



Epidemiology, Injury Severity, and Pattern of Standing E-Scooter Accidents: 6-Month Experience from a German Level I Trauma Center

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Background: E-scooter usage was lawfully approved in Germany in June 2019. Since then, a marked increase of e-scooter drivers has been noticed. Evidence concerning factors that may affect the severity of these injuries is limited. The study aimed to retrospectively analyze e-scooter-related injuries in a major German city.

Methods: All patients admitted to the emergency department of a level I trauma center in Berlin, Germany, between June 15, 2019, and December 15, 2019, were retrospectively reviewed. Patients involved in an e-scooter accident were included in this study, and their medical reports were analyzed.

Results: In the study period, 43 patients were involved in an e-scooter accident and could be included in this study. The median age of the patients was 30 years (interquartile range [IQR], 24.50–39.50 years), with 19 (44.2%) being female patients. The median Injury Severity Score of all patients was 2.0, with the highest Abbreviated Injury Scale (AIS) of 3.00 (IQR, 2.00–3.00) recorded as thoracic injuries. Seven patients had extremity fractures, of which 4 had to be stabilized operatively. In 12 patients (27.9%), the accidents occurred under the influence of alcohol.

Conclusions: The majority of injuries reported in this study were associated with a relatively low AIS, possibly due to strict local speed limits. Nonetheless, e-scooter usage bears risks of sustaining severe injuries to the head, face, and extremities, particularly under the influence of alcohol or when illegally ignoring local laws.

Keywords: *Traffic accident, Analysis, Epidemiology, Prevention and control*

Standing electric kick-scooters were first introduced in California, United States, in September, 2017.¹⁾ Since then, this transportation mode has gained popularity across the

world, presumably because of its ease of use, accessibility, and availability. Due to its lack of tailpipe emission, it has raised hopes of cutting down on carbon dioxide in urban areas to increase the proportion of electrically powered vehicles.²⁾ Critics moan that e-scooters are cluttering cities and dangerously swarm sidewalks, endangering pedestrians, as well as themselves.³⁾ Several publications reported that e-scooter injuries could be severe and account for high-energy trauma.⁴⁻⁶⁾ Because regulations concerning the use of electric kick-scooters differ vastly between countries, regions, and municipalities, comparability between those studies is limited.

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Since the official approval of standing e-scooters in Germany in June 2019, a rapid increase of privately owned and shared rental e-scooters in large cities has been recognized.⁷ Given prior reports from other countries about the threats, the restrictions on the use of electric kick-scooters were set accordingly.⁸ As a result, the maximum speed of these vehicles was limited to 20 km/hr (up to 12.4 mph), the legal age for riding was set to 14 years of age, and the use of sidewalks was outlawed. Evidence concerning the injury pattern, severity, and the injury mechanisms of standing electric kick-scooters in Germany is low.⁹ This study aimed to analyze e-scooter-related injuries of 6 months treated in a level I trauma center in Berlin.

METHODS

Medical records of all patients admitted to the emergency department (ED) of a German level I trauma center between June 15 and December 15, 2019, were retrospectively reviewed. The search process was conducted using clinical patient management software (SAP Germany SE & Co. KG, Walldorf, Germany). We included all patients with a history of an e-scooter accident. Institutional Review Board approval of the Ethics Committee of the Charité University Hospital Berlin was obtained before the study (IRB No. EA2/088/20). Patient consent was waived by the Ethics Committee since this study was performed retrospectively.

Patient data were analyzed for patient characteristics (date of birth, sex, nationality, trauma mechanism, triage code according to the Manchester Triage System, number of persons riding the e-scooter, injury mechanism, and date and time of admission). Alcohol intoxication was defined as serum ethanol level > 0.1 g/L. Final diagnoses of each patient (10th version of the International Classification of Diseases and radiology reports) were documented. Abbreviated Injury Scale (AIS) codes (ver. 2005) of all diagnoses were recorded, and the Injury Severity Score (ISS)

was calculated for each patient. The injury patterns were grouped into major and minor for detailed analysis of the injury patterns (Fig. 1). Major trauma was defined as cases that required intervention (operation and cast immobilization) or monitoring > 24 hours and had intracranial bleeding, pneumothorax, or extremity fractures. Minor trauma was defined as injuries that did not require monitoring and injuries that could not be seen in X-ray or computed tomography (CT) imaging (contusions or cerebral concussion). Soft tissues in closed fractures were classified according to Tschernie and Oestern.¹⁰

Statistical analysis was performed using R and the software RStudio (RStudio Inc., Boston, MA, USA). Normally distributed data are reported by means and standard deviations; nonnormally distributed data are reported by median and interquartile range (IQR).

