Injuries related to electric scooter and bicycle use in a Washington, DC, emergency department

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ABSTRACT

Objective: E-scooter use has grown rapidly in the United States. Its rise in popularity has coincided with the promotion of cycling in many cities, but more needs to be known about how these transportation modes compare to determine if cycling should serve as an appropriate benchmark for policy decisions and safety expectations regarding e-scooters.

Methods: We examined characteristics of adults seeking treatment in a Washington, DC, emergency department (ED) for injuries associated with riding e-scooters during 2019 (n = 103) or bicycles during 2015–2017 (n = 377).

Results: E-scooter incidents less frequently involved moving vehicles (12.6% vs. 39.5%) or occurred on roads (23.5% vs. 50.9%) than cycling incidents. Similar proportions were admitted to the hospital (8.7% vs. 8.5%) or received maximum Abbreviated Injury Scale (AIS) scores of 0–1 (62.1% vs. 59.1%) or 2 (35.9% vs. 36.0%). E-scooter riders less often sustained injuries with AIS ≥ 3 (1.9% vs. 4.8%; RR, 0.41; 95% CI, 0.10–1.41), indicating serious injury, but this difference was not statistically significant in regression controlling for age and sex. Distal lower extremity injuries were more common among e-scooter riders (14.6% vs. 4.5%; RR, 2.53; 95% CI, 1.66–3.35), and injuries to the proximal upper extremity (8.7% vs. 19.1%; RR, 0.50; 95% CI, 0.25–0.95) or chest, abdomen, and spine (2.9% vs. 13.0%; RR, 0.24; 95% CI, 0.08–0.71) were less common. Head injury rates were similar, but e-scooter riders more often experienced concussion with loss of consciousness (3.9% vs. 0.8%; RR, 2.84; 95% CI, 1.13–4.12) and were far less likely to wear helmets (1.9% vs. 66.0%). Estimated ED presentation rates per million miles traveled citywide were higher among e-scooter riders than cyclists (RR, 3.38; 95% CI, 2.77–4.13).

Conclusions: Injury severity was largely similar between cyclists and e-scooter riders despite the differences in circumstances leading to their injuries. E-scooter rider injury rates, though currently high, may decrease as they gain experience; however, if the number of new users continues to climb, they will persist in using the ED more often than cyclists per mile that they travel. Promotion of helmets among e-scooter riders could prevent serious head injury.

INTRODUCTION

Shared micromobility has grown rapidly in the United States, with 38.5 million trips logged on shared standing electric scooters (e-scooters) in 2018 and 86 million trips in 2019 (National Association of City Transportation Officials 2020). An estimated 14,000 e-scooter riders were treated in U.S. emergency departments (EDs) and over 1,000 were hospitalized in 2018 (Namiri et al. 2020).

Cities have grappled with how to fold e-scooters into existing infrastructure and regulation as this new mode has proliferated. Bicycles arguably represent a similar form of transportation, given their use within shared micromobility programs and suitability to urban transport. Accordingly, some cities subject e-scooter riders to the same rules as cyclists concerning behavior such as sidewalk riding or encourage e-scooters to use bike lanes.

Evidence comparing the circumstances leading to injuries, injury rates, and injury types of cyclists and e-scooter riders is needed to assess if cycling should serve as an appropriate benchmark for policy decisions and safety expectations regarding e-scooters. Early research has demonstrated some differences between them. E-scooter riders treated in EDs nationally during 2000–2017 were more likely to sustain fractures than cyclists (DiMaggio et al. 2019). During 2017–2018, Watson et al. (2020) reported differences in the distribution of body parts injured by e-scooter riders and cyclists presenting to EDs in a national sample and estimated higher injury rates per hour traveled among e-scooter riders than cyclists.

The goal of the current study was to compare personal and injury characteristics between e-scooter riders and cyclists presenting to a single ED in Washington, DC, and to assess estimated rates of presentation to the ED per mile traveled citywide by these modes. By November 2019, eight operators deployed over 4,600 e-scooters in Washington, DC, and the city was among the top six in ridership in the United States (National Association of City Transportation Officials 2020). While differences between injured cyclists and e-scooter riders have been identified nationally, it is unclear how they would persist within a single area where riders of both modes are exposed to similar environmental characteristics; e-scooters are available in select cities, while national statistics for cycling injuries include those occurring in urban, suburban, and rural areas. Additionally, while emerging research has begun to identify the types of injuries sustained by e-scooter riders treated in emergency departments (e.g., Badeau et al. 2019; Puzio et al. 2020; Trivedi et al. 2019), most has consisted of retrospective chart reviews and less is known about the circumstances under which e-scooter riders are injured. We combined rider interviews with medical record reviews to provide a richer picture of how these injuries occur.

METHODS

Data collection

Shared e-scooters were first deployed in Washington, DC, in March 2018. We prospectively recruited injured e-scooter riders from March 23 to November 30, 2019, who sought treatment at the ED of George Washington University Hospital, an urban academic medical center with an annual ED census of 75,000 patient visits. We had previously recruited cyclists from April 14, 2015, to September 30, 2017, presenting to the George Washington University ED as part of an earlier multisite study on infrastructure (Cicchino et al. 2020), and we compare the e-scooters recruited in 2019 to this group of cyclists in this paper. The George Washington University Institutional Review Board approved both protocols.

E-scooter riders and cyclists were required to be age 18 years or older and English-speaking to be eligible to enroll, and were ineligible if they were unable to communicate with ED staff or understand consent, injured outside the hospital's catchment area, injured more than one week prior, left the ED without being seen by a physician, or were previously enrolled for the same trip (Figure 1). Cyclists were additionally excluded if they were trick riding or racing or riding with more than one person on a bicycle. We also collected data from nonriders injured by e-scooters (e.g., pedestrians that tripped over scooters) not reported here. E-scooter riders were compensated $10 for participating; cyclists were not compensated. Participants were screened and enrolled in the ED during hours research assistants were present, which were 8:00 a.m. (during 2015–2017) or 9:00 a.m. (during 2019) to 10:00 p.m., or in the hospital if admitted. The original goal of collecting data on e-scooter riders was to examine their characteristics independently, which is why the eligibility criteria and compensation did not exactly match that for cyclists. Although the differences in time periods of data collection and eligibility criteria were not ideal, they allowed for a cost-effective opportunity to compare these groups of road users by drawing on existing data on cyclists.

