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

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► Additional material is published online only. To view, please visit the journal online (http://dx.doi.org/10.1136/injuryprev-2020-044085).

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Received 15 November 2020
Revised 22 February 2021
Accepted 24 February 2021
Published Online First 11 March 2021

Check for updates

To cite: Toofany M, Mohsenian S, Shum LK, *et al*. *Inj Prev* 2021;**27**:490–499.

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 "Micromobility", 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

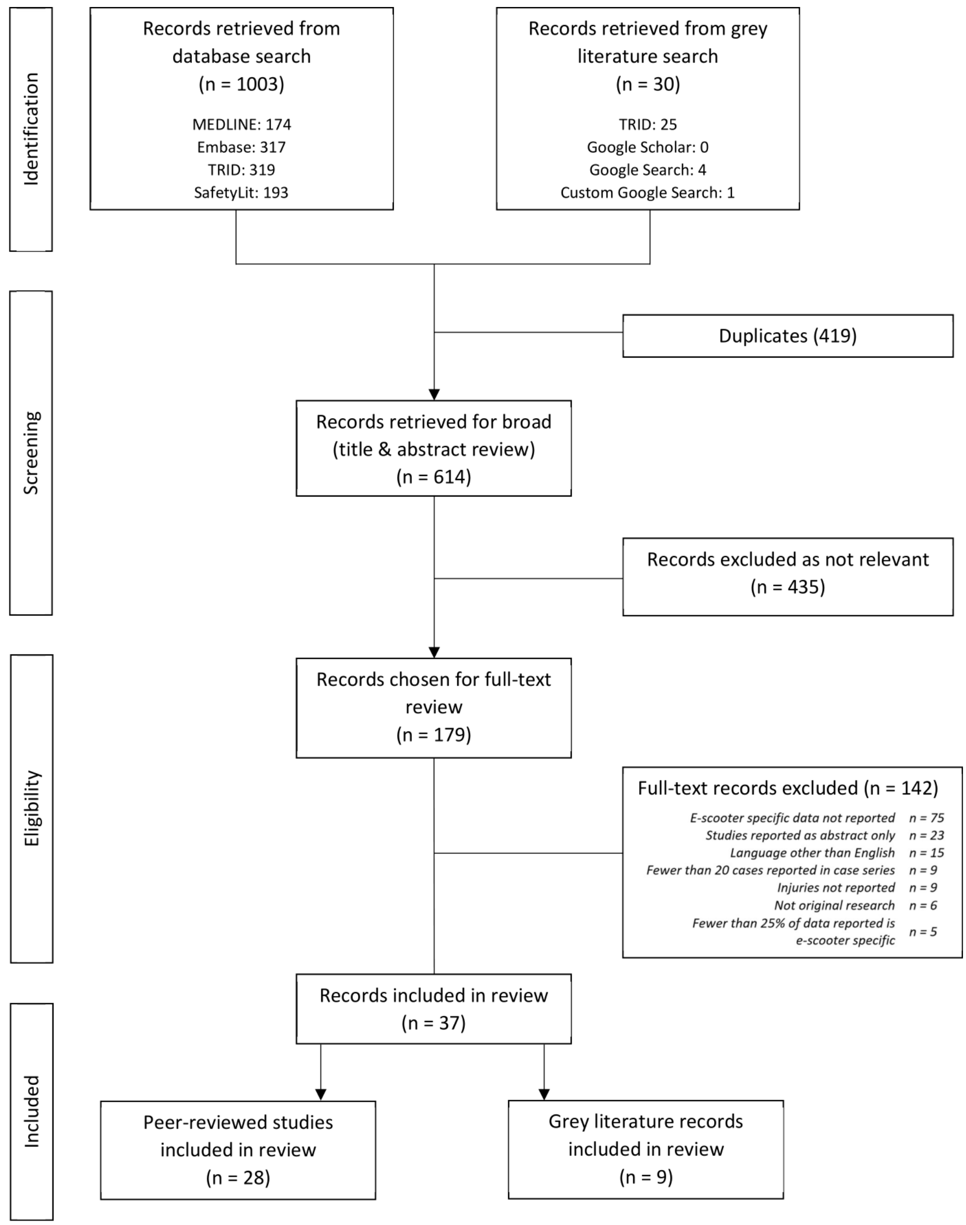

Figure 1 Preferred Reporting Items for Systematic Reviews and Meta-Analyses search decision flow chart. TRID, Transport Research International Documentation.