RESULTS

Forty-three patients were admitted to the ED due to an e-scooter accident within the study period. The median age of the patients was 30 (IQR, 24.5–39.5) with 19 (44.2%) being female patients. In 5 cases (11.6%), the accident happened with a second rider on the e-scooter. Twelve patients (27.9%) presented with an alcohol intoxication with a median serum alcohol level of 1.76 g/L (IQR, 1.43–2.28 g/L). Twenty-one patients (48.8%) were admitted between 12 AM and 6 AM. Twenty-seven accidents (62.8%) occurred during the weekend. A helmet was worn by only 1 patient (2.3%). For 24 patients (55.8%), the exact trauma mechanism was inexplicitly documented as a fall from the e-scooter; when looking at those accidents in which the trauma mechanism was documented in detail, 10 patients (23.3%) fell from the e-scooter because they hit a bump on the road (Table 1).

Twenty-nine patients (67.4%) presented with injuries of the extremities, while 21 patients had injuries of the facial region (48.8%). The body region with the highest

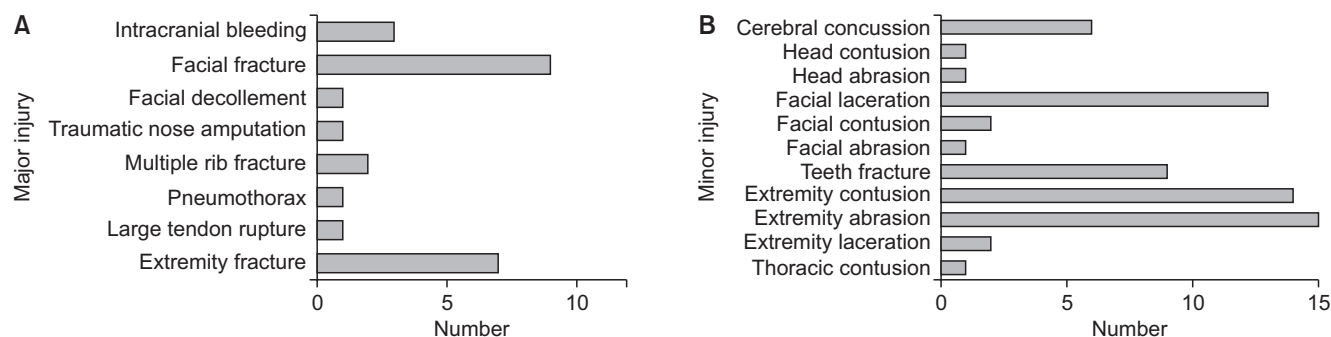


Fig. 1. Bar graphs displaying the absolute numbers of all recorded major (A) and minor (B) injuries of the study cohort.

Table 1. Baseline Characteristics of All Analyzed Patients

| Variable | Value |
|----------------------------|---------------------|
| Number | 43 |
| Female sex | 19 (44.2) |
| Age (yr) | 30.00 (24.50–39.50) |
| Triage code | |
| - | 2 (4.7) |
| 1 | 0 |
| 2 | 6 (14.0) |
| 3 | 28 (65.1) |
| 4 | 7 (16.3) |
| Presence of co-driver | 5 (11.6) |
| Time of admission | |
| 12 AM–6 AM | 21 (48.8) |
| 6 AM–12 PM | 4 (9.3) |
| 12 PM–6 PM | 8 (18.6) |
| 6 PM–12 AM | 10 (23.3) |
| Helmet use | 42 (97.7) |
| ISS | 2.00 (1.00–4.00) |
| Injury mechanism | |
| Collision with automobile | 1 (2.3) |
| Lost balance | 5 (11.6) |
| Slip and Fall | 3 (7.0) |
| Hit bump | 10 (23.3) |
| Not documented | 24 (55.8) |
| Alcohol use | 12 (27.9) |
| Blood alcohol, serum (g/L) | 1.76 (1.43–2.28) |
| AIS head/neck | 1.00 (1.00–1.00) |
| AIS face | 1.00 (1.00–1.50) |
| AIS thorax | 3.00 (2.00–3.00) |
| AIS abdomen | 1.00 (1.00–1.00) |
| AIS extremity | 1.00 (1.00–2.00) |
| AIS external | - |
| Admission (%) | 10 (23.3) |
| Days of admission | 3.50 (1.75–5.25) |
| ICU use | 3 (7.0) |

Values are presented as number (%) or median (interquartile range).
ISS: Injury Severity Score, AIS: Abbreviated Injury Scale, ICU: intensive care unit.