Trained research assistants interviewed enrolled participants on the characteristics of their trip and injury incident using a structured questionnaire. The questionnaire for e-scooter riders was derived from the survey previously administered to cyclists. A research assistant abstracted medical records of participants and coded each injury sustained using the Abbreviated Injury Scale (AIS) (Gennarelli & Wodzin 2008). AIS coding was checked for errors by a second researcher.

Estimated ED visits per mile traveled

We estimated rates of presentation to the ED per mile traveled using all screened adults who were injured while riding an e-scooter or bicycle in the hospital's catchment area in the past week during March to November in the numerator (Figures A1 and A2, see the Appendix) to match groups on seasonality.

We obtained the number of trips and miles ridden by e-scooters in Washington, DC, during the study period from the District Department of Transportation (DDOT), which received monthly trip reports from shared e-scooter operators. The number of bicycle trips citywide was extrapolated from the average number of bicycle commuters in Washington, DC, during 2015 to 2017 reported by the American Community Survey (United States Census Bureau 2015, 2016, 2017). We multiplied the number of e-scooter and cycling trips estimated citywide by the mean trip lengths prior to injury among study participants to determine total miles traveled. The Appendix describes our methods for estimating the number of trips and calculating rates in greater detail. We performed sensitivity analyses, also described in the Appendix, that varied assumptions to extrapolate the number of bicycle trips from commuting data and restricted the sample to exclude riders who did not complete their entire trip within Washington, DC.

Analysis

We compared enrolled e-scooter riders and cyclists by trip and demographic characteristics using the χ^2 test for proportions and the *t* test for means. Logistic regression was used to compare riders on evaluation, treatment, and injury characteristics, controlling for age and sex. Odds ratios from logistic regression models were transformed to relative risks using the method of Zhang and Yu (1998). We also present rate ratios and corresponding 95% confidence intervals (CIs) comparing estimated ED presentation rates per mile traveled between groups.

RESULTS

Demographic and trip characteristics

During the 2015–2017 study period, 617 individuals presented to the ED who were potentially injured while cycling, and during the 2019 period, 148 individuals presented who were potentially injured by e-scooter (Figure 1). We excluded 32 (7 possible e-scooters, 25 possible cyclists) who were missed prior to screening, 156 (27 possible e-scooters, 129 possible cyclists) who were ineligible, and 97 who were eligible but refused to participate or withdrew (11 e-scooters, 86 cyclists). The sample of 480 interviewed participants (320 [66.7%] male; mean [SD] age, 38.6 [13.5]) included 103 e-scooter riders and 377 cyclists.

Compared with cyclists, interviewed e-scooter riders were more often female or age 50 years or older (Table 1). A greater proportion of their trips occurred on weekends or at night. E-scooter riders less often wore helmets (2 e–scooter riders [1.9%] vs. 248 cyclists [66.0%]; $p < .001$). Their trips were more frequently for social purposes (39 [37.9%] vs. 38 [10.1%]; $p < .001$), while the majority of cyclists (207 [55.1%]) were commuting. E-scooter incidents less frequently occurred on the road (24 [23.5%] vs. 192 [50.9%]; $p < .001$) and most often took place on the sidewalk (58 [56.9%]). Far fewer e-scooter riders than cyclists were injured in incidents involving moving vehicles (13 [12.6%] vs. 149 [39.5%]; $p < .001$); e-scooter riders were most commonly injured because of hazardous surface features (25 [24.3%]), infrastructure such as curbs (17 [16.5%]), or other falls (27 [26.2%]).

E-scooter trips prior to injury were on average about one fourth the length of cycling trips (mean [SD] miles, 1.05 [1.11] vs. 3.90 [6.02]; $p < .001$). About a third (37 [36.3%]) of e-scooter riders were using a scooter for the first time, while most (303 [80.6%]) cyclists reported biking most days of the week during the season they predominantly ride.

ED evaluation, treatment, and injury characteristics

Table 2 describes ED evaluation, injury characteristics, and treatments performed. E-scooter riders were less likely than cyclists to arrive by ambulance (41 [39.8%] vs. 195 [51.7%]; relative risk [RR], 0.63; 95% CI, 0.42–0.92). They also less often underwent imaging to the chest (13 [12.6%] vs. 114 [30.2%]; RR, 0.37; 95% CI, 0.20–0.66), abdomen (4 [3.9%] vs. 54 [14.3%]; RR, 0.29; 95% CI, 0.11–0.75), and spine (3 [2.9%] vs. 46 [12.2%]; RR, 0.26; 95% CI, 0.08–0.77), and were less likely to have been injured in those areas (3 [2.9%] vs. 49 [13.0%]; RR, 0.24; 95% CI, 0.08–0.71). Seventeen cyclists [4.5%] were diagnosed with rib fractures and 9 [2.4%] with major intra-abdominal or intrathoracic injuries, including 5 with hemo/pneumothorax, 5 with pulmonary contusions, and 3 with liver or spleen lacerations; no e-scooter riders received these diagnoses.

Similar proportions of e-scooter riders and cyclists were diagnosed with head or neck injuries (7 [6.8%] vs. 30 [8.0%]), but the types of head injuries differed. E-scooter riders more often sustained concussions with loss of consciousness (4 [3.9%] vs. 3 [0.8%]; RR, 2.84; 95% CI, 1.13–4.12). Additionally, 2 e-scooter riders and no cyclists experienced skull fractures.

Both groups frequently experienced extremity injuries, with the most common injury to the distal upper extremity. E-scooter riders less often injured the proximal upper extremity than cyclists (9 [8.7%] vs. 72 [19.1%]; RR, 0.50; 95% CI, 0.25–0.95), and more often experienced a distal lower extremity injury (15 [14.6%] vs. 17 [4.5%]; RR, 2.53; 95% CI, 1.66–3.35). A larger proportion of e-scooter riders than cyclists required splinting (49 [47.6%] vs. 122 [32.4%]; RR, 1.71; 95% CI, 1.25–2.23) or fracture or dislocation reduction (12 [11.7%] vs. 16 [4.2%]; RR, 2.12; 95% CI, 1.25–3.05).

