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Brief Report

Motorized scooter injuries in the era of scooter-shares: A review of the national electronic surveillance system☆

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ABSTRACT

Introduction: There has been a spike in recent news regarding motorized scooter injuries due to the expansion of scooter sharing companies. Given the paucity of literature on this topic, the purpose of our study was to describe and quantify emergency department encounters associated with motorized scooter related injuries.
Methods: The National Electronic Injury Surveillance System (NEISS) was queried for motorized scooter related injuries from 2013 to 2017. Patient demographics, diagnosis, injury location, narrative description of incident, and disposition data were collected from emergency department encounters.
Results: There were an estimated 32,400 motorized scooter injuries from 2013 to 2017. The estimated incidence did not change significantly over time with 1.9 cases per 100,000 in 2013 and 2.6 cases per 100,000 in 2017. A 77.0% increase in scooter injuries was noted for millennials from 2016 to 2017. Head injuries were the most common body area injured (27.6%). Fractures or dislocations (25.9%) were the most common diagnosis. The most common site of fracture was the wrist and lower arm (35.4%). There were no deaths. Major orthopaedic injury and concussion were the strongest independent predictors of hospital admission.
Conclusions: Head injuries were the most commonly injured body part, while fractures or dislocations were the most common diagnosis. These results highlight the importance of using protective equipment while riding motorized scooters, and lay a foundation for future policies requiring helmet use.

1. Introduction

First invented in 1915 by Autoped [1], the motorized kick scooter has become a controversial mode of transportation. Scooter share companies have existed since 2012, however the two most popular companies, Lime and Bird, began operations in July and September 2017, respectively. These scooters have been proposed as a "last mile" solution to existing public transportation systems [2]. Their services have grown enormously, with the two main companies each reporting >10 million rides since launch [3]. Multiple news articles have described a spike in injuries and even a reported death associated with motorized scooters since the popularization of scooter-share companies [4-6]. Based on these reports, riders have filed a class action lawsuit against scooter-share companies [7]. Despite substantial media attention, there is little epidemiological data describing scooter related injuries in the United States.

The National Electronic Injury Surveillance System (NEISS) is a representative sample of Emergency Department encounters in the United States. Epidemiologic studies using this database have examined injury trends and patterns associated with other popular transportation modalities, such as hoverboards [8,9], bicycles [10], all-terrain-vehicles, and dirt bikes [11]. Using this database, we aimed to describe trends in incidence, injury patterns, and patient dispositions for motorized scooter related injuries in recent years.

2. Methods

Data for this study was obtained from the United States Consumer Product Safety Commission, National Electronic Injury Surveillance System (NEISS). The NEISS collects patient information on emergency department (ED) visits associated with a consumer product. Approximately 100 hospitals are sampled annually, including children's hospitals, to create a nationally representative probability sample of product related injuries occurring in the United

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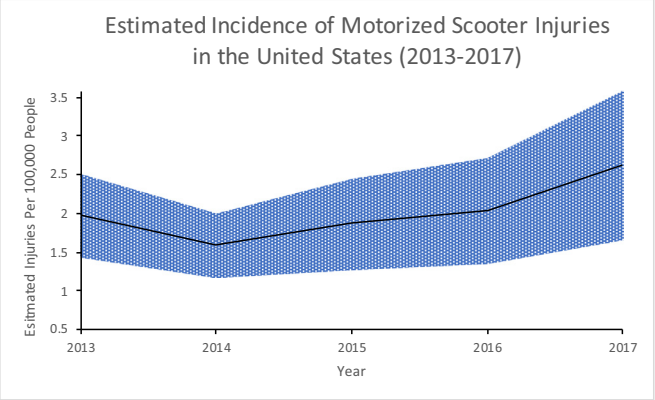

Fig. 1. Estimated incidence of motorized scooter injuries (2013–2017). *95% confidence interval bands around estimates.

