

Analysis and Comparison of Electric Scooter Crashes: A Review of Crash Characteristics and Health Outcomes in Türkiye

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ABSTRACT

Micromobility, including shared e-scooters, has become a convenient mode of transportation for short-distance trips globally. Türkiye introduced shared e-scooters in 2019, quickly expanding their presence. This study analyses and identifies the crash characteristics and health outcomes of e-scooter crashes in Türkiye. It also seeks to provide recommendations for enhancing safety.

This review focused on e-scooter crashes in Türkiye, a country with a population of 85,279,553. Our narrative analysis examined eight studies and eight media reports on e-scooter incidents in Türkiye, evaluating patient demographics, crash characteristics (user type, fall/collision, speed, time, location), injury types, interventions, hospitalizations, and modifiable risk factors like helmet use and alcohol consumption.

Accidental involvement was slightly higher in men than in women. The rate of helmet usage is quite low. Upper extremity injuries are the most common type, followed by lower extremity injuries. Fatalities have occurred, underscoring public health concerns. E-scooter crashes often involve collisions with pedestrians and vehicles, highlighting the need for adherence to traffic rules and safe riding practices.

E-scooters are a practical transportation solution but pose safety risks. Protective measures such as helmet and other protective equipment use, compliance with traffic rules, and public awareness campaigns are crucial to mitigate these risks. We conclude that e-scooter safety regulations in Türkiye should be enhanced to protect riders and pedestrians and promote a safer micromobility ecosystem.

Keywords: Crashes, micromobility, e-scooters.

1. Introduction

Micromobility is a transportation mode that offers a practical solution for short-distance travel and has been gaining popularity over time. Among micromobility systems, vehicle-sharing systems for e-scooters, which have become increasingly popular worldwide in recent years, were introduced in Türkiye in 2019. This service started in İstanbul and Ankara, but it quickly expanded to other cities. It is estimated that there are around 30,000 shared e-scooters in İstanbul alone (Diken, 2021). The first fatal crash involving a shared e-scooter in Türkiye was recorded in İstanbul in 2020 (Sözcü, 2020). However, it was not until a year later, in April 2021, that the "Electric Scooter Regulation" was published in the Official Gazette (Resmi Gazete, 2021). Following this, there has been a limited increase in education and resources related to safe riding.

Traffic accidents not only affect human life and health but also have negative implications for societies' economic and social structure. They can result in individual consequences, such as the need for care, disability, and loss of the workforce, both financially and emotionally. Additionally, crashes indirectly impact society's overall health and well-being by placing an extra burden on the healthcare system and healthcare workers. A portion of healthcare resources and spending must be allocated to the treatment, recovery, and reintegration of injured individuals. For these reasons, e-scooter crashes are both safety and public health concerns (Masilkova 2017, Singh 2022).

The United Nations has introduced a new hospital code specifically for micromobility vehicle crashes within the NEISS (National Electronic Injury Surveillance System) by the United States Consumer Product Safety Commission. The NEISS gathers data on patients admitted to emergency services following crashes and uses these data to compile statistics and reports. Between 2014 and 2019, 70,644 micromobility crashes were reported. In 2014, 4,881 crashes nearly sixfold to 29,628 in 2019 (Farley, 2020). Each of these crashes cost the country approximately €3,854. Notably, e-scooter crashes occurred at a rate of 5.2 per 10,000

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miles traveled, car crashes occurred at a rate of 0.1, and motorcycle crashes occurred at a rate of 0.05 per 10,000 miles. Excluding individual vehicles, shared e-scooters have a crash rate of 2.2 per 10,000 miles of travel (Pobudzei 2022).

It is possible to categorize crashes based on their characteristics, such as the time of occurrence, location, involvement of other vehicles, and severity of the impact. When examining their effects, crashes involving e-scooters can be categorized into two main groups: crashes caused by the e-scooter rider (e.g., falls, collisions with objects, collisions with pedestrians) and crashes where the e-scooter rider is involved with other traffic elements (e.g., collisions with other vehicles, where the rider user is the victim) (Mitropoulos, 2023). An example of the first category is a collision between an e-scooter rider and pedestrian on a sidewalk. In contrast, an example of the second category is a crash in which an automobile collides with an e-scooter.

According to recent data (Yılmaz 2022, İğrek & Ulusay 2023), a significant proportion of crashes are more likely to be caused by e-scooter riders than incidents where they are the victims. The impact and consequences of such crashes are directly related to how they occur and the severity of the crash. Obtaining information about the formation of e-scooter crashes in Türkiye is often difficult because crashes resulting from falls or e-scooter-pedestrian collisions are reported to the police only if there are severe injuries; therefore, no records are kept if none of the involved people are sent to the hospital. The inability to determine the characteristics of a crash hinders the development of preventive methods and measures, making it challenging to determine the complete picture.

