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Injury patterns and circumstances associated with electric scooter collisions: a scoping review

Manish Toofany,¹ Sasha Mohsenian,² Leona K Shum,³ Herbert Chan,^{3,4} Jeffrey R Brubacher ^{3,4}

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¹Faculty of Medicine, The University of British Columbia, Vancouver, British Columbia, Canada

²Faculty of Science, The University of British Columbia, Vancouver, British Columbia, Canada

³Department of Emergency Medicine, Faculty of Medicine, The University of British Columbia, Vancouver, British Columbia, Canada

⁴Centre for Clinical Epidemiology & Evaluation (C2E2), Vancouver, British Columbia, Canada

Correspondence to

Dr Jeffrey R Brubacher, Department of Emergency Medicine, Faculty of Medicine, The University of British Columbia, Vancouver, BC, V6T 1Z4, Canada; jeff.brubacher@ubc.ca

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ABSTRACT

Background Electric scooters are personal mobility devices that have risen in popularity worldwide since 2017. Emerging reports suggest that both riders and other road users, such as pedestrians and cyclists, have been injured in electric scooter-associated incidents. We undertook a scoping review of the current literature to evaluate the injury patterns and circumstances of electric scooter-associated injuries.

Methods A scoping review of literature published from 2010 to 2020 was undertaken following accepted guidelines. Relevant articles were identified in Medline, Embase, SafetyLit and Transport Research International Documentation using terms related to electric scooters, injuries and incident circumstances. Supplemental searches were conducted to identify relevant grey literature (non-peer-reviewed reports).

Results Twenty-eight peer-reviewed studies and nine grey literature records were included in the review. The current literature surrounding electric scooter-associated injuries mainly comprises retrospective case series reporting clinical variables. Factors relating to injury circumstances are inconsistently reported. Findings suggest that the head, upper extremities and lower extremities are particularly vulnerable in electric scooter falls or collisions, while injuries to the chest and abdomen are less common. Injury severity was inconsistently reported, but most reported injuries were minor. Low rates of helmet use among electric scooter users were noted in several studies.

Conclusion Electric scooters leave riders vulnerable to traumatic injuries of varying severity. Future work should prospectively collect standardised data that include information on the context of the injury event and key clinical variables. Research on interventions to prevent electric scooter injuries is also needed to address this growing area of concern.

INTRODUCTION

Electric scooters are personal mobility devices that have been adopted as a convenient, environmentally friendly alternative to traditional modes of inner-city transportation. These scooters are typically comprised of a shaft that connects handlebars to a thin metal deck with two wheels, leaving riders only a few inches from the ground.¹ Electric scooters can reach speeds up to 25 km/hour which allow the rider to travel on roadways or bicycle lanes. Conversely, the compact size of electric scooters also allows riders to easily manoeuvre through pedestrian traffic.² Thus, electric scooter riders can switch between different types of road

infrastructure, leaving them and other road users, including cyclists and pedestrians, vulnerable to traumatic injuries in the case of a collision.

The incidence of electric scooter-associated injuries has increased considerably since the expansion of electric scooter sharing companies in late 2017.³ So far, research on electric scooter injuries has been conducted in major urban areas across Europe, Asia and Oceania.⁴ In some emergency departments, the number of injuries associated with electric scooters is now similar to that of cycling injuries.⁵ Legislators have struggled to adapt road safety regulations to mitigate injuries due to the recent influx of electric scooters. Some jurisdictions have mandated use of protective equipment such as helmets.⁶ Additional evidence on injury patterns and circumstances associated with electric scooter collisions is needed to guide clinical management and inform development of policy and interventions that target modifiable risk factors for these events.

In this study, we undertook a scoping review of the current literature on electric scooter-related injuries to evaluate injury patterns, circumstances and outcomes. With evidence pertaining to trauma associated with electric scooters still emerging, this review aimed to identify gaps in the current body of literature and suggest areas for further investigation.

METHODS

This scoping review was conducted according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses extension for Scoping Reviews methodology.⁷ Our search protocol was published in the Open Science Framework (<https://osf.io/fp5uv>) prior to study commencement.

Search methodology

A systematic search of English-language peer-reviewed studies was conducted using four databases: Medline, Embase, SafetyLit, and the Transport Research International Documentation (TRID). The TRID database also includes non-peer reviewed 'grey literature' such as reports (see below). As the popularity of electric scooters is fairly recent, the search was limited to articles published between January 2010 and December 2020. Keywords and/or subject headings were used to define three concepts (electric scooter, injury and circumstances) as per online supplemental table 6.

The first two concepts (electric scooter and injury) were combined to examine injury patterns specifically regarding severity, type and location of injury. The first and third concepts (electric



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scooter and circumstances) were combined to examine the injury circumstances specifically regarding the street/road environment, motor vehicle traffic and causes of the events. A sample search is included in online supplemental table 7. References from selected articles were examined to look for relevant articles that were not included in the database search.

Inclusion criteria

To be included, studies and documents needed to: (1) examine the injuries of patients following electric scooter-associated injury events; (2) have electric scooter-specific data; (3) have electric scooter-associated injury events comprise at least 25% of the study sample; and (4) be published between January 2010 and December 2020.

Exclusion criteria

Studies and documents were excluded if: (1) only injuries requiring a specific medical treatment were included; (2) only the treatment or management of injuries was reported; (3) case series included fewer than 20 cases; or (4) studies were reported as an abstract only.