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
Peer-reviewed publications							
Trivedi *et al* 2019[16]	USA	Retrospective	2	Medical charts	September 2017–August 2018	249	Good
Störmann *et al* 2020[15]	Germany	Prospective	2	Prospective data collection	July 2019–March 2020	76	Good
Mitchell *et al* 2019[13]	Australia	Retrospective	1	Medical charts	November 2018–January 2019	54	Good
Liew *et al* 2020[28]	Singapore	Retrospective	1	Medical charts	2015–2016	36	Good
Kobayashi *et al* 2019[12]	USA	Retrospective	Multiple	Medical charts	September 2017–October 2018	103	Good
Brownson *et al* 2019[11]	New Zealand	Retrospective	1	Medical charts	October 2018–February 2019	180	Good
Blomberg *et al* 2019[4]	Denmark	Retrospective	Multiple	Medical charts	January 2016–July 2019	130	Good
Beck *et al* 2019	New Zealand	Retrospective	1	Medical charts	January 2018–February 2018 and January 2019–February 2019	54	Good
Bauer *et al* 2020[10]	USA	Retrospective	1	Medical charts	October 2018–October 2019	61	Good
Puzio *et al* 2020[14]	USA	Retrospective	2	Medical charts	September 2018–November 2018	92	Fair
Badeau *et al* 2019[32]	USA	Retrospective	2	Medical charts	June 2017–November 2017 and June 2018–November 2018	50	Good
Namiri *et al* 2020[3]	USA	Retrospective	Multiple	NEISS	2014–2018	988	Fair
Aizpuru *et al* 2019[9]	USA	Retrospective	Multiple	NEISS	2013–2017	820	Fair
Bresler *et al* 2019[23]	USA	Retrospective	Multiple	NEISS	2008–2017	990	Fair
Farley *et al* 2020[47]	USA	Retrospective	Multiple	NEISS	2014–2019	1823	Fair
Yarmohammadi *et al* 2020[20]	USA	Retrospective	2	Medical charts	June 2018–May 2019	34	Fair
Faraji *et al* 2020[21]	USA	Retrospective	1	Medical charts	April 2018–September 2019	203	Good
Trivedi *et al* 2019[22]	USA	Retrospective	1	Medical charts	July 2018–January 2019	90	Good
Siow *et al* 2020[29]	USA	Retrospective	1	Medical charts	November 2017–January 2020	486	Good
Ishmael *et al* 2020[33]	USA	Retrospective	2	Medical charts	September 2017–August 2019	73	Fair
Dhillon *et al* 2020[27]	USA	Retrospective	Multiple	Medical charts	January 2018–December 2018	87	Good
Nellamattathil *et al* 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 *et al* 2020[18]	USA	Prospective	2	Interviews and medical charts	September 2018–November 2018	124	Good
Hennocq *et al* 2020[24]	France	Prospective and retrospective	2	Interviews and medical charts	January 2017–October 2019	125	Good
Kim *et al* 2020[25]	South Korea	Retrospective	1	Medical charts	January 2017–March 2020	256	Good
Oksanen *et al* 2020[26]	Finland	Retrospective	1	Medical charts	2019	23	Good
Shiffler *et al* 2020[19]	USA	Retrospective	Multiple	Database	2017–2019	165	Good
Grey literature (non-journal reports)							
Pearson *et al* 2019[35]	Australia	Retrospective	NR	NR	November 2018–February 2019	82	
Hojjat *et al* 2019[36]	USA	Retrospective	Multiple	NEISS	2013–2017	3458 [a]	
Beck *et al* 2020[37]	New Zealand	Retrospective	1	Medical charts	2018–2019	56	
Changand Diamond 2019[38]	USA	Retrospective	Multiple	NEISS	2013–2017	444	
Allen *et al* 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 *et al* 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
				Peer-reviewed publications				
Trivedi *et al* 2019[16]	18	6	40	6	2		1	
Störmann *et al* 2020[15]	47	36	17	21	9	0		
Mitchell *et al* 2019[13]	54	25	15		1	6		
Liew *et al* 2020[28]				11	6			Extremities: 33% External, unspecified: 72%
Kobayashi *et al* 2019 *[12]	13	22		26				
Brownson *et al* 2019[11]			17	11	3	0		Extremities: 55%
Blomberg *et al* 2019[4]	26	28	22	28	3		3	
Beck *et al* 2019 *	18	9	26	6				
Bauer *et al* 2020[10]	16	18						Head, face, and/or neck: 44% Torso: 12%
Puzio *et al* 2020[14]	36	17	18	12	1	3		Multisystem: 12%
Badeau *et al* 2019[32]			20					MSK: 70% Superficial, unspecified: 40%
Namiri *et al* 2020[3]	26	32	32					Torso: 10%
Aizpuru *et al* 2019[9]	26	35	28					Torso: 11%
Dhillon *et al* 2020[27]					9		9	Extremities: 22% Craniofacial: 23%
English *et al* 2020[18]	56	34	18	33	8	2		
Farley *et al* 2020[47]			27					
Bresler *et al* 2019[23]			65	24			4	Mouth: 7% Neck: 6% Ear: 1% Eye: 1%
