OPEN ACCESS

# 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]

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

[1]Faculty of Medicine, The University of British Columbia, Vancouver, British Columbia, Canada
[2]Faculty of Science, The University of British Columbia, Vancouver, British Columbia, Canada
[3]Department of Emergency Medicine, Faculty of Medicine, The University of British Columbia, Vancouver, British Columbia, Canada
[4]Centre 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

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



BMJ

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

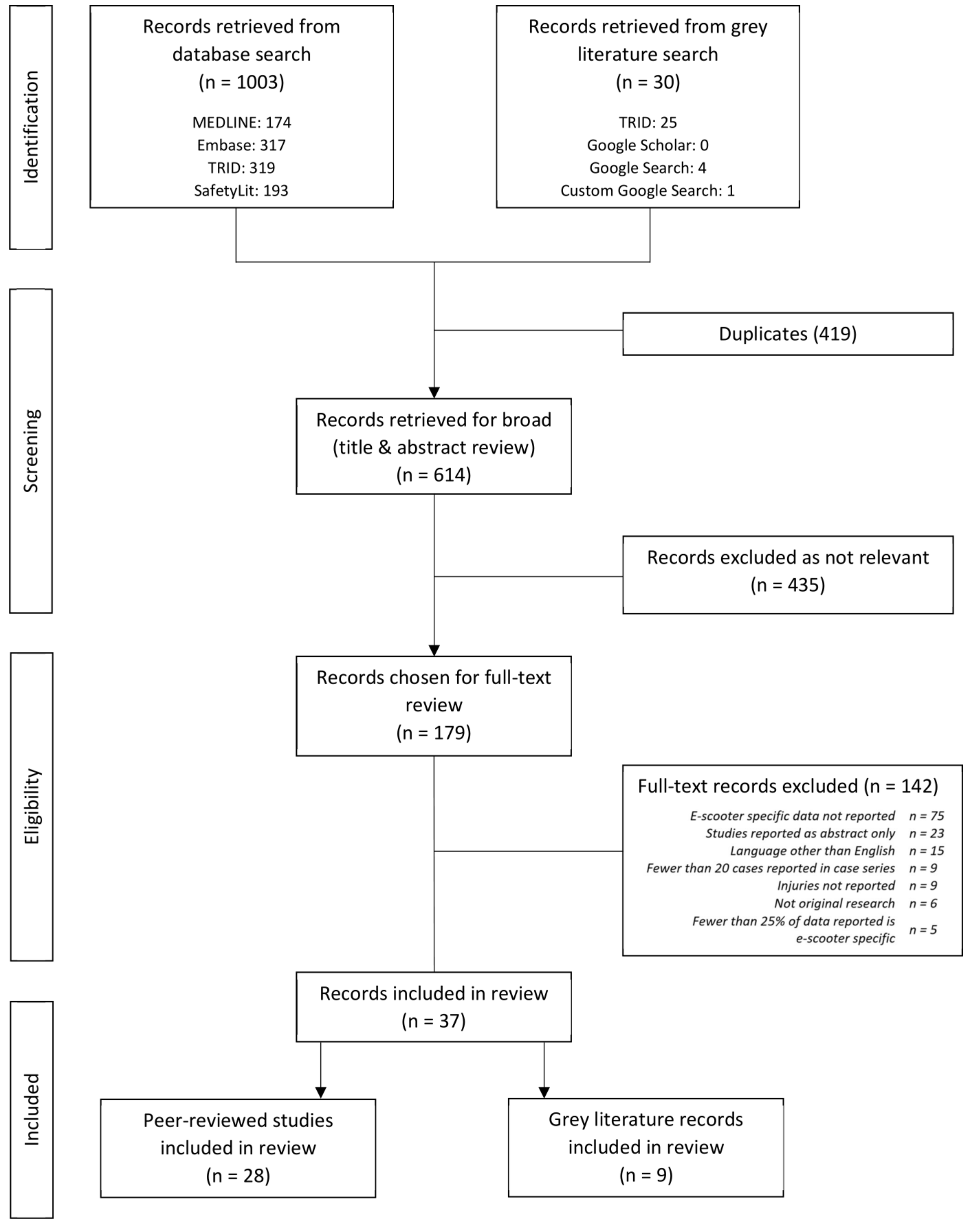


**Figure 1** Preferred Reporting Items for Systematic Reviews and Meta-Analyses search decision flow chart. TRID, Transport Research International Documentation.