States [12]. In addition to patient demographics, incident date, ED diagnosis, injury location, and patient disposition, the NEISS contains a brief narrative describing incident scenarios. This narrative can be queried to elucidate data that would not otherwise be captured with coding provided by the NEISS.

As an analysis of publicly available de-identified data, this study is exempt from our Institutional Review Board. We queried the NEISS for years 2013–2017 using product code 5042 ("Scooters/skateboards, powered") and identified 2675 unweighted emergency department encounters. The search term "scooter" was subsequently used to identify motorized scooter related injuries from the patient narrative. 827 unweighted cases were identified using this criterion. Hoverboard and powered skateboard injuries were excluded with the use of the word "hover", "board", and "skate". A search and exclusion of patients whose narrative included terms "wheelchair," "motorbike," and "motorcycle" was performed to further eliminate any miscoded patients in the dataset. After our search and exclusion was performed, 820 unweighted motorized scooter injuries were included in the study.

Incident date, patient demographics, diagnosis, injury location, narrative description of incident, and disposition data were collected from emergency department encounters. Population data for incidence estimates were acquired from the United States Census Bureau [13].

National estimates were created using weights provided by the NEISS. Statistical analyses were performed using IBM SPSS Statistics, Version 25.0 (Armonk, NY: IBM Corp). The complex samples function of SPSS was used to create 95% confidence intervals (95% C.I.). All data and analyses in this study are weighted estimates except when noted. Descriptive analyses, chi-square for categorical variables, and Mann U Whitney tests for continuous variables were employed. Patient diagnoses and demographic factors were entered into a binomial logistic regression to elucidate independent predictors of inpatient admission. 95% confidence intervals were used to determine statistical significance.

3. Results

3.1. The incidence of motorized scooter injuries

There were an estimated 32,400 (95% C.I. 25,403–39,396; 820 unweighted) motorized scooter injuries in the United States between 2013 and 2017. The estimated yearly incidence of motorized scooter injuries appeared to rise over time, from 1.9 cases per 100,000 (6230 total cases) in 2013 to 2.6 cases per 100,000 (8525 total cases) in 2017, however this trend did not reach statistical significance (Fig. 1). A spike in