Risk of bias (quality) assessment

The quality of studies was independently assessed by two reviewers using the National Heart Lung, and Blood Institute (NHLBI) assessment tools for evaluating observational studies. The specific tool applied was chosen based on study design.⁸ This ensured that the internal validity and risk of bias of each study were assessed in a similar manner irrespective of study design. Disagreements were resolved through discussions between two reviewers (MT, SM) and by consulting a third reviewer when needed.

Grey literature search

Grey literature was identified through a TRID search, a Google Scholar search, a general Google search and a Google custom search. The Google custom search focused on government documents. In all cases, the following terms: (“Scooter” or “Micro-mobility”, or “Personal Mobility”) and (“Injury” or “Trauma” or “Accident”) were used to search for exact terms. Searches were conducted up to 31 December 2020.

Data extraction

Two reviewers (MT, SM) independently screened titles and abstracts for eligible articles from the initial search. For articles that were unclear for eligibility, consensus was made through discussions among all team members. The selected articles were then reviewed in detail using standardised inclusion and exclusion criteria by MT and SM. Disagreements were resolved through discussions among all team members. Inter-rater reliability was measured with Cohen’s kappa coefficient. For each included study, the following data were independently extracted by the two reviewers: study title, first author, year of publication, data collection period, study aims, study methodology, country, participant demographics, sample road user type (ie, electric scooter driver, non-driver), injury distribution, injury type, injury rate, injury severity, clinical care in emergency department, emergency department disposition, hospital admission length, mechanism of injury, collision road type, helmet use and substance use.

Analysis

Due to heterogeneity in the data reported, narrative syntheses were used to summarise principal findings. Descriptive statistics

were performed when possible for key data categories that were reported using similar metrics across numerous studies.

RESULTS

Search results

The search strategy yielded 614 unique records. Twenty-eight peer-reviewed studies and nine grey literature records were included in the final review following the title, abstract and full-text eligibility review (figure 1). Cohen’s Kappa coefficient between the two reviewers (MT and SM) was 0.83. There were no disagreements between the two reviewers in the quality assessment of selected studies.

Peer-reviewed studies

Twenty-eight peer-reviewed studies were included, of which 25 were retrospective case series and three were prospective observational studies. No scoping or systematic reviews related to electric scooter trauma were identified. Twenty-three studies were conducted in urban regional trauma centres: 11 single-site studies and 12 multisite. Of these studies, 13 were conducted in the USA, 3 in New Zealand and 1 each in Singapore, Australia, Denmark, France, Finland, South Korea and Germany. Four nationwide studies were conducted in the USA through analyses of the United States Consumer Product Safety Commission National Electronic Injury Surveillance System (NEISS). These four studies were counted as a single study when reporting injury patterns and circumstances in the following sections as they used the same database. Additionally, one study employed information from a city-wide database in the USA. Publication dates ranged from 2019 to 2020. No included studies were published between 2010 and 2018. The NHLBI assessment of the included studies ranged from ‘Fair’ to ‘Good’. A summary of the study designs can be found in table 1.

The majority of studies sampled patients retrospectively through emergency department or trauma services databases (table 1). All studies reported electric scooter riders as part of their sample, eight studies also reported non-riders injured in an electric scooter collision. Data collection (table 1) was performed through retrospective medical chart reviews for 20 studies. Four studies used NEISS data. Four studies were based on interviews with injured electric scooter riders, including one study that conducted interviews during participants’ emergency department visits.

The most frequently reported aspects relating to injury patterns were injury distribution (n=28), injury type (n=28) and emergency department disposition (n=19). Emergency department procedures (n=10), injury rate (n=9) and surgical procedures (n=7) were also commonly reported.

The most frequently reported factors relating to injury circumstances were helmet use (n=21), alcohol use (n=18) and mechanism of injury (n=13). The location of the event (eg, road, sidewalk, bike path) was only reported in four studies.

Injury patterns

The distribution (table 2) of electric scooter-associated injuries was reported in 25 separate studies (counting the NEISS studies as one study), but the categorisation of injuries varied between studies. Thirteen studies categorised all injuries into the same six body regions (ie, head, face, chest, upper extremity, abdomen and lower extremity).^{3 4 9–19} In these studies, the most commonly injured regions were the upper extremity (one of three most frequently injured regions in 12 studies), head (11 studies) and lower extremity (10 studies) whereas the chest and abdomen