Most riders were discharged home from the ED. Of the 9 (8.7%) e-scooter riders and 32 (8.5%) cyclists who were admitted or transferred, 4 cyclists (1.1%) and no e-scooter riders were admitted to the intensive care unit. Similar proportions of e-scooter riders and cyclists sustained no injuries or had maximum AIS scores of 1 (64 [62.1%] vs. 220 [59.1%]) or 2 (37 [35.9%] vs. 134 [36.0%]). Although slightly more cyclists than e-scooter riders had maximum AIS scores of 3 or greater (2 [1.9%] vs. 18 [4.8%]), indicating serious injury, the difference was not significant (RR compared with maximum AIS 0–1, 0.41; 95% CI, 0.10–1.41).

Estimated ED visits per mile traveled

We estimate that 20.7 (95% CI, 17.3–24.7) e-scooter riders sought treatment in the ED during enrollment hours in March to November per million miles traveled citywide, compared with 6.1 cyclists (95% CI, 5.6–6.7) (Table 3). More cyclists presented to the ED per month than e-scooter riders (20 cyclists compared with 15 e-scooter riders screened monthly during March to November), but estimated miles traveled were higher among cyclists. Higher ED visit rates per mile traveled for e-scooter riders persisted in sensitivity analyses where we used different assumptions to estimate total cycling trips from commuting trips and restricted the sample to riders whose trips occurred entirely in Washington, DC (Table A1, see the Appendix).

DISCUSSION

E-scooters and bicycles are both popular forms of micromobility, but the characteristics of riders injured on them and the ways in which they become injured differ substantially. We found in this analysis that in Washington, DC, injured cyclists tend to be regular riders biking for utilitarian reasons, while injured e-scooter riders are more often infrequent users who are riding for social reasons. Cyclists are more frequently injured in the road in incidents involving motor vehicles, and e-scooter riders sustain more injuries on sidewalks and due to uneven surface features. Countermeasures to prevent cycling injuries implemented by cities primarily focus on providing facilities for cyclists to ride where they are separated from motor vehicles (DiGioia et al. 2017). Because the circumstances leading to e-scooter riders' injuries are so different, treatments such as bike lanes and other vehicle-separated facilities have the potential to prevent a smaller proportion of their injuries. E-scooters have a harder time handling uneven pavement and other obstacles because of their smaller tires, and their riders may especially benefit from better maintenance of the surfaces they use the most.

It was surprising that injury severity was remarkably similar between the rider groups given the differences in how they sustained their injuries. Similar proportions had maximum AIS scores of 0–1 or 2 injuries and were admitted to the hospital. There were disparities in the types of injuries sustained, however, that likely reflect the dissimilar injury mechanisms. Cyclists more often had injuries to the chest, abdomen, and spine, including some major intra-abdominal or intrathoracic injuries. These injuries may result from the larger proportion of cyclists involved in motor vehicle crashes, higher speeds among cyclists than e-scooters, and handlebar position (Amoros et al. 2011; Beck et al. 2019; Thompson & Rivara 2001; Tin Tin et al. 2010).

Head injury rates were similar in both groups, but some serious head injury types were more prevalent among e-scooter riders. This was unexpected since motor vehicle crashes, which were seen most often among cyclists, are linked with head injury (Malczyk et al. 2014). Like the findings in observational and other ED studies (English et al. 2020; Trivedi et al. 2019), we documented very low helmet use among injured e-scooter riders, while two thirds of cyclists were helmeted. Helmets are well-established to reduce head injury risk (Thompson et al. 1999), and the lack of helmet use among e-scooter riders likely contributed to their head injuries.

We estimated that e-scooter riders are injured more often per mile that they travel, which is consistent with national trends (Watson et al. 2020) and reports observing more e-scooter riders than cyclists presenting to EDs during equivalent time periods (Puzio et al. 2020; Trivedi et al. 2019). It remains to be seen if this gap in injury rates will persist as e-scooter riders gain more experience and e-scooter sharing programs mature; for other modes, such as cycling (Poulos et al. 2015), inexperience increases crash risk. Over a third of injured e-scooter riders in our study were using a scooter for the first time. However, if e-scooter ridership growth persists, there will continue to be new, inexperienced riders well into the future.

A strength of this study is that we learned through interviews about injury mechanisms and could confirm with patients that they were riding e-scooters, which can be challenging to identify retrospectively (English et al. 2020). This also introduced the limitation that riders who refused to be interviewed or presented after hours were excluded. Other limitations should also be noted. Some riders excluded because they were too injured to communicate may have had more severe injuries. Because this study used data on cyclists that had been previously collected for a different study, e-scooter riders were injured in a different year than cyclists. Cyclists and e-scooter riders were subject to different exclusion criteria and incentives for participation, which resulted in fewer excluded e-scooter riders. It is unclear how these variations between study groups affected injury outcomes. Data from a single ED have limited generalizability. Washington, DC, requires that e-scooters be speed-limited at 10 mph, which is unique among programs in major U.S. cities.

Our estimate of ED visits per mile traveled include riders presenting to a single ED out of the five that serve adults in Washington, DC, but mileage represented travel citywide. Thus, the rates we report are smaller than the actual rate of riders treated in EDs throughout Washington, DC, and are lower than injury incident rates per mile traveled reported from comprehensive citywide surveillance of e-scooter riders treated in EDs in Austin, TX (English et al. 2020). The difference in rates between e-scooter riders and cyclists may be over- or underestimated if a larger proportion of use for one mode occurred more often near George Washington University Hospital.

Our values for cyclist miles traveled were extrapolated from commuting trip data and were a less accurate measure than what was available for e-scooter riders. However, ED presentation rates were consistently higher for e-scooter riders than cyclists when we varied the assumptions used to calculate them. Because mean trip lengths among cyclists were nearly four times as long as the average e-scooter trip, e-scooter riders would need to complete nearly three times as many trips as cyclists to result in equivalent ED presentation rates.