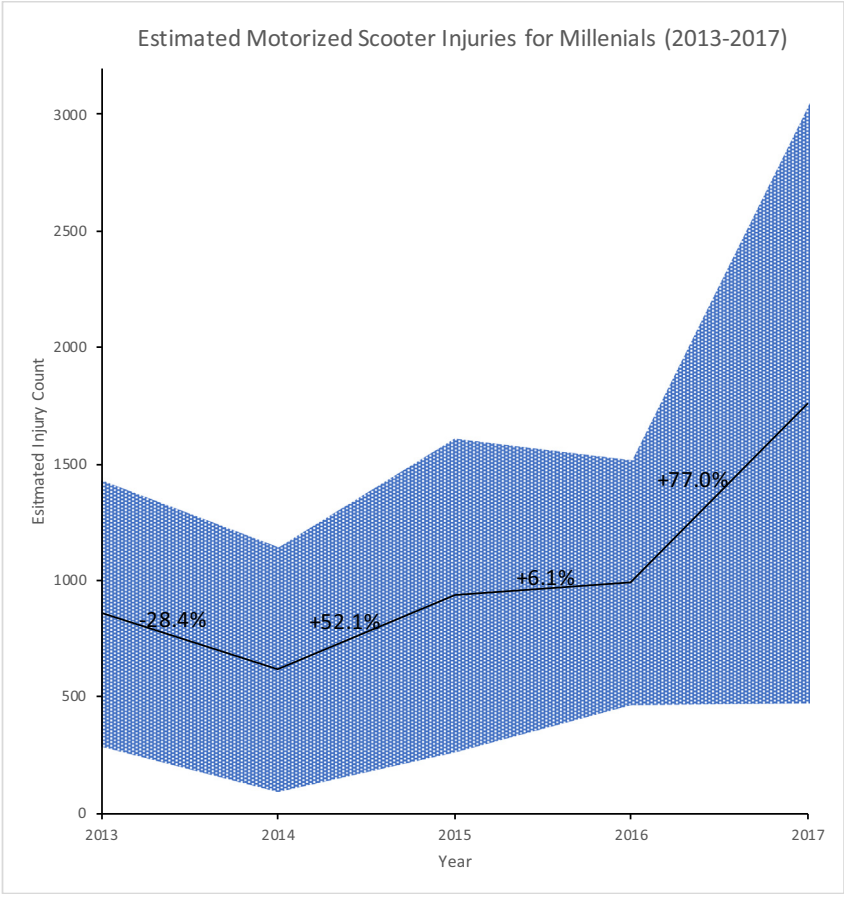

Fig. 2. Estimated motorized scooter injuries for millennials. *95% confidence interval bands around estimates.

Table 1
Demographics of patients with motorized scooter injuries.

		Estimated patients (95% C.I.)	Percentage of total
Age	Infant/toddler (0–5)	1628 (990–2264)	5.0%
	School age (6–12)	11,199 (8136–14,261)	34.6%
	Adolescent (13—22)	5186 (3164–7208)	16.0%
	Millennial (23–39)	5161 (2750–7573)	15.9%
	Adult (40–64)	6209 (4160–8259)	19.2%
	Elderly (65+)	3017 (1509–4525)	9.3%
Gender	Male	19,425 (14,682–24,168)	60.0%
	Female	12,975 (9188–16,761)	40.0%
Race	White	17,741 (12,945–22,538)	54.8%
	Black	3534 (1814–5253)	10.9%
	Asian	294 (38–550)	0.9%
	American Indian	153 (0–368)	0.5%
	Unknown/other	10,678 (5125–16,231)	33.0%

scooter injuries was noted for millennials (aged 22 to 39) from 2016 to 2017 (+77.0%, Fig. 2). Injury trends over time, stratified by age group, are displayed in Supplemental Table 1.

3.2. Risk factors for admission

Demographic characteristics of scooter injury patients are described in Table 1. The majority of patients were white (54.8%) and male (60.0%). Scooter injuries occurred more frequently on weekend days (Fig. 3). Patient dispositions are described in Table 2. 90.8% of patients were discharged from the ED after treatment, 5.6% were admitted, 1.5% were transferred to another facility, 0.8% were held for observation, and 1.3% left without being seen. There were no fatalities. Univariate analyses of factors associated with admission to the hospital are displayed in Table 4. Binomial logistic regression analysis (Table 5) revealed major orthopaedic injury (fracture/dislocation, amputation, crush injury; OR = 17.75, 95% C.I. 14.57–21.61, $p < 0.001$), internal organ injury (OR = 13.83, 95% C.I. 11.01–17.38, $p < 0.001$) concussion (OR 4.06, 95% C.I. 2.10–7.82, $p < 0.001$), male gender (OR 2.60, 95% C.I. 2.26–2.99, $p < 0.001$), weekday presentation (OR = 2.51, 95% C.I. 2.15–2.93, $p < 0.001$), White race (OR = 2.26, 95% C.I. 1.89–2.69, $p < 0.001$), and each additional year of older age (OR = 1.044, 95% C.I. 1.041–1.046, $p < 0.001$) were independent predictors of hospital admission after motorized scooter injury.

Table 2
Patient diagnoses and disposition after presentation to emergency department with motorized scooter injury.