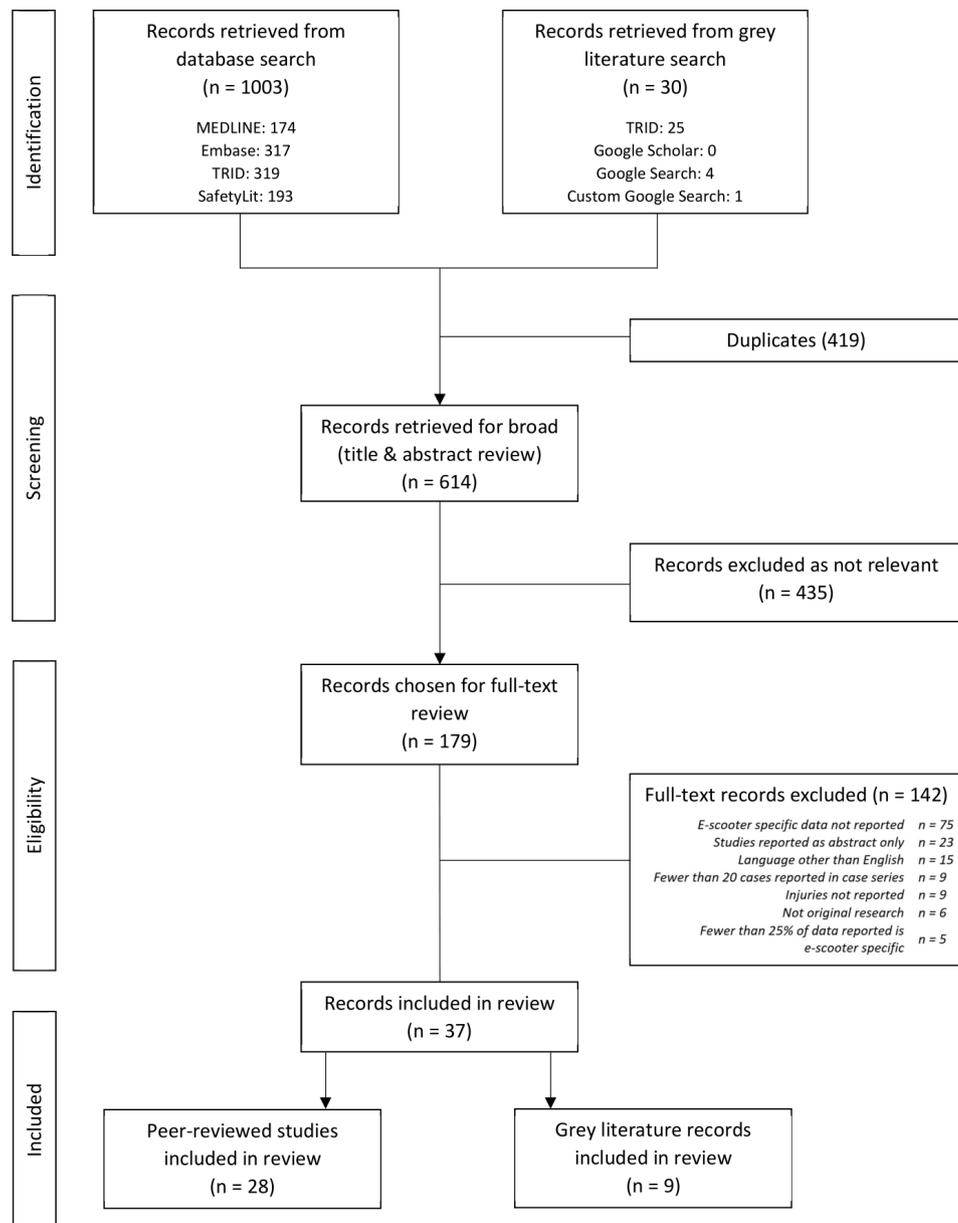


Figure 1 Preferred Reporting Items for Systematic Reviews and Meta-Analyses search decision flow chart. TRID, Transport Research International Documentation.

were the least frequently injured regions (table 2). Eight studies looked specifically at craniofacial injuries and all reported that the upper and mid regions of the face as well as the orbit were especially vulnerable to injuries (table 2). Dental injuries were also noted as being common in patients with craniofacial injuries.^{19–26}

Ten studies included all patients with electric scooter-associated trauma and reported the number of patients who sustained fractures (table 3).^{3 4 10 11 13–18} Overall almost a third of all patients in these studies sustained a fracture (341/1112=30.7%; range: 11.5%–70.5%).

The median Injury Severity Score (ISS) was reported in seven studies (table 3) that assessed all electric scooter-associated trauma emergency department patients and ranged from 1.0 to 5.5.^{11 12 14 18 27–29}

The number of patients who underwent imaging procedures (table 4) in the emergency department was reported in six studies.^{5 11 13 16 18 28} Two-thirds of all patients in these six studies

required a procedure (480/696=68.9%; range: 32.6%–90.3%). Consistent findings between these six studies, and in two additional studies that focused on imaging, suggest that radiographs account for the majority of these procedures.^{30 31}

As for emergency department disposition (table 4), data from 13 studies (n=2022 participants) showed that most patients injured as a result of an electric scooter collision (1690/2022=86%; range 66.7%–94.0%) did not require hospital admission and could be treated as outpatients.^{3 5 9–11 13–17 19 26 28 30 32}

Injury circumstances

Ten studies (n=1214 participants) reported mechanism of injury (table 5) in all patients with electric scooter-related trauma.^{4 10 11 15–19 28 33} These studies report that 92.8% of riders were injured in single road user events, while 7.1% were injured in multiple road user events. Single user events included falls, collisions with objects, excessive speed and unfavourable road conditions,