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%<br>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%<br>Torso: 12% |
| Puzio *et al* 2020[14] | 36 | 17 | 18 | 12 | 1 | 3 | | Multisystem: 12% |
| Badeau *et al* 2019[32] | | | 20 | | | | | MSK: 70%<br>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%<br>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%<br>Neck: 6%<br>Ear: 1%<br>Eye: 1% |
| Yarmohammadi *et al* 2020†[20] | | | | 100 | | | | Lateral orbital wall: 56%<br>Orbital floor: 53%<br>Orbital roof: 28%<br>Medial orbital wall: 25%<br>Jaw: 15%<br>Nose: 9% |
| Faraji *et al* 2020 †[21] | | | 11 | 50 | | | | Mouth: 15%<br>Ear: 1%<br>Nose: 8% |
| Trivedi *et al* 2019[22] | | | 37 | 44 | 2 | 3 | 2 | Extremities: 64% |
| Hennocq *et al* 2020†[24] | | | | 100 | | | | Forehead: 18%<br>Nose: 11%<br>Cheek: 3%<br>Lips: 28%<br>Chin: 40% |
| Kim *et al* 2020[25] | | | | | | | | Craniofacial: 49% |
| Oksanen *et al* 2020†[26] | | | | | 4 | | | Midface: 43%<br>Mandible: 26%<br>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%<br>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

| | Type of injury | | | | Injury severity | |
|---|---|---|---|---|---|---|
| **Study** | **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<br>Range 1–5 | |
| Kobayashi *et al* 2019[12] | NR | 42 | 19 | | Median 5.5<br>IQR 5–9 | |
| Brownson *et al* 2019[11] | 66 | 42 | 17 | | Median 4<br>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<br>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<br>Median 5<br>IQR 2–10 | |
| English *et al* 2020[18] | 65 | 33 | 18 | 1 | Median 5<br>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<br>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<br>Wound care: 35<br>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 |
| *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<br>Sidewalk: 3<br>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<br>Sidewalk: 33 | 1 | | | 29 | |
| City of Santa Monica 2019 | | | | | | | | |
| Cicchino *et al* 2020[34] | 69 | 28 | Sidewalk: 57<br>Road: 24<br>Off-road: 10<br>Bike lane: 8<br>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.



**ORCID iD**

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

## REFERENCES

1 Choron RL, Sakran JV. The integration of electric Scooters: useful technology or public health problem? *Am J Public Health* 2019;109:555–6.
2 Todd J, Krauss D, Zimmerman J. *Behavior of electric scooter operators in naturalistic environments: SAE technical paper series*. , 2019: 01, 10007.
3 Namiri NK, Lui H, Tangney T, *et al*. Electric scooter injuries and hospital admissions in the United States, 2014-2018. *JAMA Surg* 2020;155:357–9.