Table 2. Overview of the Percentual Distribution of Minor and Major Injuries

| Variable | Minor | Major |
|----------------------|-----------|-----------|
| Number (%) | 67 (70.5) | 28 (29.5) |
| Head and brain = yes | 8 (8.4) | 3 (3.2) |
| Face = yes | 25 (26.3) | 14 (14.7) |
| Extremity = yes | 31 (32.6) | 8 (8.4) |
| Thorax = yes | 1 (1.1) | 3 (3.2) |

Values are presented as number (%). Percentages of each subset are related to the sum of all injuries. Minor injuries: e.g., abrasions, concussion, lacerations. Major injuries: e.g., intracranial hemorrhage, fractures, pneumothoraces.

AIS was the thorax with a median AIS of 3 (IQR, 2–3) and was recorded for thoracic injuries with multiple (≥ 3) rib fractures. In total, 4 patients (9.3%) sustained injuries to the thorax (Table 2). The median ISS of the entire cohort was 2 (IQR, 1–4).

Sixty-seven injuries (70.5%) were minor injuries compared to 28 major injuries (29.5%) (Table 2). Two patients had intracranial bleeding and were admitted to an intensive care unit (ICU). However, a neurosurgical intervention was not required in any of the cases. Nine patients (20.9%) sustained facial fractures, of which 6 had to undergo surgery, as recently reported in detail.¹¹⁾ Seven patients (16.3%) sustained extremity fractures, of which 4 had to undergo surgery. One patient had a dislocated radial head fracture with an additional shearing fracture of the humerus' capitulum, which was not operated in our clinic because the patient visited Berlin as a tourist and wanted to undergo surgery back home. One patient sustained a rupture of the patellar tendon, which was treated operatively (operation time: 74 minutes; 8 days of hospital treatment). The 3 other fractures were as follows: 1 split-depression fracture of the medial tibial condyle (operation time: 91 minutes; 9 days of hospital treatment) (Fig. 2), 1 ankle fracture (operation time: 34 minutes; 3 days of hospital treatment), and 1 fracture of the clavicle (operation time: 83 minutes; 6 days of hospital treatment). Three patients underwent conservative fracture treatment (2 fractures of the radial head and 1 fracture of the distal radius). In total, 10 patients (22.7%) had to be admitted to the hospital, and 3 patients (7.0%) had to be monitored at the ICU. The median hospital stay was 3 days (IQR, 1.5–5 days). The median score of the additional fracture scoring by Tscherné and Oestern was 1 (IQR, 0–1).

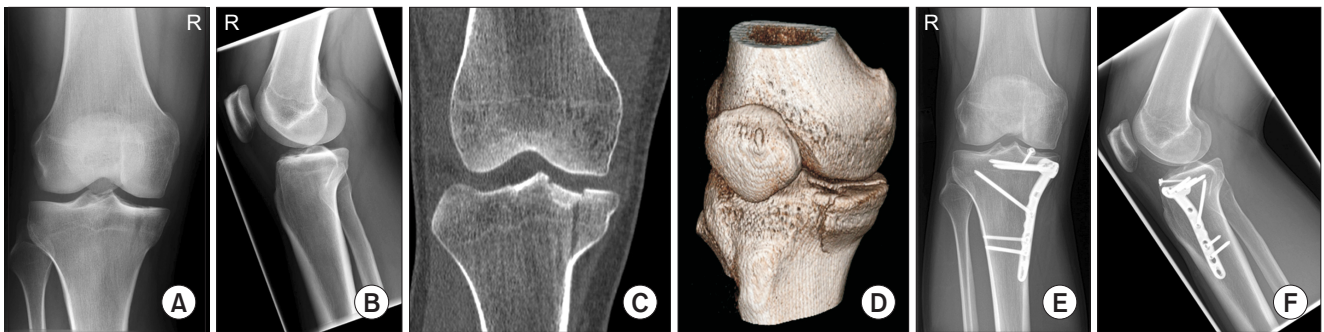


Fig. 2. (A-D) Clinical case of a 27-year-old male patient who drove an e-scooter to work and fell off the vehicle after he struck a bump on the road. Clinical examination, X-ray, and computed tomography imaging demonstrated a split depression fracture of the medial tibial plateau (41B3.2 according to the AO/OTA classification). Open reduction and internal fixation was performed 2 days later. (E, F) One year after the operation, the patient demonstrated good recovery with no pain at all, as well as a good joint function with a range of motion of 5° extension and 150° flexion.

DISCUSSION

This study reports the injury pattern following accidents with e-scooters in a level I trauma center in Germany. It shows that e-scooter accidents are responsible for a significant proportion of patients in the ED. However, these accidents are most often associated with less severe injuries, as demonstrated by the low AIS and ISS scores.