Table 1 Characteristics of selected studies

Study	Country	Study design	Number of sites	Primary data source	Time period	Sample size	Critical appraisal
<i>Peer-reviewed publications</i>							
Trivedi <i>et al</i> 2019 ¹⁶	USA	Retrospective	2	Medical charts	September 2017–August 2018	249	Good
Störmann <i>et al</i> 2020 ¹⁵	Germany	Prospective	2	Prospective data collection	July 2019–March 2020	76	Good
Mitchell <i>et al</i> 2019 ¹³	Australia	Retrospective	1	Medical charts	November 2018–January 2019	54	Good
Liew <i>et al</i> 2020 ²⁸	Singapore	Retrospective	1	Medical charts	2015–2016	36	Good
Kobayashi <i>et al</i> 2019 ¹²	USA	Retrospective	Multiple	Medical charts	September 2017–October 2018	103	Good
Brownson <i>et al</i> 2019 ¹¹	New Zealand	Retrospective	1	Medical charts	October 2018–February 2019	180	Good
Blomberg <i>et al</i> 2019 ⁴	Denmark	Retrospective	Multiple	Medical charts	January 2016–July 2019	130	Good
Beck <i>et al</i> 2019	New Zealand	Retrospective	1	Medical charts	January 2018–February 2018 and January 2019–February 2019	54	Good
Bauer <i>et al</i> 2020 ¹⁰	USA	Retrospective	1	Medical charts	October 2018–October 2019	61	Good
Puzio <i>et al</i> 2020 ¹⁴	USA	Retrospective	2	Medical charts	September 2018–November 2018	92	Fair
Badeau <i>et al</i> 2019 ³²	USA	Retrospective	2	Medical charts	June 2017–November 2017 and June 2018–November 2018	50	Good
Namiri <i>et al</i> 2020 ³	USA	Retrospective	Multiple	NEISS	2014–2018	988	Fair
Aizpuru <i>et al</i> 2019 ⁹	USA	Retrospective	Multiple	NEISS	2013–2017	820	Fair
Bresler <i>et al</i> 2019 ²³	USA	Retrospective	Multiple	NEISS	2008–2017	990	Fair
Farley <i>et al</i> 2020 ⁴⁷	USA	Retrospective	Multiple	NEISS	2014–2019	1823	Fair
Yarmohammadi <i>et al</i> 2020 ²⁰	USA	Retrospective	2	Medical charts	June 2018–May 2019	34	Fair
Faraji <i>et al</i> 2020 ²¹	USA	Retrospective	1	Medical charts	April 2018–September 2019	203	Good
Trivedi <i>et al</i> 2019 ²²	USA	Retrospective	1	Medical charts	July 2018–January 2019	90	Good
Siow <i>et al</i> 2020 ²⁹	USA	Retrospective	1	Medical charts	November 2017–January 2020	486	Good
Ishmael <i>et al</i> 2020 ³³	USA	Retrospective	2	Medical charts	September 2017–August 2019	73	Fair
Dhillon <i>et al</i> 2020 ²⁷	USA	Retrospective	Multiple	Medical charts	January 2018–December 2018	87	Good
Nellamattathil <i>et al</i> 2020 ³¹	USA	Retrospective	Multiple	Medical charts	September 2017–December 2018	54	Good
Mayhew and Bergin 2019 ³⁰	New Zealand	Retrospective	1	Medical charts	August 2018–December 2018	64	Fair
English <i>et al</i> 2020 ¹⁸	USA	Prospective	2	Interviews and medical charts	September 2018–November 2018	124	Good
Hennoq <i>et al</i> 2020 ²⁴	France	Prospective and retrospective	2	Interviews and medical charts	January 2017–October 2019	125	Good
Kim <i>et al</i> 2020 ²⁵	South Korea	Retrospective	1	Medical charts	January 2017–March 2020	256	Good
Oksanen <i>et al</i> 2020 ²⁶	Finland	Retrospective	1	Medical charts	2019	23	Good
Shiffler <i>et al</i> 2020 ¹⁹	USA	Retrospective	Multiple	Database	2017–2019	165	Good
<i>Grey literature (non-journal reports)</i>							
Pearson <i>et al</i> 2019 ³⁵	Australia	Retrospective	NR	NR	November 2018–February 2019	82	
Hojjat <i>et al</i> 2019 ³⁶	USA	Retrospective	Multiple	NEISS	2013–2017	3458 ^a	
Beck <i>et al</i> 2020 ³⁷	New Zealand	Retrospective	1	Medical charts	2018–2019	56	
Changand Diamond 2019 ³⁸	USA	Retrospective	Multiple	NEISS	2013–2017	444	
Allen <i>et al</i> 2019 ³⁹	USA	Retrospective	NR	Medical charts	September 2018–November 2018	200	
Sedor and Caswell 2019 ⁴⁰	Canada	NR	NR	NR	July 2019–August 2019	33	
Austin Public Health Unit 2019 ¹⁷	USA	Retrospective	NR	Interviews	September 2018–November 2019	192	
City of Santa Monica 2019 ⁴¹	USA	NR	NR	NR	January 2017–September 2019	NR	
Cicchino <i>et al</i> 2020 ³⁴	USA	Prospective	1	Interviews	March 2019–September 2019	103	

NEISS, National Electronic Injury Surveillance System; NR, not reported.

with falls (94.6%) being the most common (table 5). Five of these 10 studies included injury circumstances for non-electric scooter riders (table 5), namely pedestrians and cyclists (n=44). In these five studies, the most common mechanisms of injury to non-riders included being struck by an electric scooter (26/44=59.1%) and tripping over a stationary electric scooter (13/44=29.5%).^{4 5 14 18 28}

Data from 16 studies (n=1656) showed that only 4.5% of electric scooter riders were helmeted (table 5) at the time of their injury, while 67.5% were unhelmeted, and the remaining 28.0% had

unknown helmet status.^{4 5 10 11 13–17 19 22 23 26 28 29 32} A protective effect of helmets on the incidence of head injuries was noted in the sole study where this association was examined.¹³