Although bicycles, one of the oldest forms of micromobility, have been used in Türkiye for many years, a significant portion of the public perceives them more as a means of sport or recreation rather than transportation (Dündar et. al 2022). On the other hand, the inclusion of e-scooters in the transportation system has strengthened the perception among some people that they are more of a recreational vehicle than a mode of transport (Dündar 2023a). Additionally, traffic accidents involving e-scooters and their negative impact on traffic (Dündar, 2023b) have further contributed to the growing negative perception of e-scooters among the public. This perception is not unique to Türkiye; restrictions on e-scooter use have also been implemented in France (Schofield, 2023) and Australia (Wong, 2024).

E-scooters can play an important role in transportation, particularly in journeys defined as the "last mile" or "last kilometer." However, the negative public perception of e-scooters severely undermines this potential. Unlike motor vehicles such as cars, e-scooters do not provide a protective environment around the driver, which means that in the event of an accident, the consequences can be severe. Therefore, the use of protective equipment such as helmets, knee pads, elbow pads, and wrist guards is recommended. In fact, in some countries, the use of such protective gear is a legal requirement (Deveci 2023). Although the literature contains various studies (Kleinertz 2021, Kazemzadeh et al. 2022, Zhao et al 2022) examining the factors and outcomes of accidents in different countries, no study has evaluated these studies and analyzed the factors affecting accident outcomes in this context. Therefore, the objectives are to examine publications and internet news about e-scooter crashes, their characteristics, and outcomes in Türkiye. Thus, this study aimed to support the development of various rules or regulations related to e-scooter usage by evaluating how different factors, such as the use of protective equipment and alcohol consumption, affect accident outcomes. The secondary objective of this study is to develop recommendations to reduce the severity of e-scooter crashes and their consequences in Türkiye.

2. Materials and methods

The present article is a narrative review of the existing literature on e-scooter crashes and their health outcomes. Narrative review is chosen for their ability to provide a wide-ranging exploration of e-scooter accidents and to discuss the outcomes of accidents with respect to factors such as protective equipment or alcohol use. Narrative review is also chosen since the various effects of e-scooter usage are emerging topics, and a more flexible approach is required to integrate diverse findings. A search of the PubMed and Google Scholar electronic databases was undertaken using the search terms "e-scooter crashes," "micromobility crashes," "health outcomes," "health," "hospital," "emergency," "injury pattern," "impact," and "falls" in various permutations and combinations. A total of 142 citations were retrieved using this method. On reviewing the above citations, 134 articles were excluded: 35 because they concerned other types of micromobility vehicles, one because it was a preprint version, one article because we had no access to full text, one because it is a congress paper, one addressed only a single health outcome (ligament injury), 63 because they dealt with other subjects (such as road danger, modeling mobility, emission), and 32 because they dealt with other aspects of e-scooter crashes (such as; safety, sustainability, cost-effectiveness, parking).

As it was not possible to conduct a formal systematic review or meta-analysis given the nature of the above publications, it was instead decided to conduct a narrative review, giving priority to eight studies (Yavuz 2022, Yılmaz 2022, Büyükceran 2023, Demir 2023, Avıncı Taş 2024, İğrek & Ulusoy 2023, Kültür et al. 2023, Baca et al. 2024) from Türkiye and eight media reports briefly summarizing the health outcomes of e-scooter injuries. The news report mining method has been successfully employed in

previous studies (Yang et. al 2020, Scquizzato et. al 2022, Brauner et. al 2022), and we replicate this approach within the context of Türkiye.

Articles were reviewed to assess patient demographics, crash characteristics (e.g., user vs. non-user, fall vs. collision, speed, time of day, and crash location), injury regions and types, interventions, hospitalizations following crashes, and modifiable risk factors that increase the likelihood of crashes, such as helmet use and alcohol consumption. Descriptive data; were expressed as Mean (m), Standard deviation (SD), frequency (%), and number of participants (n).

3. Results

We identified relevant articles and media reports on e-scooter crashes in Türkiye. Our search yielded seven retrospective studies (Yavuz 2022, Yılmaz 2022, Büyükceran 2023, Demir 2023, İğrek & Ulusoy 2023, Kültür et al. 2023, Baca et al. 2024), one prospective study (Avıncı & Taş 2024) from academic sources. Table 1 presents the patient and crash characteristics of the studies, while Table 2 outlines the health outcomes related to e-scooter crashes in these studies. Additionally, we identified eight media reports on the subject (Sözcü 2020, 61Medya 2022, Haber61 2022, Sözcü 2022, Habertürk 2022, TRT Haber 2022, Sabah 2022a, Cumhuriyet 2022b). The compilation of media news records involved gathering data from national news sources in Türkiye published between 2020 and 2023. Although the literature review identified a significantly higher number of e-scooter accidents during these dates, the accidents that made it to the news were those considered newsworthy, involving rule violations or accidents that resulted in fatalities or significant injuries. Therefore, only accidents that appeared in news sources were included in the study. Additionally, accidents covered by multiple news sources were incorporated into the research, with references made to the sources that provided the most detailed information about the incident.

Table 1. The patient and crash characteristics from the studies.