		Number of patients (95% C.I.)	Percentage of total
Diagnosis	Fracture/dislocation	8405 (6346–10,305)	25.9%
	Contusion	8366 (5632–11,101)	25.8%
	Laceration/avulsion	4912 (3623–6201)	15.2%
	Internal organ injury	3526 (2327–4725)	10.9%
	Other/unreported	3308 (1889–4727)	10.2%
	Sprain or strain	2367 (1288–3445)	7.3%
	Concussion	824 (364–1283)	2.5%
	Dental Injury	253 (18–488)	0.8%
	Burn	275 (11–539)	0.8%
	Hematoma	143 (0–345)	0.4%
	Amputation	14 (0–43)	<0.1%
	Crush	10 (0—22)	<0.1%
Disposition	Treated & released	29,426 (23,368–35,484)	90.8%
	Admitted to inpatient	1815 (972–2657)	5.6%
	Treated & transferred	472 (137–807)	1.5%
	Left without being seen	416 (0—1023)	1.3%
	Held for observation	271 (0–624)	0.8%

3.3. Distribution of injury

The anatomic distribution of motorized scooter injuries is demonstrated in Fig. 4. Head injuries were most common, representing 27.6% of all injuries. Patient diagnoses are described in Table 2. The most common injuries were fracture or dislocation (25.9%), contusion (25.8%), and laceration (15.2%). Of the 8405 (95% C.I. 6346–10,305) fracture/dislocations, 78 (95% C.I. 0–182) were dislocations. There were an estimated 14 (95% C.I. 0–43) (<0.1%) amputations reported in the last five years. The anatomic locations of fracture/dislocations are further described in Table 3. The wrist and lower arm constituted 35.4% of fractures or dislocations.

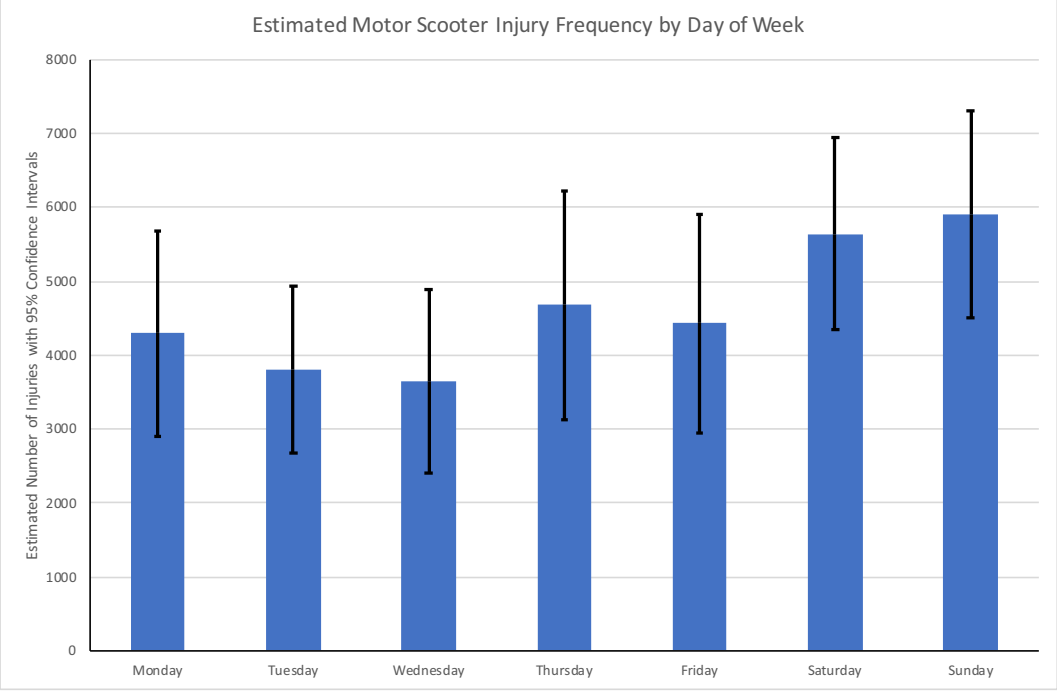

Fig. 3. Estimated motor scooter injury frequency by day of the week. *95% confidence interval bands around estimates.