The median per cent of patients whose injuries were associated with alcohol use (table 5) was 26.5% (IQR 13–48) as reported across 10 studies that reported alcohol use in all electric scooter-associated trauma patients.^{4 5 10–14 16 17 19}

The five included studies that reported the location (table 5) of the event (eg, road, sidewalk, bike path) found that streets

Table 2 Key findings of selected literature: injury distribution

Study	Upper limb (%)	Lower limb (%)	Head (%)	Face (%)	Chest (%)	Abdomen (%)	Spine (%)	Other
<i>Peer-reviewed publications</i>								
Trivedi <i>et al</i> 2019 ¹⁶	18	6	40	6	2		1	
Störmann <i>et al</i> 2020 ¹⁵	47	36	17	21	9	0		
Mitchell <i>et al</i> 2019 ¹³	54	25	15		1	6		
Liew <i>et al</i> 2020 ²⁸				11	6			Extremities: 33% External, unspecified: 72%
Kobayashi <i>et al</i> 2019 * ¹²	13	22		26				
Brownson <i>et al</i> 2019 ¹¹			17	11	3	0		Extremities: 55%
Blomberg <i>et al</i> 2019 ⁴	26	28	22	28	3		3	
Beck <i>et al</i> 2019 *	18	9	26	6				
Bauer <i>et al</i> 2020 ¹⁰	16	18						Head, face, and/or neck: 44% Torso: 12%
Puzio <i>et al</i> 2020 ¹⁴	36	17	18	12	1	3		Multisystem: 12%
Badeau <i>et al</i> 2019 ³²			20					MSK: 70% Superficial, unspecified: 40%
Namiri <i>et al</i> 2020 ³	26	32	32					Torso: 10%
Aizpuru <i>et al</i> 2019 ⁹	26	35	28					Torso: 11%
Dhillon <i>et al</i> 2020 ²⁷					9		9	Extremities: 22% Craniofacial: 23%
English <i>et al</i> 2020 ¹⁸	56	34	18	33	8	2		
Farley <i>et al</i> 2020 ⁴⁷			27					
Bresler <i>et al</i> 2019 ²³			65	24			4	Mouth: 7% Neck: 6% Ear: 1% Eye: 1%
Yarmohammadi <i>et al</i> 2020† ²⁰				100				Lateral orbital wall: 56% Orbital floor: 53% Orbital roof: 28% Medial orbital wall: 25% Jaw: 15% Nose: 9%
Faraji <i>et al</i> 2020 † ²¹			11	50				Mouth: 15% Ear: 1% Nose: 8%
Trivedi <i>et al</i> 2019 ²²			37	44	2	3	2	Extremities: 64%
Hennocq <i>et al</i> 2020† ²⁴				100				Forehead: 18% Nose: 11% Cheek: 3% Lips: 28% Chin: 40%
Kim <i>et al</i> 2020 ²⁵								Craniofacial: 49%
Oksanen <i>et al</i> 2020† ²⁶					4			Midface: 43% Mandible: 26% Skull base: 9%
Shiffler <i>et al</i> 2020 ¹⁹	47	18			1	0	0	Craniofacial: 23%
Siow <i>et al</i> 2020† ²⁹	49	25					4	Polytrauma: 10%
Ishmael <i>et al</i> 2020† ³³	44	58						
Nellamattathil and Amber 2020* ³¹	15	6		4	4			
Mayhew and Bergin 2019 ³⁰					10		3	Extremities: 84% Head/face: 44%
<i>Grey literature (non-journal reports)</i>								
Pearson <i>et al</i> 2019 ³⁵								Most common: upper limb, lower limb, head/neck
Hojjat <i>et al</i> 2019 ³⁶								
Beck <i>et al</i> 2020 ³⁷								Most common: head, upper limb, lower limb.
Chang and Diamond 2019 ³⁸								Most common: head/face
Allen <i>et al</i> 2019 ³⁹	56	36						Head/face: 46%
Sedor and Caswell 2019 ⁴⁰								
Austin Public Health Unit 2019 ¹⁷	70	55	48					Chest/abdomen: 18%
City of Santa Monica 2019 ⁴¹								
Cicchino <i>et al</i> 2020 ³⁴	34	18	7	9				Chest, abdomen, or spine: 3%

*Reported distribution of fractures.

†Reported distribution of craniofacial injuries.

‡Reported distribution of orthopaedic injuries.