Yarmohammadi *et al* 2020†[20]				100				Lateral orbital wall: 56% Orbital floor: 53% Orbital roof: 28% Medial orbital wall: 25% Jaw: 15% Nose: 9%
Faraji *et al* 2020 †[21]			11	50				Mouth: 15% Ear: 1% Nose: 8%
Trivedi *et al* 2019[22]			37	44	2	3	2	Extremities: 64%
Hennocq *et al* 2020†[24]				100				Forehead: 18% Nose: 11% Cheek: 3% Lips: 28% Chin: 40%
Kim *et al* 2020[25]								Craniofacial: 49%
Oksanen *et al* 2020†[26]					4			Midface: 43% Mandible: 26% Skull base: 9%
Shiffler *et al* 2020[19]	47	18			1	0	0	Craniofacial: 23%
Siow *et al* 2020‡[29]	49	25					4	Polytrauma: 10%
Ishmael *et al* 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%
				Grey literature (non-journal reports)				
Pearson *et al* 2019[35]								Most common: upper limb, lower limb, head/neck
Hojjat *et al* 2019[36]								
Beck *et al* 2020[37]								Most common: head, upper limb, lower limb.
Chang and Diamond 2019[38]								Most common: head/face
Allen *et al* 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 *et al* 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
Peer-reviewed publications						
Trivedi *et al* 2019[16]	56	36	40	1		Urgent * 33%
Störmann *et al* 2020[15]	58	42	17			
Mitchell *et al* 2019[13]	60	24	15			
Liew *et al* 2020[28]	72	33			Median 1 Range 1–5	
Kobayashi *et al* 2019[12]	NR	42	19		Median 5.5 IQR 5–9	
Brownson *et al* 2019[11]	66	42	17		Median 4 Range 1–29	
Blomberg *et al* 2019[4]	31	12	22			Urgent* 7%
Beck *et al* 2019	46	32	26			Urgent* 17%
Bauer *et al* 2020[10]	54	33	17		Mean 6.3 SD 6.0	
Puzio *et al* 2020[14]	34	24	17		Median 1	
Badeau *et al* 2019[32]	74	36	20			
Namiri *et al* 2020[3]	37	27	32			
Aizpuru *et al* 2019[9]	31	26	28			
Dhillon *et al* 2020[27]		55	23		Mean 7.2 Median 5 IQR 2–10	
English *et al* 2020[18]	65	33	18	1	Median 5 IQR 4–9	
Farley *et al* 2020[47]			15	27		
Bresler *et al* 2019[23]	32	5	36			
Yarmohammadi *et al* 2020 †[20]		94	21			
Faraji *et al* 2020[21]	65	27				
Trivedi *et al* 2019[22]	42					Severe‡ 58%
Hennocq *et al* 2020[24]	62	47				
Kim *et al* 2020[25]	44	9	30			
Oksanen *et al* 2020[26]	91	65	22			
Shiffler *et al* 2020[19]	20	23				
Siow *et al* 2020 §[29]	NR	49			Mean 8.4 Median 5.0	
Ishmael *et al* 2020 §[33]	NR	93				
Nellamattathil and Amber 2020[31]	NR	26				
Mayhew and Bergin 2019[30]	NR	57	24			
Grey literature (non-journal reports)						
Pearson *et al* 2019[35]						
Hojjat *et al* 2019[36]						
Beck *et al* 2020[37]		32	26			
Chang and Diamond 2019[38]						
Allen *et al* 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 *et al* 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 (%)
Peer-reviewed publications							
Trivedi *et al* 2019[16]	80						6
Störmann *et al* 2020[15]						28	
Mitchell *et al* 2019[13]	92	78	24	0			13
Liew *et al* 2020[28]	72	72	15			9	26
Kobayashi *et al* 2019[12]						33	
Brownson *et al* 2019[11]	45		33			22	20
Blomberg *et al* 2019[4]							
Beck *et al* 2019	72	69	17			7	22
Bauer *et al* 2020[10]							25
Puzio *et al* 2020[14]						24	9
Badeau *et al* 2019[32]						14	16
Namiri *et al* 2020[3]							
Aizpuru *et al* 2019[9]							9
Dhillon *et al* 2020[27]						17	
English *et al* 2020[18]	90	71	40		63	21	28
Farley *et al* 2020[47]							8
Bresler *et al* 2019[23]							
Yarmohammadi *et al* 2020[20]						24	76
Faraji *et al* 2020[21]							
Trivedi *et al* 2019[22]							23
Hennocq *et al* 2020[24]							
Kim *et al* 2020[25]							
Oksanen *et al* 2020[26]							61
Shiffler *et al* 2020[19]							21
Siow *et al* 2020[29]						26	37
Ishmael *et al* 2020[33]							
Nellamattathil and Amber 2020*[31]	100	83	15	0			
Mayhew and Bergin 2019*[30]	100	82	18	0		25	40
Grey literature (non-journal reports)							
Pearson *et al* 2019[35]	87						
Hojjat *et al* 2019[36]							
Beck *et al* 2020[37]	65					9	20
Chang and Diamond 2019[38]							
Allen *et al* 2019[39]	91				61	21	29
Sedor and Caswell 2019[40]							
Austin Public Health Unit 2019[17]							15
City of Santa Monica 2019							
Cicchino *et al* 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