In summary, e-scooter riders in Washington, DC, are involved in more incidents leading to ED presentation per mile traveled than cyclists. The severity of the injuries they sustain are largely similar despite differences in injury mechanisms, but the types of injuries differ. Our findings suggest that promoting helmet use and offering well-maintained surfaces for e-scooters to ride on could decrease their injuries. While some solutions to prevent cycling and e-scooter injuries are similar, such as promoting helmet use, the differences in how they are injured suggest that cyclists serve as an imperfect benchmark of what to expect in terms of e-scooter rider safety. Decisions regarding countermeasures to implement to make e-scooter riding safer should not be made solely based on what has worked for other, more established forms of micromobility such as cycling.

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TABLES

Table 1. Demographic and trip characteristics of cyclists (2015–2017) and e-scooter riders (2019) seeking treatment in a Washington, DC, ED

Characteristic	**No. (%) or Mean ± SD** **E-scooter riders (n=103)**	**Cyclists (n=377)**	***p* Value**[a]
Demographic characteristics			
Age (years)			
18–29	34 (33.0)	114 (30.2)	.02
30–49	35 (34.0)	181 (48.0)	
50+	34 (33.0)	82 (21.8)	
Female	49 (47.6)	111 (29.4)	<.001
Race/ethnicity[b]			
White, non-Hispanic	62 (61.4)	259 (70.0)	.33
Black, non-Hispanic	13 (12.9)	47 (12.7)	
Hispanic	13 (12.9)	32 (8.7)	
Asian/Pacific Islander	7 (6.9)	13 (3.5)	
Other	6 (5.9)	19 (5.1)	
College degree or higher[b]	72 (70.0)	306 (81.4)	.01
Trip characteristics			
Wore helmet[b]	2 (1.9)	248 (66.0)	<.001
Rode shared or rental e-scooter/bike[b]	87 (85.3)	27 (7.2)	<.001
Mean trip length (miles)[c]	1.05 ± 1.11	3.90 ± 6.02	<.001
Entire trip in Washington, DC[d]	84 (94.4)	276 (73.6)	<.001
Weekend	33 (32.0)	60 (15.9)	<.001
Time of day[b]			
7 a.m.–2:59 p.m.	58 (56.9)	261 (69.2)	.003
3 p.m.–10:59 p.m.	31 (30.4)	100 (26.5)	
11 p.m.–6:59 a.m.	13 (12.8)	16 (4.2)	
Riding frequency[b,e]			
First time	37 (36.3)	N/A	N/A
Less than weekly	18 (17.7)	18 (4.8)	
At least once a week, but not most days	16 (15.7)	55 (14.6)	
Most days	31 (30.4)	303 (80.6)	
Trip purpose[b]			
Social reasons (e.g., movies, visit friends)	39 (37.9)	38 (10.1)	<.001
Commute to/from work	25 (24.3)	207 (55.1)	
Recreation	19 (18.5)	70 (18.6)	
Personal business (e.g., errands)	18 (17.5)	37 (9.8)	
To/from school	0	7 (1.9)	
Other	2 (1.9)	17 (4.5)	
Intersection[b]	35 (34.3)	130 (34.5)	.97
Location[b]			
Sidewalk	58 (56.9)	55 (14.6)	<.001
Road	24 (23.5)	192 (50.9)	
Off-road/multiuse trail	10 (9.8)	54 (14.3)	
Bike lane	8 (7.8)	71 (18.8)	
Alley, driveway, parking lot	2 (1.9)	5 (1.3)	

Table 1. Demographic and trip characteristics of cyclists (2015–2017) and e-scooter riders (2019) seeking treatment in a Washington, DC, ED (continued)

Characteristic	No. (%) or Mean ± SD		*p* Value[a]
	E-scooter riders (n=103)	Cyclists (n=377)	
Mechanism of injury[f]			
Moving vehicle[g]	13 (12.6)	149 (39.5)	<.001
Parked or stopped vehicle	2 (1.9)	46 (12.2)	
Pedestrian	12 (11.7)	20 (5.3)	
Cyclist or scooter[h]	3 (2.9)	22 (5.8)	
Surface feature (e.g., potholes, uneven pavement)	25 (24.3)	51 (13.5)	
Infrastructure (e.g., curb, pole, fence)	17 (16.5)	19 (5.0)	
Other fall	27 (26.2)	67 (17.8)	
Other mechanism	4 (3.9)	3 (0.8)	

Abbreviations: ED, emergency department; N/A, not applicable.

[a]Determined through χ^2 test or proportions and *t* test for means.

[b]Proportions exclude cases with missing data; <2% missing

[c]Data on trip length were missing for 12 e-scooter riders (11.7%).

[d]Data on trip location were missing for 14 e-scooter riders (13.6%) and 2 (0.5%) cyclists.

[e]Responses are not compared by user type because the question differed. E-scooter riders were asked how often they rode during the past month; cyclists were asked how often they ride during the season when they ride the most. Cyclists did not have a response option of “first time”.

[f]Unless specifically labeled as a fall, mechanisms included crashes with and falls to avoid listed element

[g]10 (9.7%) e-scooter riders and 132 cyclists (35.0%) crashed with moving vehicles.

[h]1 e-scooter rider collided with another scooter. Other crashes and falls in this category involved collisions with or falls to avoid cyclists.