Table 3 Key findings of selected literature: injury type and severity

Study	Type of injury				Injury severity	
	Superficial soft tissue injury (%)	Fracture or dislocation (%)	Head injury (%)	Internal injury (%)	ISS	Other
<i>Peer-reviewed publications</i>						
Trivedi <i>et al</i> 2019 ¹⁶	56	36	40	1		Urgent* 33%
Störmann <i>et al</i> 2020 ¹⁵	58	42	17			
Mitchell <i>et al</i> 2019 ¹³	60	24	15			
Liew <i>et al</i> 2020 ²⁸	72	33			Median 1 Range 1–5	
Kobayashi <i>et al</i> 2019 ¹²	NR	42	19		Median 5.5 IQR 5–9	
Brownson <i>et al</i> 2019 ¹¹	66	42	17		Median 4 Range 1–29	
Blomberg <i>et al</i> 2019 ⁴	31	12	22			Urgent* 7%
Beck <i>et al</i> 2019	46	32	26			Urgent* 17%
Bauer <i>et al</i> 2020 ¹⁰	54	33	17		Mean 6.3 SD 6.0	
Puzio <i>et al</i> 2020 ¹⁴	34	24	17		Median 1	
Badeau <i>et al</i> 2019 ³²	74	36	20			
Namiri <i>et al</i> 2020 ³	37	27	32			
Aizpuru <i>et al</i> 2019 ⁹	31	26	28			
Dhillon <i>et al</i> 2020 ²⁷		55	23		Mean 7.2 Median 5 IQR 2–10	
English <i>et al</i> 2020 ¹⁸	65	33	18	1	Median 5 IQR 4–9	
Farley <i>et al</i> 2020 ⁴⁷			15	27		
Bresler <i>et al</i> 2019 ²³	32	5	36			
Yarmohammadi <i>et al</i> 2020† ²⁰		94	21			
Faraji <i>et al</i> 2020 ²¹	65	27				
Trivedi <i>et al</i> 2019 ²²	42					Severe‡ 58%
Hennocq <i>et al</i> 2020 ²⁴	62	47				
Kim <i>et al</i> 2020 ²⁵	44	9	30			
Oksanen <i>et al</i> 2020 ²⁶	91	65	22			
Shiffler <i>et al</i> 2020 ¹⁹	20	23				
Siow <i>et al</i> 2020§ ²⁹	NR	49			Mean 8.4 Median 5.0	
Ishmael <i>et al</i> 2020§ ³³	NR	93				
Nellamattathil and Amber 2020 ³¹	NR	26				
Mayhew and Bergin 2019 ³⁰	NR	57	24			
<i>Grey literature (non-journal reports)</i>						
Pearson <i>et al</i> 2019 ³⁵						
Hojjat <i>et al</i> 2019 ³⁶						
Beck <i>et al</i> 2020 ³⁷		32	26			
Chang and Diamond 2019 ³⁸						
Allen <i>et al</i> 2019 ³⁹						
Sedor and Caswell 2019 ⁴⁰						
Austin Public Health Unit 2019 ¹⁷		35	15			
City of Santa Monica 2019						Minor injuries in 80%
Cicchino <i>et al</i> 2020 ³⁴	53		7			Max. AIS≤2 in 98%

*Urgent defined as Canadian Triage Acuity Score of 1 (resuscitation), 2 (emergent) or 3 (urgent).

†Reported for patients with facial injuries.

‡Severe defined as fracture, concussion or intracranial haematoma.

§Reported for patients with orthopaedic injuries.

AIS, Abbreviated Injury Scale; ISS, Injury Severity Score.

and sidewalks were most common.^{17 18 24 31 34} Additional details of injury circumstances are summarised in online supplemental appendix table 6.

Grey literature

The grey literature search yielded five conference proceedings, three government reports, and one report from a scientific

organisation.^{17 34–41} The included grey literature supported the injury distribution, injury severity, mechanism of injury and low rates of helmet use reported by the peer-reviewed studies.

DISCUSSION

To the best of our knowledge, this is the first scoping review of electric scooter trauma. All 28 included peer-reviewed

Table 4 Key findings of selected literature: resource utilisation

Study	Diagnostic studies				Hospital resources		
	Any imaging (%)	Radiograph (%)	CT scan (%)	Ultrasound (%)	Emergency department procedure (%)	Surgical intervention (%)	Admission to hospital (%)
<i>Peer-reviewed publications</i>							
Trivedi <i>et al</i> 2019 ¹⁶	80						6
Störmann <i>et al</i> 2020 ¹⁵						28	
Mitchell <i>et al</i> 2019 ¹³	92	78	24	0			13
Liew <i>et al</i> 2020 ²⁸	72	72	15			9	26
Kobayashi <i>et al</i> 2019 ¹²						33	
Brownson <i>et al</i> 2019 ¹¹	45		33			22	20
Blomberg <i>et al</i> 2019 ⁴							
Beck <i>et al</i> 2019	72	69	17			7	22
Bauer <i>et al</i> 2020 ¹⁰							25
Puzio <i>et al</i> 2020 ¹⁴						24	9
Badeau <i>et al</i> 2019 ³²						14	16
Namiri <i>et al</i> 2020 ³							
Aizpuru <i>et al</i> 2019 ⁹							9
Dhillon <i>et al</i> 2020 ²⁷						17	
English <i>et al</i> 2020 ¹⁸	90	71	40		63	21	28
Farley <i>et al</i> 2020 ⁴⁷							8
Bresler <i>et al</i> 2019 ²³							
Yarmohammadi <i>et al</i> 2020 ²⁰						24	76
Faraji <i>et al</i> 2020 ²¹							
Trivedi <i>et al</i> 2019 ²²							23
Hennocq <i>et al</i> 2020 ²⁴							
Kim <i>et al</i> 2020 ²⁵							
Oksanen <i>et al</i> 2020 ²⁶							61
Shiffler <i>et al</i> 2020 ¹⁹							21
Siow <i>et al</i> 2020 ²⁹						26	37
Ishmael <i>et al</i> 2020 ³³							
Nellamattathil and Amber 2020 ^{*31}	100	83	15	0			
Mayhew and Bergin 2019 ^{*30}	100	82	18	0		25	40
<i>Grey literature (non-journal reports)</i>							
Pearson <i>et al</i> 2019 ³⁵	87						
Hojjat <i>et al</i> 2019 ³⁶							
Beck <i>et al</i> 2020 ³⁷	65					9	20
Chang and Diamond 2019 ³⁸							
Allen <i>et al</i> 2019 ³⁹	91				61	21	29
Sedor and Caswell 2019 ⁴⁰							
Austin Public Health Unit 2019 ¹⁷							15
City of Santa Monica 2019							
Cicchino <i>et al</i> 2020 ³⁴					Splinting: 48 Wound care: 35 Laceration repair: 24	12	9