	Mechanism (%)		Location (%)	Helmet use (%)			Substance use (%)	
Study	**Single user**	**Collision ***		**Yes**	**No**	**Unknown**	**Alcohol**	**Other**
Peer-reviewed publications								
Trivedi *et al* 2019[16]	88	9		4	32	63	5	
Störmann *et al* 2020[15]	92	8		1				
Mitchell *et al* 2019[13]	69	31		46	20	30		
Liew *et al* 2020[28]				6				
Kobayashi *et al* 2019[12]				7	88	5	48	Positive toxicology screen: 30
Brownson *et al* 2019[11]	97	3		2	19	79	13	
Blomberg *et al* 2019[4]	91	9		4	55	41	37	
Beck *et al* 2019				2	19	79	13	
Bauer *et al* 2020[10]	97	3					49	
Puzio *et al* 2020[14]				0†	–		33	
Badeau *et al* 2019[32]			Sidewalk: 44					
Namiri *et al* 2020[3]								
Aizpuru *et al* 2019[9]								
Dhillon *et al* 2020[27]	34	58		18	71	11	24	
English *et al* 2020[18]	85	15	Street: 71 Sidewalk: 3 Unknown: 26	1.6			11	
Farley *et al* 2020[47]								
Bresler *et al* 2019[23]				5	10	85		
Yarmohammadi *et al* 2020[20]				0†			74	
Faraji *et al* 2020[21]							46	Cannabis: 7
Trivedi *et al* 2019[22]				0†			18	
Hennocq 2020[24]			Sidewalk: 31	12			49	Other substance: 12
Kim *et al* 2020[25]								
Oksanen *et al* 2020[26]				17	0	83	91	
Shiffler *et al* 2020[19]	97	3		12	1	87	12	Other substance: 4
Siow *et al* 2020[29]				3			27	
Ishmael *et al* 2020[33]	89	11						
Nellamattathil and Amber 2020[31]								
Mayhew and Bergin 2019[30]						84		
Grey literature (non-journal reports)								
Pearson *et al* 2019[35]								
Hojjat *et al* 2019[36]								
Beck *et al* 2020[37]								
Chang and Diamond 2019[38]								
Allen *et al* 2019[39]	85	10		2				
Sedor and Caswell 2019[40]	94	6		3			24	
Austin Public Health Unit 2019[17]			Street: 55 Sidewalk: 33	1			29	
City of Santa Monica 2019								
Cicchino *et al* 2020[34]	69	28	Sidewalk: 57 Road: 24 Off-road: 10 Bike lane: 8 Other: 2	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 heterogenous 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 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.

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.

Contributors The study was conceived of by MT. JRB and HC provided methodological guidance. MT and SM conducted the systematic review with guidance from JRB, HC and LKS. All authors contributed to the writing of the manuscript and reviewed and approved the final version of the manuscript.

Funding The authors have not declared a specific grant for this research from any funding agency in the public, commercial or not-for-profit sectors.

Competing interests None declared.

Patient consent for publication Not required.

Ethics approval This study consisted solely of a literature review and requirement for ethics review was waived by the University of British Columbia Research Ethics Board.

Provenance and peer review Not commissioned; externally peer reviewed.

Data availability statement Data are available in public, open access repositories.

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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

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Table 7. Sample Search Strategy

Search Number	*Scooter*	Number of Results
1	Scooter.mp	352
2	Micromobility.mp	25
3	Personal mobility.mp	271
4	**1 or 2 or 3**	**622**
	Injuries	
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**
	Circumstances	
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**

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