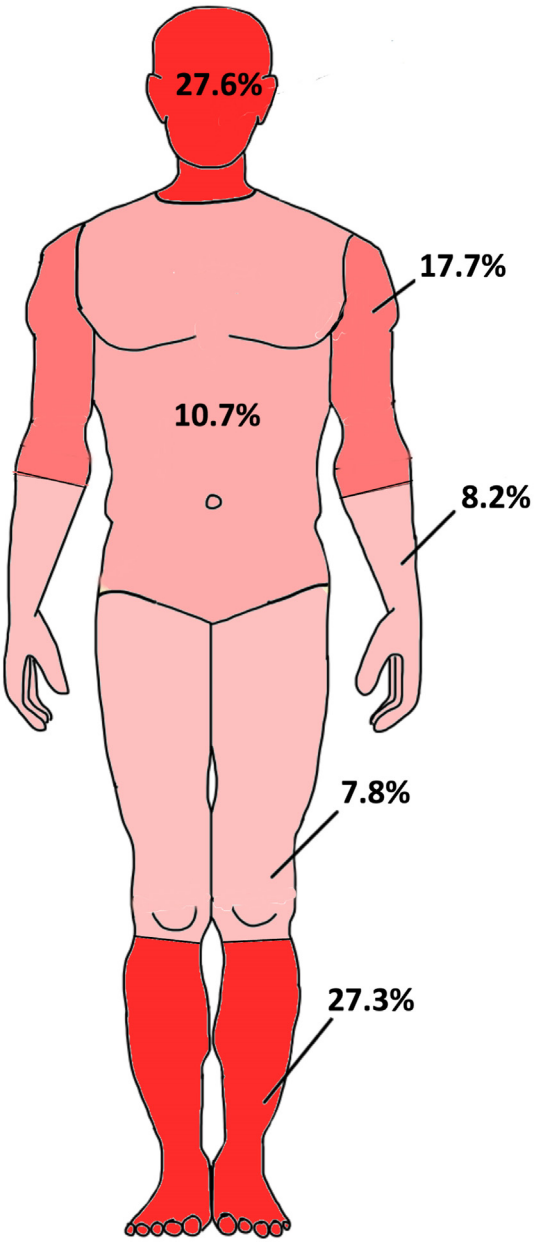

Fig. 4. Anatomic distribution of motorized scooter injuries.

4. Discussion

4.1. Epidemiology of motorized scooter injuries

Motorized scooter use has become exceedingly popular since the mainstream launch of scooter share companies in 2017, with Bird and Lime each reporting >10 million rides since launch [3]. Although we were unable to detect a significant difference in incidence between 2013 and 2017, it is reasonable to anticipate a significant increase in the incidence of motorized scooter related injuries as their use continues to rise. This is particularly relevant for millennials, for whom we noted a discrete uptick in injuries between 2016 and 2017. This study is likely underestimating the true burden of motorized scooter injuries, as our data ends in 2017 and scooter share companies did not become widely popular until 2018 [3]. Despite this limitation, we believe it is important to characterize patterns of use, injury profiles, and outcomes for motorized scooter riders.

The majority of injuries occurred in school age children (34.6%), who likely represent the majority of riders prior to scooter-shares. Bird and Lime prohibit children from riding their devices [14,15], however, media reports of underaged users remain prevalent [16]. While several states have helmet regulations for young bicycle riders, these regulations may not extend to electric kick scooter riders. If states do not have laws protecting young users of electric-scooters, state legislation should be considered.

The literature suggests that alternative transportation methods are getting safer, or at least utilization is decreasing. Skateboard injuries continue to decline [8]. Bicycle injury severity may be decreasing [17]. In 2017, motorcycle accidents decreased by 5.6% from the previous year [18] and motorcycle related injuries decreased 3% from 2014 to 2015 [19]. These safety improvement trends highlight the urgency in studying motorized scooters, a new and potentially dangerous form of transportation.