*Reported only for patients who required imaging during their visit.

studies were published between 2019 and 2020, which suggests research in this area is recent and may increase rapidly in the coming years. The recent literature may be in response to the recent proliferation of shared electric scooter schemes leading to increases in related emergency department visits.³

The most commonly injured body parts following electric scooter-associated trauma were the head, upper extremities and lower extremities as expected. The chest and abdomen were consistently the two least common injured regions. This injury pattern is similar to that observed in certain non-motorised mobility devices such as skateboards and non-motorised scooters.⁴² However, electric scooter injuries are likely more severe due to their increased speeds, as noted in two included

studies.^{4 34} Falls were the leading cause of injuries in electric scooter riders, and many upper extremity injuries result from falls on an outstretched hand, a common reaction used to break the impact of a fall.⁴³ Electric scooters' low height off the ground along with riders' reflex to step off the scooter in risky situations may explain the high frequency of lower extremity injuries.¹

Low rates of helmet use among riders were noted in several studies, which may be linked to the high prevalence of head injuries following electric scooter-associated trauma. Moreover, one study noted a protective effect of helmets on craniofacial injuries suggesting many of these injuries may be preventable.¹³ This assertion is supported by a large body of work showing the effectiveness of helmets in preventing head injuries in cyclists.⁴⁴

Table 5 Key findings of selected literature: injury circumstances

Study	Mechanism (%)		Location (%)		Helmet use (%)			Substance use (%)	
	Single user	Collision *	Yes	No	Unknown	Alcohol	Other		
<i>Peer-reviewed publications</i>									
Trivedi <i>et al</i> 2019 ¹⁶	88	9	4	32	63	5			
Störmann <i>et al</i> 2020 ¹⁵	92	8	1						
Mitchell <i>et al</i> 2019 ¹³	69	31	46	20	30				
Liew <i>et al</i> 2020 ²⁸			6						
Kobayashi <i>et al</i> 2019 ¹²			7	88	5	48		Positive toxicology screen: 30	
Brownson <i>et al</i> 2019 ¹¹	97	3	2	19	79	13			
Blomberg <i>et al</i> 2019 ⁴	91	9	4	55	41	37			
Beck <i>et al</i> 2019			2	19	79	13			
Bauer <i>et al</i> 2020 ¹⁰	97	3				49			
Puzio <i>et al</i> 2020 ¹⁴			0†	–		33			
Badeau <i>et al</i> 2019 ³²								Sidewalk: 44	
Namiri <i>et al</i> 2020 ³									
Aizpuru <i>et al</i> 2019 ⁹									
Dhillon <i>et al</i> 2020 ²⁷	34	58	18	71	11	24			
English <i>et al</i> 2020 ¹⁸	85	15				11		Street: 71 Sidewalk: 3 Unknown: 26	
Farley <i>et al</i> 2020 ⁴⁷									
Bresler <i>et al</i> 2019 ²³			5	10	85				
Yarmohammadi <i>et al</i> 2020 ²⁰			0†			74			
Faraji <i>et al</i> 2020 ²¹						46		Cannabis: 7	
Trivedi <i>et al</i> 2019 ²²			0†			18			
Hennocq 2020 ²⁴						49		Sidewalk: 31 Other substance: 12	
Kim <i>et al</i> 2020 ²⁵									
Oksanen <i>et al</i> 2020 ²⁶			17	0	83	91			
Shiffler <i>et al</i> 2020 ¹⁹	97	3	12	1	87	12		Other substance: 4	
Siow <i>et al</i> 2020 ²⁹			3			27			
Ishmael <i>et al</i> 2020 ³³	89	11							
Nellamattathil and Amber 2020 ³¹									
Mayhew and Bergin 2019 ³⁰						84			
<i>Grey literature (non-journal reports)</i>									
Pearson <i>et al</i> 2019 ³⁵									
Hojjat <i>et al</i> 2019 ³⁶									
Beck <i>et al</i> 2020 ³⁷									
Chang and Diamond 2019 ³⁸									
Allen <i>et al</i> 2019 ³⁹	85	10	2						
Sedor and Caswell 2019 ⁴⁰	94	6	3			24			
Austin Public Health Unit 2019 ¹⁷						29		Street: 55 Sidewalk: 33	
City of Santa Monica 2019									
Cicchino <i>et al</i> 2020 ³⁴	69	28						Sidewalk: 57 Road: 24 Off-road: 10 Bike lane: 8 Other: 2	

*Collision with another road user.

†Did not report unknown helmet status.

This evidence is relevant for many cities that are considering helmet laws for electric scooter users.⁶ A 2019 study in Brisbane, Australia found that previously low rates of helmet use increased to 64% among electric scooter riders following the introduction of a mandatory helmet law.⁴⁵ More broadly, helmet use among electric scooter riders should be promoted in public health messaging as an effective means to reduce the high incidence of head injuries.