Table 2. ED evaluation, treatment, and injury characteristics of cyclists (2015–2017) and e-scooter riders (2019) seeking treatment in a Washington, DC, ED

Characteristic	No. (%) E-scooter riders (n=103)	Cyclists (n=377)	RR (95% CI)[a]
Arrived by ambulance	41 (39.8)	195 (51.7)	0.63 (0.42, 0.92)
Imaging performed in ED			
Head or neck	30 (29.1)	90 (23.9)	1.20 (0.81, 1.70)
Chest	13 (12.6)	114 (30.2)	0.37 (0.20, 0.66)
Abdomen	4 (3.9)	54 (14.3)	0.29 (0.11, 0.75)
Spine	3 (2.9)	46 (12.2)	0.26 (0.08, 0.77)
Extremity	69 (67.0)	250 (66.3)	1.00 (0.68, 1.42)
FAST	4 (3.9)	17 (4.5)	1.02 (0.38, 2.18)
Procedures performed in ED			
Wound care	36 (35.0)	166 (44.0)	0.74 (0.49, 1.07)
Laceration repair	25 (24.3)	82 (21.8)	1.12 (0.74, 1.63)
Splinting	49 (47.6)	122 (32.4)	1.71 (1.25, 2.23)
Fracture or dislocation reduction	12 (11.7)	16 (4.2)	2.12 (1.25, 3.05)
Admitted or transferred	9 (8.7)	32 (8.5)	1.05 (0.54, 1.83)
Procedures performed in hospital			
Orthopedic	5 (4.9)	18 (4.8)	1.11 (0.47, 2.18)
Neurosurgical	0	1 (0.3)	N/A
Other operative procedure	1 (1.0)	4 (1.1)	0.92 (0.11, 3.29)
Maximum AIS severity score[b]			
0–1 (no or minor injury)[c]	64 (62.1)	220 (59.1)	Reference
2 (moderate injury)	37 (35.9)	134 (36.0)	1.00 (0.68, 1.12)
3+ (serious injury)	2 (1.9)	18 (4.8)	0.41 (0.10, 1.41)
Body region injured[d]			
Head or neck[e]	7 (6.8)	30 (8.0)	0.90 (0.42, 1.70)
AIS 2+ head injury	4 (3.9)	6 (1.6)	1.97 (0.76, 3.43)
AIS 2+ concussion (with LOC)	4 (3.9)	3 (0.8)	2.84 (1.13, 4.12)
Skull fracture	2 (1.9)	0	N/A
Intracranial hemorrhage	1 (1.0)	3 (0.8)	0.98 (0.11, 3.43)
Face	9 (8.7)	22 (5.8)	1.30 (0.67, 2.20)
Chest, abdomen, or spine	3 (2.9)	49 (13.0)	0.24 (0.08, 0.71)
Extremity	52 (50.5)	169 (44.8)	1.27 (0.90, 1.73)
Upper extremity	35 (34.0)	146 (38.7)	0.89 (0.60, 1.28)
Upper extremity, proximal[f]	9 (8.7)	72 (19.1)	0.50 (0.25, 0.95)
Upper extremity, distal[g]	28 (27.2)	80 (21.2)	1.30 (0.88, 1.84)
Lower extremity	18 (17.5)	24 (6.4)	2.21 (1.47, 2.98)
Lower extremity, proximal[h]	3 (2.9)	7 (1.9)	1.21 (0.37, 2.74)
Lower extremity, distal[i]	15 (14.6)	17 (4.5)	2.53 (1.66, 3.35)
External	55 (53.4)	274 (72.7)	0.46 (0.30, 0.69)

Abbreviations: AIS, abbreviated injury scale; CI, confidence interval; ED, emergency department; FAST, focused assessment with sonography for trauma; LOC, loss of consciousness; N/A, not applicable; RR, relative risk.

[a]Adjusted for age and sex.

[b]Proportions exclude cases with unknown severity; <2% missing.

[c]2 e-scooter riders (1.9%) and 5 cyclists (1.3%) had maximum AIS of 0 (no injury).

[d]External injuries include lacerations, contusions, and abrasions, which are assigned to the external body region when calculating the Injury Severity Score (ISS). Injuries reported to other body regions exclude external injuries and otherwise are categorized based on the AIS rather than the ISS body regions.

[e]1 cyclist experienced a neck injury. Other injuries in this category are head injuries.

[f]Proximal upper extremity includes clavicle, scapula, shoulder, humerus.

[g]Distal upper extremity includes elbow, forearm, wrist, hand, finger.

[h]Proximal lower extremity includes pelvis, hip, femur. [i]Distal lower extremity includes knee, tibia/fibula, ankle, foot.

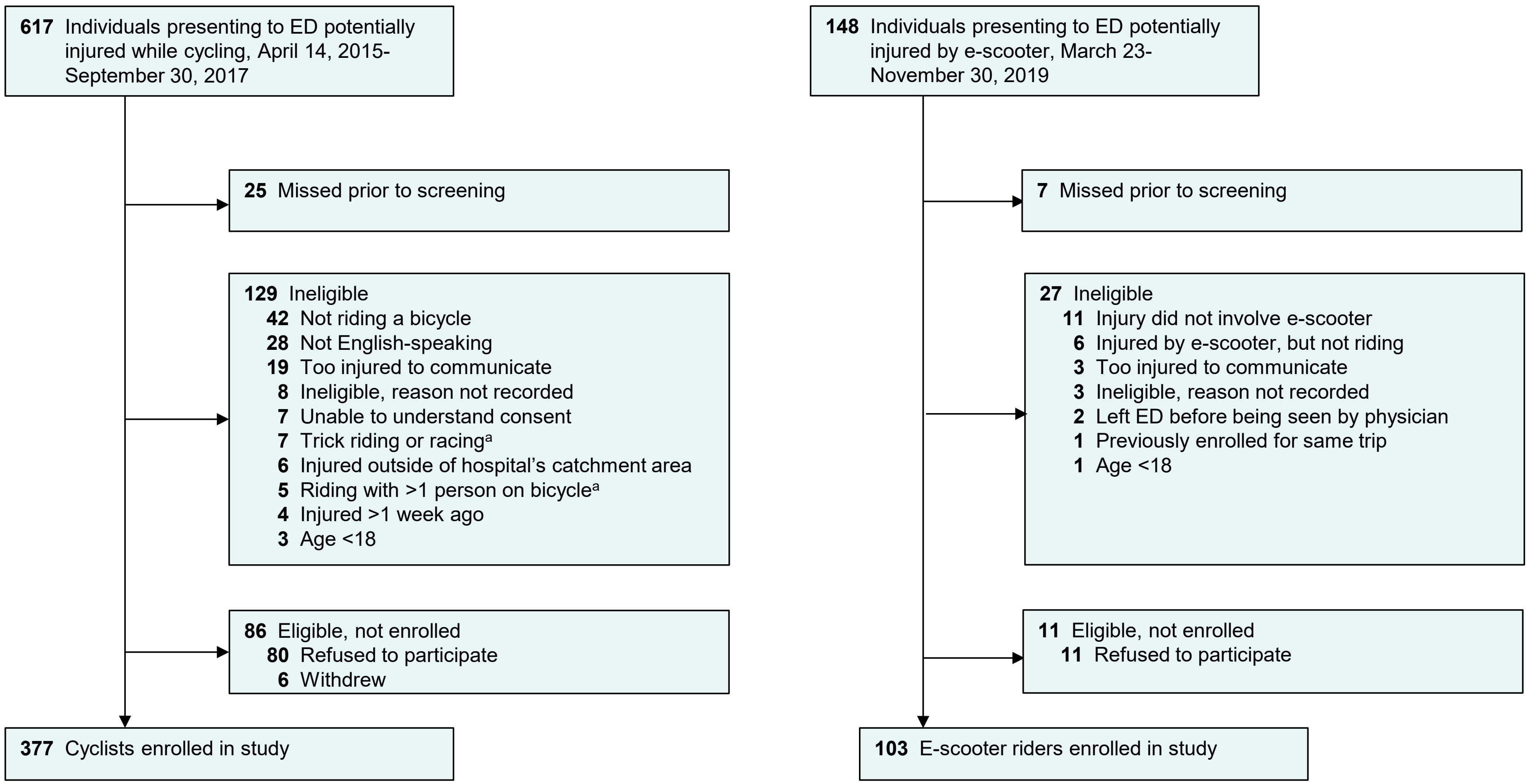
Table 3. Estimated ED visits per mile traveled in Washington, DC, March to November 2015–2017 (cyclists) or 2019 (e-scooter riders)