4.2. Risk factors for hospitalization

Multivariate analysis (Table 4) revealed older age, white race, and male gender were demographic factors that independently predicted hospitalization after motorized scooter injury. Older people have been shown to have more severe injuries in other trauma settings [20]. Older individuals who choose to ride motorized scooters should exercise particular caution as they are at increased risk of serious injury. Although weekend injuries were more common (Fig. 3), weekday presentation was associated with increased odds of hospitalization. Similarly, weekday motor vehicle collisions have been previously associated with increased hospitalization [21], however, the underlying cause of these variations is not clear.

4.3. Head injuries and concussions

Head injuries constituted 27.6% of all injuries and were the most common site of injury. This striking number has the potential to serve as a foundation for future legislation requiring head protection for motorized scooter riders. Furthermore, concussions were diagnosed in 2.5% of patients, with an associated four-fold increased risk of hospital admission. Concussions are notoriously difficult to diagnose [26] and are routinely underdiagnosed in emergency settings [27]. Therefore, our data likely grossly underestimates the true concussion incidence in this cohort.

Helmet laws are already an area of controversy for scooter share companies. California recently passed a state law removing helmet regulations for electric scooter riders over the age of 18 [28]. This is

Table 3
Anatomic distribution of fractures and dislocations.

		Number of patients ($n = 8405$)	Percentage of total
Head/neck	Skull	40 (0–82)	0.5%
	Facial	497 (142–852)	5.9%
	Neck	156 (0–377)	1.9%
Trunk	Upper trunk	401 (104–696)	4.8%
	Lower trunk	468 (101–835)	5.6%
Upper extremity	Shoulder	359 (70–649)	4.3%
	Upper arm	184 (0–408)	2.2%
	Elbow	277 (0–625)	3.3%
	Lower arm	1688 (890–2386)	20.1%
	Wrist	1290 (665–11,916)	15.3%
	Hand	108 (0–272)	1.3%
	Finger	176 (0–354)	2.1%
	Upper leg	94 (0–197)	1.1%
	Knee	57 (0–145)	0.7%
Lower extremity	Lower leg	1293 (643–1943)	15.4%
	Ankle	592 (267–916)	7.0%
	Foot	429 (110–748)	5.1%
	Toe	296 (26–566)	3.5%

Table 4
Univariate analysis of factors associated with inpatient admission following motorized scooter injury.

Factor		Not admitted ($n = 30,585$)		Inpatient admission ($n = 1815$)	
		Percentage	95% C.I.	Percentage	95% C.I.
Gender	Male	93.4% (18,147)	91.1–95.2%	6.6% (1279)	4.8–8.9%
	Female	95.9% (12,439)	90.1–98.3%	4.1% (536)	1.7–9.9%
Race	Non-White	96.6% (5100)	90.5–98.9%	3.4% (177)	1.8–9.5%
	White	92.4% (16,400)	88.5–95.1%	7.6% (1341)	1.6–4.9%
Time	Weekday	93.0% (19,393)	89.9–95.2%	7.0% (1456)	4.8–10.1%
	Weekend	96.9% (11,192)	93.6–98.5%	5.6% (1815)	1.5–6.4%
Age		26.8 (16) years[a]	23.0–30.5 years	49.1 (49) years[a]	38.8–59.5 years

[a] Mean with median in parentheses.

particularly concerning, given legislation requiring helmet use in other modes of transportation, including motorcycles and mopeds, has been shown to reduce the burden of maxillofacial injury and traumatic brain injury [29]. In our study, 6.4% of all fractures involved facial bones or the skull. These injuries could have potentially been averted with helmet use. Additionally, universal helmet laws for motorcycles and mopeds, such as those proposed in California and Rome, Italy, have been shown to be effective in increasing the proportion of helmet users from <20% to over 96% [30]. This study highlights the risk of head injuries associated with motorized scooter use. Regulatory bodies should consider the data in this study as part of the scientific foundation supporting helmet regulation for motorized scooter riders.