4 Blomberg SNF, Rosenkrantz OCM, Lippert F, *et al*. Injury from electric scooters in Copenhagen: a retrospective cohort study. *BMJ Open* 2019;9:e033988.
5 Beck S, Barker L, Chan A, *et al*. Emergency department impact following the introduction of an electric scooter sharing service. *Emerg Med Australas* 2020;32:409–15.
6 Gössling S. Integrating e-scooters in urban transportation: problems, policies, and the prospect of system change. *Transp Res D Transp Environ* 2020;79:102230.
7 Tricco AC, Lillie E, Zarin W, *et al*. PRISMA extension for scoping reviews (PRISMA-ScR): checklist and explanation. *Ann Intern Med* 2018;169:467–73.
8 National Heart, Lung, and Blood Institute. Study quality assessment tools, 2019. Available: https://www.nhlbi.nih.gov/health-topics/study-quality-assessment-tools
9 Aizpuru M, Farley KX, Rojas JC, *et al*. Motorized scooter injuries in the era of scooter-shares: a review of the National electronic surveillance system. *Am J Emerg Med* 2019;37:1133–8.
10 Bauer F, Riley JD, Lewandowski K, *et al*. Traumatic injuries associated with standing motorized Scooters. *JAMA Netw Open* 2020;3:e201925.
11 Brownson AB, Fagan PV, Dickson S, *et al*. Electric scooter injuries at Auckland City Hospital. *N Z Med J* 2019;132:62–72.
12 Kobayashi LM, Williams E, Brown CV, *et al*. The e-merging e-pidemic of e-scooters. *Trauma Surg Acute Care Open* 2019;4:e000337.
13 Mitchell G, Tsao H, Randell T, *et al*. Impact of electric scooters to a tertiary emergency department: 8-week review after implementation of a scooter share scheme. *Emerg Med Australas* 2019;31:930–4.
14 Puzio TJ, Murphy PB, Gazzetta J, *et al*. The electric scooter: a surging new mode of transportation that comes with risk to riders. *Traffic Inj Prev* 2020;21:175–8.
15 Störmann P, Klug A, Nau C, *et al*. Characteristics and injury patterns in electric-scooter related accidents-a prospective two-center report from Germany. *J Clin Med* 2020;9:1569–e69.
16 Trivedi TK, Liu C, Antonio ALM, *et al*. Injuries associated with standing electric scooter use. *JAMA Netw Open* 2019;2:e187381.
17 Austin Public Health Unit. *Dockless electric Scooter-Related injuries study*. Austin, Texas, 2019.
18 English KC, Allen JR, Rix K, *et al*. The characteristics of dockless electric rental scooter-related injuries in a large U.S. City. *Traffic Inj Prev* 2020;21:476–81.
19 Shiffler K, Mancini K, Wilson M, *et al*. Intoxication is a significant risk factor for severe Craniomaxillofacial injuries in standing electric scooter accidents. *J Oral Maxillofac Surg* 2020;S0278-2391(20:31194–0.
20 Yarmohammadi A, Baxter SL, Ediriwickrema LS, *et al*. Characterization of facial trauma associated with standing electric scooter injuries. *Ophthalmology* 2020;127:988–90.
21 Faraji F, Lee JH, Faraji FLee JH, MacDonald B, *et al*. Electric scooter craniofacial trauma. *Laryngoscope Investig Otolaryngol* 2020;5:390–5.
22 Trivedi B, Kesterke MJ, Bhattacharjee R, *et al*. Craniofacial injuries seen with the introduction of Bicycle-Share electric Scooters in an urban setting. *J Oral Maxillofac Surg* 2019;77:2292–7.
23 Bresler AY, Hanba C, Svider P, *et al*. Craniofacial injuries related to motorized scooter use: a rising epidemic. *Am J Otolaryngol* 2019;40:662–6.
24 Hennocq Q, Schouman T, Khonsari RH, *et al*. Evaluation of electric scooter head and neck injuries in Paris, 2017-2019. *JAMA Netw Open* 2020;3:e2026698.
25 Kim M, Lee S, Ko DR, *et al*. Craniofacial and dental injuries associated with stand-up electric scooters. *Dent Traumatol* 2020;00:1–5.