	No. screened		Estimated no. trips			Estimated miles traveled			
Type of rider	**Total**	**Per month**	**Total**	**Per month**	**Mean trip length (miles)**	**Total**	**Per month**	**ED visits per million miles traveled (95% CI)**	**RR (95% CI)**
E-scooter	121	15	5,573,966	669,757	1.05	5,852,664	703,245	20.7 (17.3, 24.7)	3.38 (2.77, 4.13)
Cyclist	483	20	20,259,552	855,403	3.90	79,012,252	3,336,073	6.1 (5.6, 6.7)	

Abbreviations: CI, confidence interval; ED, emergency department; RR, relative risk.

FIGURE 1

Figure 1. Identification of study sample from patients presenting to Washington, DC, ED during 2015–2017 (cyclists) or 2019 (e-scooter riders)



Abbreviations: ED, emergency department.
Note: Data were collected during hours that research assistants staffed the ED (8:00 a.m.–10:00 p.m. during 2015–2017, 9:00 a.m.–10:00 p.m. during 2019); patients presenting outside these hours were not captured.
[a]Riding with >1 person and trick riding or racing were exclusion criteria for bicyclists only.

APPENDIX: SUPPLEMENTAL METHODS

ED VISIT RATE CALCULATIONS

Number of ED visits

The number of emergency department (ED) visits that we used in rates per mile traveled included the adult cyclists (Figure A1) and e-scooter riders (Figure A2) who were screened during March to November and injured in the hospital's catchment area within the past week. Screened patients who were eligible and refused participation or withdrew, or were ineligible for enrollment because they were not English-speaking, too injured to communicate, unable to understand consent, left the ED without being seen by a physician, ineligible for a reason not recorded, or bicyclists trick riding or racing or riding with more than one person on a bicycle were included in the count of ED visits. Potential participants who were missed prior to screening, not injured while riding a bicycle or e-scooter, under age 18 years, injured outside of the hospital's catchment area, injured more than one week before their ED visit, or previously enrolled in the study were excluded. This process resulted in 483 cyclists and 121 e-scooter riders.

E-scooter exposure

Shared e-scooter operators in Washington, DC, submitted monthly data on the length and date of each trip taken to the District Department of Transportation (DDOT) and monthly summaries of the total number of trips. We extracted the number of trips during March 23 to November 30, 2019, from the data on individual trips and used counts from the monthly summary data for operators from whom trip-level data were unavailable. We adjusted the 4,737,871 trips reported by DDOT during this period to reflect that 85% of e-scooter riders in our sample reported riding shared e-scooters (Table 1), resulting in an adjusted total of 5,573,966 trips. The adjusted number of trips was multiplied by the average trip length among enrolled e-scooter participants of 1.05 miles (Table 1) to calculate miles traveled.

Bicycle exposure

There is no comprehensive measure of cycling exposure that exists for Washington, DC, and so we extrapolated cycling miles traveled from available sources. Our method of estimating cycling trips was derived loosely from Pucher and Buehler (2016) and the New York City Department of Transportation (2019). We obtained the number of people who commute by bicycle in Washington, DC, from the 2015, 2016, and 2017 American Community Survey, which is a yearly survey administered by the United States Census Bureau (2020) with an annual sample size of over 4,500 in Washington, DC, and with sampling weights used to compute population-level counts. We assumed that the average of 16,663 bicycle commuters (14,718 commuters in 2015, 16,647 in 2016, 18,624 in 2017; United States Census Bureau 2015, 2016, 2017) each made 339 commute trips per year, which was the mean number of annual commute trips per U.S. worker reported in the 2017 National Household Travel Survey (McGuckin & Fucci 2018), a nationally-representative survey of travel behavior that sampled 130,000 households. Based on these figures, we estimated that cyclists in Washington, DC, completed 5,648,757 commuting trips annually.

We assumed that the share of cycling trips that were made for commuting in Washington, DC, was equal to the share among enrolled study cyclists (55%; Table 1), and extrapolated that cyclists completed 10,270,467 total trips annually. There were 720 days when bicycle data were collected during the months of March to November, which resulted in an estimate of 20,259,552 total trips during these months of the study period. Trips were multiplied by the average cyclist trip length among enrolled cyclists of 3.90 miles (Table 1).

