ease of accessibility and confidence with app-based products and increased top velocity relative to self-propelled scooters. Older children may also be more likely to attempt tricks and venture into intersections with more obstacles. Interestingly, while electric scooters were more frequently associated with increased craniofacial injuries, the opposite trend was identified with electric skateboards. Because skateboards lack the handlebars that assist with stabilization and maneuvering on scooters, individuals may tend to be better coordinated, better able to adapt to surrounding obstacles and dangers, and more likely to demonstrate safer behaviors. Electric skateboards are also significantly more expensive than less accessible compared to electric scooters, thus children who do have these products are more likely to be more proficient in their use as a significant investment and means of transportation.

While the Center for Disease Control has clear recommendations on consistent use of bicycle helmets to decrease the risk of brain and skull injury,[33–35] no formal recommendations extend specifically to electric or self-propelled scooter use. Scooter companies have made recommendations for safety measures that include wearing a helmet, not riding on the sidewalk, not riding with two people on the same scooter, but these recommendations are often not followed.[1] In our cohort group, 5.0% of patients presenting with craniofacial injuries were wearing a helmet at the time of injury, and 15.5% of patients with electric scooter injuries were wearing a helmet. These rates are notably higher than a 2019 CDC epidemiologic study conducted of individuals injured from electric scooters in Austin, Texas identifying less than 1% of individuals wearing helmets at the time of injury.

Importantly, most of the individuals in this latter study were adults over the age of 18, who are more likely to consider helmets as an unnecessary inconvenience.

Thus, despite a relatively increased likelihood of helmet use in the pediatric population within our study, most individuals with craniofacial injuries did not wear helmets at the time of injury. As expected, absence of helmet utilization was associated with increased risk of skull fractures and serious injuries. Low adoption rate of pediatric helmet use may reflect inconsistent state laws and a perceived sense of relatively safety with electric scooters. While a recent guideline from the American Academy of Pediatrics (AAP) recommends children under the age of 16 not ride on any electric scooter, and anyone 16 or older to wear a helmet and protective gear on an electric scooter,[36] these guidelines are clearly far from being consistently adopted. This study does have some limitations, which include the retrospective nature of analysis, a population defined by presentation to an Emergency Department, thus not inclusive of patients not seen at an urgent care center, through a primary care provider, or those electing for observation, and finally, inability to control for rural versus urban cities.

5 | CONCLUSION

Since the global acceptance of electrically motorized recreational conveyances, there has been a surge of pediatric traumas. Compared to their self-propelled counterparts, motorized recreational conveyances have twice the risk of serious injuries and twice the risk of craniofacial fractures. Only 30% of children riding electrically motorized conveyances wear helmets, compared to 60% of those riding self-propelled recreational conveyances. This presents an opportunity for increased public health awareness to formalize recommendations on pediatric use of electrically motorized recreational conveyances and communicate the significant risk of trauma that is inherent to recreational conveyances.

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CONFLICT OF INTEREST STATEMENT

The authors have no conflicts of interest to disclose.

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