4.4. Orthopaedic injuries and preventative measures

Orthopaedic injuries were very common. The most common diagnosis was a fracture or dislocation (Table 2). Upper extremity fractures or dislocations accounted for nearly half of all orthopaedic injuries, with "wrist" and "lower arm" being the most common sites of injury. Furthermore, major orthopaedic injuries were an independent risk factor for admission to the hospital after motorized scooter injury, perhaps implying that these patients required surgical treatment.

Wrist guards have been demonstrated to reduce the risk of fractures in biomechanical cadaveric studies [22-24], and in the skiing/snowboarding literature, another medium-energy mechanism [25]. Given the frequency of upper extremity fractures in our study, we strongly advocate the use of wrist guards while riding motorized scooters until more specific research evaluating their efficacy becomes available. In addition to wrist guards, any reduction in speed would decrease the energy of collisions and likely decrease the risk of serious orthopaedic injury for motorized scooter riders. Further research efforts should examine potentially safer scooter designs, such as more rugged wheels or three-wheeled scooters.

4.5. Limitations

This study examining data from the NEISS has inherent limitations. The NEISS does not include nuanced pre-hospital data, comprehensive clinical data, or detailed outcomes after initial triage in the ED. This dataset does not include injuries that did not present to an emergency department and thus likely underestimates the true incidence of motorized scooter injuries. As previously stated, it is likely that motorized scooter injuries have increased substantially in the last year, alongside the increase in scooter use, but 2018 NEISS data is not yet available [3]. The NEISS underreports mortality as it excludes pre-hospital and post-hospital deaths. NEISS narratives are imprecisely transcribed. Data on race was unknown for approximately one-third of the patients in the study, limiting our ability to meaningfully comment on racial differences in motorized scooter injuries. Additionally, based on review of the narratives, our data may include some injuries from mechanisms other than motorized scooters. The NEISS has distinct codes for moped (3215), dirt bike (5036) and minibikes (5035). The NEISS coding manual further specifies that powered wheelchair and motorcycle injuries should not be included in the dataset [31]. On review of the narratives, however, it was clear that some motorbike and wheelchair related injuries were misclassified and appeared in the initial database. To counter this potential confounder, we performed a search and exclusion of potentially miscoded patients as described in the methods. Despite these efforts, the data likely includes some misclassified wheelchair injuries. These potential inclusions are likely of minimal significance as a small fraction of the patients in the study are elderly. Lastly, we were unable to determine if patients in the study were intoxicated. Scooter use while under the influence of alcohol is an important safety concern. Future studies should consider the additional risks of scooter operation while intoxicated, as many individuals who would otherwise use a taxi, or walk, may be riding scooters.

Table 5
Multivariate analysis of independent predictors of inpatient admission following motorized scooter injury.

Factor	Odds ratio (OR)	*p*-Value	95% C.I.
Major orthopaedic injury[a,b]	17.75	<0.001	14.57–21.61
Internal organ injury[a]	13.83	<0.001	11.01–17.38
Concussion[a]	4.06	<0.001	2.10–7.82
Male gender	2.6	<0.001	2.26–2.99
Weekday presentation	2.51	<0.001	2.15–2.93
White race	2.26	<0.001	1.89–2.69
Age (years)	1.044	<0.001	1.041–1.046

[a] Reference category is soft tissue injury (hematoma, contusion, sprain and strain).
[b] Includes fracture, dislocation, amputation, and crush injuries.

5. Conclusions

Head injuries are the most common site of injury for motorized scooter riders presenting to the ED. A significant proportion of these patients had fractures and/or concussions. Extremity fractures or dislocations were the most common diagnosis. Through a better understanding of the injury pattern associated with motorized scooter use, stronger injury prevention efforts can be devised and future serious injuries can be averted. Future legislation to improve the safety of motorized scooters could consider strategies such as helmet use, extremity pads, and speed limits to protect riders from potentially devastating injuries during motorized scooter use.

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ajem.2019.03.049.

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