While the majority of electric scooter riders were injured in single road user events, a considerable portion were injured through collisions with other vehicles. Moreover, in some cases,

cyclists and pedestrians were injured through collisions with electric scooter riders. These findings may in part be due to the scooters' high speeds and small size allowing them to be used on different types of road infrastructure.² The five studies that reported location found that streets and sidewalks were common locations where these events occurred.^{17 18 24 32 34} This suggests that policies restricting electric scooter use to specific road infrastructure such as bicycle lanes should be considered as both devices operate at similar speeds.⁶

Multiple findings highlight a large healthcare burden in cities where electric scooters are popular. For instance, although the

majority of patients seen in the emergency department were discharged home, a considerable portion required admission to hospital. Moreover, over two-thirds of patients (68.9%) required at least one procedure during their emergency department visit. These findings are supported by a New Zealand study which found that the introduction of electric scooters had a large impact on regional healthcare costs.⁴⁶ This may be of particular interest to cities considering the adoption of shared electric scooter schemes, as the introduction of such services may increase the demand of already-stretched emergency services.⁴⁷

Limitations

Our findings are affected by the limitations of the included literature. The majority of included studies were retrospective case series in design that only reported on clinically relevant variables present in medical charts or databases. Additionally, most studies only reported the clinical course of the patients' emergency department visits; information on long-term health outcomes is lacking. Metrics used to report important factors such as injury distribution and severity were heterogeneous across studies, limiting the scope of comparisons. Factors relating to the circumstances of the injury such as the location of the event and substance use were inconsistently reported, while helmet use was difficult to ascertain due to high rates of unknown helmet status.

Recommendations for future research

The three studies with prospective observational designs benefitted from emergency department clinicians consistently documenting circumstances of the incidents as well as patients' clinical course and outcome.¹⁵ Future research on electric scooter trauma would benefit from a similar prospective observational design with an emphasis on using standard metrics such as ICD-10 body regions for reporting injury distribution, and ISS or Abbreviated Injury Scale for injury severity. Such research would provide better evidence on the injury patterns and severity of electric scooter-associated trauma. Details of the injury circumstance, such as time of day, road infrastructure (eg, sidewalk, roadway, bike path), involvement of other road users, and contributory factors should be systematically collected in order to identify modifiable risk factors for electric scooter injuries. Similarly, as electric scooter use increases, it is important for injury surveillance databases to capture electric scooter injuries, including injuries to other road users resulting from collisions with electric scooters. Moreover, as many urban areas lack legislation mandating the use of protective equipment by electric scooter riders, future evaluations of interventions for preventing electric scooter injuries, especially measures to increase helmet use, will help inform policy decisions.

CONCLUSION

While electric scooters are a convenient mode of inner-city transportation, they leave riders vulnerable to traumatic injuries. This review suggests that the head, upper extremities and lower extremities are particularly vulnerable in electric scooter trauma, while injuries to the chest and abdomen are less common. Notably, the low rates of helmet use reported among injured electric scooter users, and high rates of head injuries suggest the need for interventions to increase helmet use in this group of road users. Our findings also highlight the large burden placed on emergency departments by this popular mode of transportation. Most electric scooter studies to date have been retrospective case series. Future work should prospectively collect standardised data that include information on the context of the

What is already known on this subject

- ▶ The rise in electric scooter use has led to an increase in the incidence of electric scooter-associated injuries, which have involved both riders and other road users.
- ▶ Studies of electric scooter injuries have been conducted in different settings using a range of methodologies.

What does this study add

- ▶ Review findings suggest that the head, the upper extremities and the lower extremities are particularly vulnerable in electric scooter injuries.
- ▶ Most electric scooter injuries involve a single user, with falls being the most common mechanism of injury.
- ▶ Low rates of helmet use among electric scooter riders were noted in multiple studies, potentially leaving riders more vulnerable to head injuries.

injury events and electric scooter usage patterns, as well as key clinical variables. Finally, research on interventions to prevent electric scooter injuries will be important to address this growing concern and advance public health.

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ORCID iD

Jeffrey R Brubacher <http://orcid.org/0000-0002-4866-4231>

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SUPPLEMENTARY MATERIAL**Table 6.** Three concepts used for the systematic literature search and corresponding search terms

Concept	Search Terms
Electric scooter	Scooter, micromobility, personal mobility
Injury	Injury, wound, trauma, fracture, laceration, burn, hospital, emergency service
Circumstances	Accident, traffic accident, fall, motor vehicle collision, motor vehicle incident, motor vehicle crash

Table 7. Sample Search Strategy

Search Number	<i>Scooter</i>	Number of Results
1	Scooter.mp	352
2	Micromobility.mp	25
3	Personal mobility.mp	271
4	1 or 2 or 3	622
<i>Injuries</i>		
5	Exp Wounds and Injuries/ or injury.mp	1380006
6	Trauma.mp or multitrauma.mp	262510
7	Fracture.mp	204312
8	Laceration.mp	7531
9	Burn.mp	37308
10	Exp Hospitals/ or hospital.mp	1328688
11	Exp Emergency Service, Hospital/ or emergency department.mp	123100
12	5 or 6 or 7 or 8 or 9 or 10 or 11	2794178
<i>Circumstances</i>		
13	Exp Accidents/ or accident.mp or incident.mp	188278
14	Exp Accidents, Traffic/ or traffic accident.mp	45423
15	Exp Accidental Falls/ or fall.mp	130142
16	Motor vehicle collision.mp	910
17	Motor vehicle incident.mp	3
18	Motor vehicle crash.mp	1260
19	13 or 14 or 15 or 16 or 17 or 18	174051
20	Scooter and (Injuries or Circumstances) 4 and 12 OR 19	293