26 Oksanen E, Turunen A, Thorén H. Assessment of Craniomaxillofacial injuries after electric scooter accidents in Turku, Finland, in 2019. *J Oral Maxillofac Surg* 2020;78:2273–8.
27 Dhillon NK, Juillard C, Barmparas G, *et al*. Electric scooter injury in southern California trauma centers. *J Am Coll Surg* 2020;231:133–8.
28 Liew YK, Wee CPJ, Pek JH. New peril on our roads: a retrospective study of electric scooter-related injuries. *Singapore Med J* 2020;61:92–5.
29 Siow MY, Lavoie-Gagne O, Politzer CS, *et al*. Electric scooter orthopaedic injury demographics at an urban level I trauma center. *J Orthop Trauma* 2020;34:e424–9.
30 Mayhew LJ, Bergin C. Impact of e-scooter injuries on emergency department imaging. *J Med Imaging Radiat Oncol* 2019;63:461–6.
31 Nellamattathil M, Amber I. An evaluation of scooter injury and injury patterns following widespread adoption of E-scooters in a major metropolitan area. *Clin Imaging* 2020;60:200–3.
32 Badeau A, Carman C, Newman M, *et al*. Emergency department visits for electric scooter-related injuries after introduction of an urban rental program. *Am J Emerg Med* 2019;37:1531–3.
33 Ishmael CR, Hsiue PP, Zoller SD, *et al*. An early look at operative orthopaedic injuries associated with electric scooter accidents: bringing high-energy trauma to a wider Audience. *J Bone Joint Surg Am* 2020;102:e18.
34 Cicchino JB, Kulie PE, McCarthy ML. Injuries related to electric scooter and bicycle use in a Washington, DC emergency department, 2020. Available: https://www.iihs.org/api/datastoredocument/bibliography/2215
35 Pearson T, Mitchell G, Hacking C. Injury patterns in e-scooter trauma. *J Med Imaging Radiat Oncol* 2019;63:69.
36 Hojjat H, Cowan B, Lucas J. Gliding into the emergency department: scooter injuries to the head and neck. *Otolaryngol Head Neck Surg* 2019;161.
37 Beck S, Barker L, Chan A. Emergency department impact of injuries associated with standing electric scooters - A retrospective case series. *Emerg Med Australas* 2020;32:66–7.
38 Chang A, Diamond P. Traumatic brain injury related to Stand-up motorized scooter usage. *Arch Phys Med Rehabil* 2019;100:e207.
39 Allen JR, English KC, Rix K, *et al*. 262 epidemiology of Dockless electric Rental scooter injuries. *Ann Emerg Med* 2019;74:S103.
40 Sedor A, Caswell N. Shared e-Bike and e-Scooter Mid-Pilot report (city of Calgary), 2019. Available: https://www.calgary.ca/content/dam/www/transportation/tp/documents/cycling/cycling_strategy/shared-e-scooter-and-e-bike-mid-pilot-council-report.pdf
41 City of Santa M. *Shared mobility pilot program summary report*, 2019: 71p.
42 Nathanson BH, Ribeiro K, Henneman PL. An analysis of US emergency department visits from falls from skiing, Snowboarding, Skateboarding, Roller-Skating, and using Nonmotorized Scooters. *Clin Pediatr* 2016;55:738–44.
43 Chiu J, Robinovitch SN. Prediction of upper extremity impact forces during falls on the outstretched hand. *J Biomech* 1998;31:1169–76.
44 Olivier J, Creighton P. Bicycle injuries and helmet use: a systematic review and meta-analysis. *Int J Epidemiol* 2017;46:1:278–92.
45 Haworth NL, Schramm A. Illegal and risky riding of electric scooters in Brisbane. *Med J Aust* 2019;211:412–3.
46 Bekhit MNZ, Le Fevre J, Bergin CJ. Regional healthcare costs and burden of injury associated with electric scooters. *Injury* 2020;51:271–7.
47 Farley KX, Aizpuru M, Wilson JM, *et al*. Estimated incidence of electric scooter injuries in the US from 2014 to 2019. *JAMA Netw Open* 2020;3:e2014500.