Sensitivity analyses

We also calculated injury rates under different trip length and bicycling commute share assumptions (Table A1). Our exposure data were drawn from Washington, DC, but study cyclists could have been injured in or part of their trip could have occurred in the greater metropolitan area. Average cycling trip lengths were shorter for cyclists whose entire trips occurred in Washington, DC, which would result in fewer total miles traveled. We multiplied the number of ED visits used in the primary incident rates by the proportion of enrolled riders with trips completely entirely in the District (Table 1; 94% of e-scooter riders and 74% of cyclists) to estimate that there were 114 e-scooter riders and 357 cyclists who presented to the ED where all exposure occurred in Washington, DC.

Among the enrolled riders whose trips occurred entirely within Washington, DC, mean trip length was 1.04 (SD 1.13) miles for e-scooter riders and 2.26 (SD 3.64) miles for cyclists. We additionally extracted trip lengths for all shared e-scooter trips completed in Washington, DC, from DDOT trip data; data were cleaned to remove implausibly long values of 100 miles or greater. Mean e-scooter trip length from this source was 0.93 (SD 1.12) miles. We used these trip lengths to compute ED visit rates per mile traveled for riders estimated to have only traveled in Washington, DC, prior to sustaining their injuries.

Our method of extrapolating total cycling trips from commuting trips was more conservative than prior studies, which assumed that bicycle commuters took two trips daily and that commuting trips made up 20% of all cycling trips (New York City Department of Transportation 2019; Pucher & Buehler 2016). Table A1 shows that the total estimated number of cycling trips would be larger, and thus cycling ED visit rates per mile traveled would be lower, if we assumed that 20% of trips were for commuting.

Supplemental references

McGuckin N, Fucci A. Summary of travel trends: 2017 National Household Travel Survey. Washington, DC: Federal Highway Administration; 2018.

New York City Department of Transportation. Cycling in the city: cycling trends in NYC, May 2019. 2019; https://www1.nyc.gov/html/dot/downloads/pdf/cycling-in-the-city.pdf. Accessed June, 2020.

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United States Census Bureau. American Community Survey, Commuting characteristics by sex, 1-year estimates subject table. 2015, 2016, 2017. Accessed April, 2020.

United States Census Bureau. American Community Survey: Methodology. 2020; https://www.census.gov/programs-surveys/acs/methodology.html. Accessed June, 2020.

Supplemental table

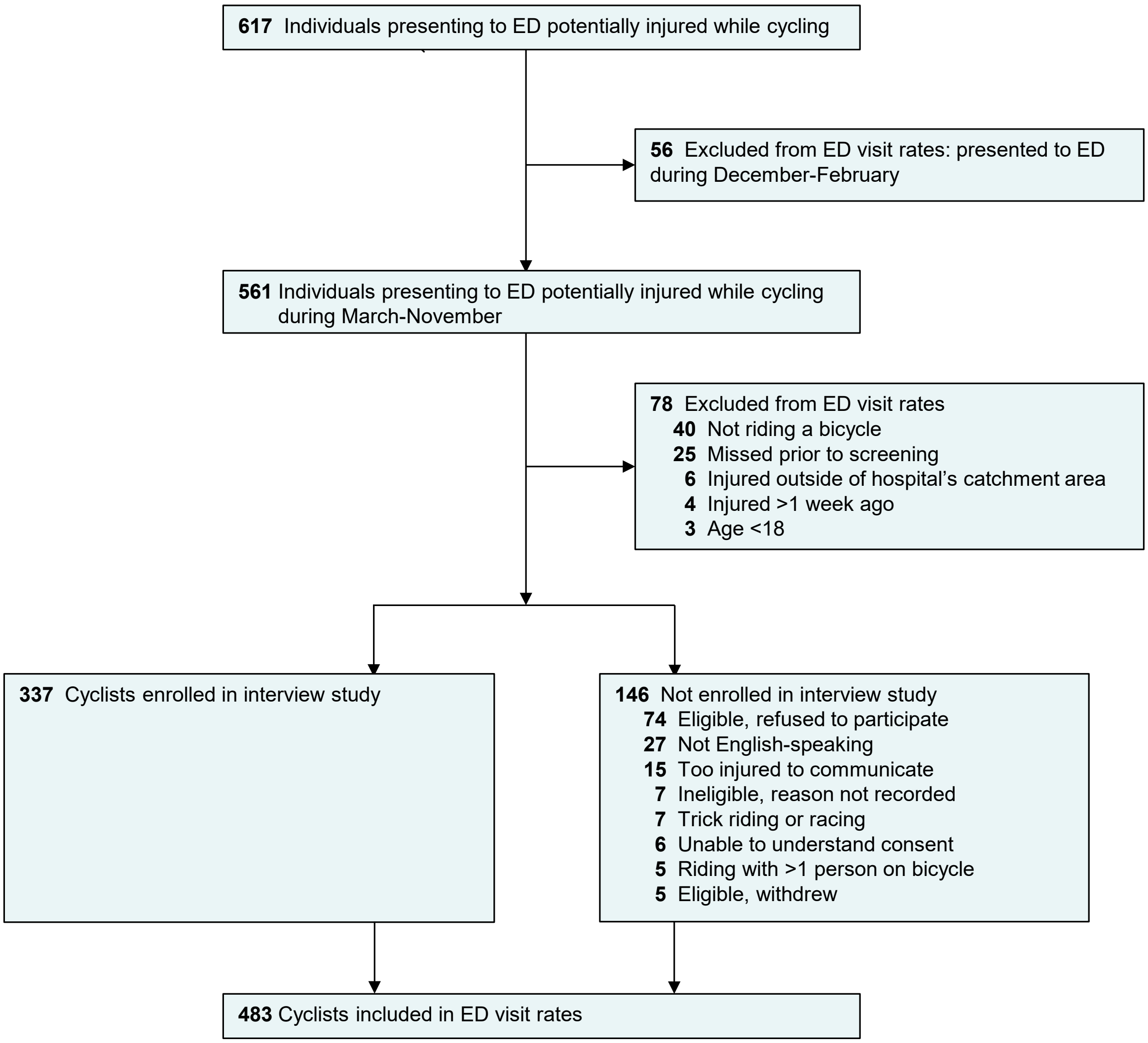
Table A1. Estimated ED visits per million miles traveled for e-scooter riders and cyclists under various assumptions, March to November 2015–2017 (cyclists) or 2019 (e-scooter riders)