Trivedi et al.¹⁾ recently reported approximately 240 patients were admitted due to e-scooter-associated injuries in two trauma centers in California (USA) in 1-year period. They reported patients had fractures of the extremities or contusions/lacerations in 31.7% and 27.7%, respectively. While they did not report the fractures' severity, the fractures' percentage was higher compared to our data (31.7% vs. 15.9%). Similarly, Badeau et al.¹²⁾ studied 50 patients following e-scooter accidents, with 36% having significant musculoskeletal injuries. Ishmael et al.⁴⁾ analyzed surgically treated e-scooter-based injuries over 2 years in two trauma centers (Santa Monica, CA, USA). They reported 75 injuries requiring surgery, of which nine were open fractures and mostly located at the elbow, wrist, hip, and knee. Beck et al.¹³⁾ reported 56 e-scooter accidents during six weeks in a single trauma center (Dundin, Australia) and showed fractures or dislocations in 32% of the cases. Although New Zealand restricted e-scooters' maximum power to 300 watts, the official speed limit was 30 km/hr.^{14,15)} Interestingly, Haworth and Schramm⁶⁾ from Brisbane, Australia, studied 109 patients with an e-scooter-related accident, of which 23.9% suffered extremity fractures. By that time, the official speed limit was reduced to 25 km/hr.⁶⁾ Blomberg et al.¹⁶⁾ studied all centers in Copenhagen (Denmark) over 3.5 years to reveal 112 patients with e-scooter-associated injuries: 11.6% sustained fractures, but the majority suffered from lacerations or contusions/sprains. As in Germany, the

speed limit of e-scooters in Denmark was set to 20 km/hr.

Uluk et al.⁹⁾ reported on 16.1% of the patients with fractures of the extremities during a 1-month period, which compare well to our data. Although the study designs differ significantly, the severity of injuries seems to be directly related to the local speed limit while a speed limit of more than 20 km/hr results in a higher percentage of severely injured patients. This might serve as a base for future considerations or regulations by local authorities.

Risk factors previously identified in e-scooter accidents are as follows: speeding (> 30 km/hr), driving without a helmet, and drunk driving.^{6,17)} Therefore, Australia's legal bodies issued that wearing a helmet when driving an e-scooter was mandatory.⁶⁾ Nonetheless, Haworth and Schramm⁶⁾ found that in Brisbane, 45% of the shared e-scooters observed were driven illegally (no helmet, doubling a passenger, or riding on the road). In Germany and other countries, wearing a helmet is not compulsory. Our data showed eight patients with minor and three with significant head injuries (intracranial bleeding). The majority of patients did not wear a helmet. These results are comparable to findings of other studies.^{1,9,13,18)} Because of the high proportion of patients with intracranial or facial injuries/fractures, CT imaging has to be performed, if necessary. Maxillofacial injuries described in our study have previously been discussed in depth.¹¹⁾ In our study cohort, 27.9% of the patients were drunk driving with a median serum blood alcohol of 1.76 g/l. This compares well to Blomberg et al.,¹⁶⁾ who showed 36.6% of all patients drove under the influence of alcohol. However, other studies revealed distinctly lower alcohol abuse proportions (4%–16%).^{9,12,13)}

To our knowledge, this is the first report with a detailed overview of the distribution of injuries following e-scooter accidents using AIS and ISS. Both the AIS and ISS

scores were developed to describe injury patterns and predict mortality in multiple injured patients, i.e., polytrauma patients.¹⁹⁾ This study revealed that most e-scooter-related injuries had low AIS and ISS scores, which corresponds to the low-energy trauma, given a speed limit of 20 km/hr. Both scores, however, are inaccurate in describing orthopedic extremity trauma.²⁰⁾ For instance, hip and shoulder dislocations score equally (2 points), although both trauma mechanism and energy are not comparable in these injuries. We also reported the classification according to Tscherne and Oestern for all fractures to present additional information on the fracture severity to anticipate this discrepancy. However, in concordance with the AIS/ISS scores, these results showed low severity.

This study has several limitations. It is retrospective in design with all its disadvantages. Subsequently, data that rely on the patients' reports (e.g., co-rider and helmet) may be prone to error. The exact mechanism of injury was not sufficiently documented in 55.8% of all cases. Furthermore, the blood alcohol level was not measured routinely, but in cases of suspicion only. Nevertheless, this study demonstrated important risk factors concerning e-scooter injuries and the severity thereof. Comparability between studies is currently limited because of a lack of studies reporting AIS and ISS scores and orthopedic-specific scores such as the Tscherne and Oestern classification.¹⁰⁾ Future prospective

studies are therefore required to further specify the risk factors and injury patterns of e-scooter-related injuries and formulate recommendations for legal authorities.

We could demonstrate that most of these injuries were associated with minor injuries, possibly due to local strict speed limits. Nonetheless, e-scooter use bears risks of sustaining severe injuries to the head, face, and extremities, particularly under the influence of alcohol or when illegally ignoring local laws.

CONFLICT OF INTEREST

No potential conflict of interest relevant to this article was reported.

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