Type of rider	Type of trip	No. screened	% of trips that were commuting	Estimated no. trips	Mean trip length (miles)	Estimated miles traveled	ED visits per million miles traveled (95% CI)
E-scooter	All	121	N/A	5,573,966	1.05	5,852,664	20.7 (17.3, 24.7)
	Entirely in DC	114			1.04	5,796,925	19.7 (16.4, 23.6)
					0.93	5,183,788	22.0 (18.3, 26.4)
Cyclist	All	483	55%	20,259,552	3.90	79,012,252	6.1 (5.6, 6.7)
	Entirely in DC	357			2.26	45,786,587	7.8 (7.0, 8.6)
	All	483	20%	55,713,768	3.90	217,283,694	2.2 (2.0, 2.4)
	Entirely in DC	357			2.26	125,913,115	2.8 (2.6, 3.1)

Abbreviations: CI, confidence interval; ED, emergency department. N/A, not applicable.

Supplemental figures

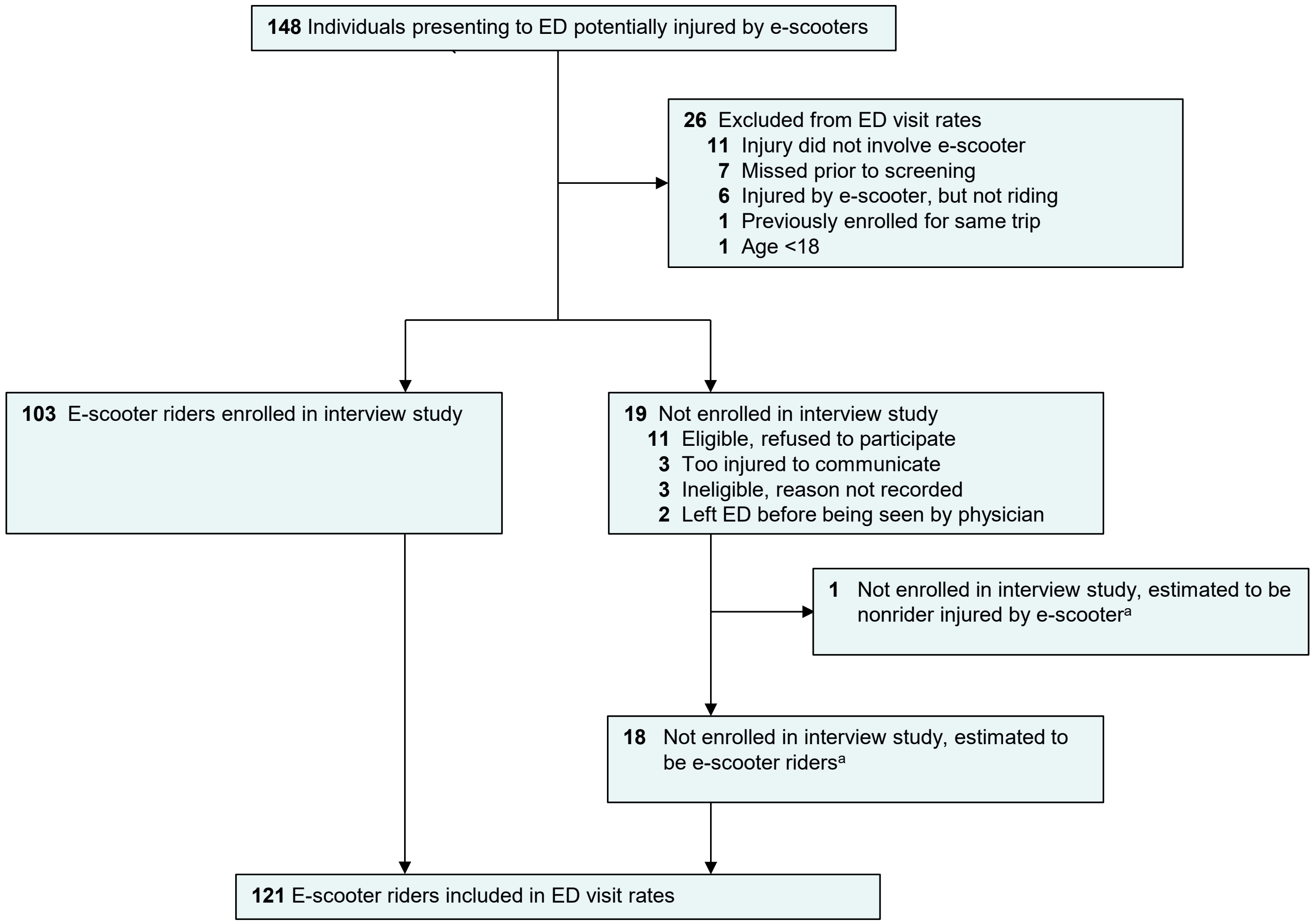
Figure A1. Identification of cyclist ED visits used in rates per mile traveled from patients presenting to Washington, DC, ED, 2015–2017



Abbreviations: ED, emergency department

Note: Data were collected during hours that research assistants staffed the ED (8:00 a.m.–10:00 p.m.); patients presenting outside these hours were not captured.

Figure A2. Identification of e-scooter rider ED visits used in rates per mile traveled from patients presenting to Washington, DC, ED, 2019



Abbreviations: ED, emergency department

Note: Data were collected during hours that research assistants staffed the ED (9:00 AM-10:00 PM); patients presenting outside these hours were not captured.

[a]A total of 6% (6 of 109) of individuals injured by e-scooters that we interviewed were nonriders. We assumed that 6% of individuals injured by e-scooters who were ineligible for the interview study (1 of 19) were nonriders.