	Mean age m±sd (range)	Patients < 18 years (%)	Female gender (%)	User/non- user (%)	Speed (km/s)	Fall/collision (%)	Alcohol involvement (%)	Helmet use (%)	Day of accident/time of accident (%)	Location of accident (%)
Yavuz 2022 (n=70)	25.82±8.04 (15-57)	8.5%	47.1%	NA	NA	94.2% fall 4.3% collision with an object or person 1.4% collision-with of moving object	2.9% (n=2)	4.3% (n=3)	NA	NA
Yılmaz 2022 (n=117)	27.20±11.90 (5-76)	13.7%	35.9%	96.6%/3.4 %	NA	NA	0%	0%	41.9% weekend	85.5% beach 6% pavement 3.4% road 2.6% sidewalk 2.6% other locations
Büyükceran 2023 (n=99)	NA	49.4%	50.5%	NA	NA	58.5% fall 37.3% collision with moving objects 4.2% collision with an object or person	NA	NA	54.6% 18.00-24.00 31.3% 00.00-06.00 14.1% 12.00-18.00	NA
Demir, 2023 (n=60)	25.3 (6-62)	16.7%	48.3%	1.7% non- user	NA	68.3% fall 18.4% collision with an object or person 11.7% collision with moving objects	0%	1.7%	75% weekdays 51.7% 12.00-18.00 23.3% 06.00-12.00 18.3% 18.00-24.00 6.7% 00.00-06.00	60% urban
Avıncı & Taş 2024 (n=247)	22.93±8.085 (13-44)	0.49%	39%	NA	NA	NA	NA	NA	NA	NA
İğrek & Ulusoy, 2023 (n=62)	34.21 (9-58)	25.8%	27.5%	90.3%/9.7 %	NA	75% fall 14.2% collision with moving objects 10.8% collision with an object or person	19.3%	6.4%	66.1% weekend or weekdays 17.00- 08.00 33.9% weekdays 08.00-17.00	45.1% cycling path 35.4% road 19.5% sidewalk
Kültür et al. 2023 (n=43)	35.9 (16-61)	0%	46%	NA	30.2% highest speed (25km/ h)	NA	34.9%	4.7%	44.2% 23.00-07.00 25.6% 07.00-15.00 30.2% 15-23.00	37.2% driveway 62.8% sidewalks
Baca et al. 2024 (n=56)	25.01±2.38 (9- 52)	35%	32%	NA	NA	67% fall	NA	NA	62.5% weekend 66.1% daytime	NA

This retrospective study analyzed patients who presented to hospital emergency departments in Istanbul. The study by Yavuz et al. (2022) is the first scientific publication to address the clinical and demographic characteristics of patients presenting to the emergency department due to e-scooter crashes in Türkiye. The type and pattern of injuries in e-scooter crashes, use of protective gear, and health-related findings were retrospectively examined and analyzed in 70 cases. Of the cases, 47.1% were female, 52.9% were male, and the average age was 25.82±8.04 (ranging from 15 to 57 years old). According to how the crashes occurred, it was determined that 94.2% involved the rider falling, 4.3% involved colliding with an object or a person, and 1.4% involved colliding with a vehicle. Alcohol was detected in the blood in 2.9% of cases (n=2), and helmet use was recorded in only 4.3% (n=3) of cases.

The most common injuries resulting from crashes were soft tissue trauma (45.7%, n=32), followed by head trauma (40%, n=28), lower or upper limb fractures (8.5%), spinal fractures (2.9%), frontal bone fractures (1.4%), intracranial hemorrhage (1.4%), jaw and facial fractures (11.4%), and injuries requiring stitches (20%). While 94.2% of cases were discharged, 5.7% were admitted to the hospital for treatment (3 to the ward and 1 to the emergency department).

Table 2. The health outcomes related to e-scooter crashes in these studies

	Yavuz 2022	Yılmaz 2022	Büyükercan 2023	Demir 2023	Avıncı and Taş, 2024	İğrek & Ulusoy, 2023	Kültür et al. (2023)	Baca et al. (2024)
Injured body region								
Head/neck	51.4%	36.8%	NA	57.2%	19.51%	0%	0%	NA
Thoracic	0	8.5%	NA	6.3%		NA	0%	NA
Extremities (lower/upper)	8.5%	94.9% (49.6%/45.3%)	86.7% (27.2%/59.5%)	59.4% (29.2%/30.2%)	78.05%	88.5% (36.3%/52.2%)	34.7%/65.3%	NA
Spine	2.9%	1.8%	NA	NA	2.44%	4.5%	0%	NA
The type of injury								
Fracture	24.2%	15.5%	100%	31.7%	24.39%	41.9%	100%	100%
Soft tissue trauma	45.7%	7.7%	NA	100%	75.61%	NA	NA	NA
Hemorrhage	1.4%	0.9%	NA	NA	NA	NA	NA	NA
Intervention								
Suturing	20%	NA	NA	NA	7.34%	NA	NA	NA
Imaging (MRI, X-ray, etc)	63.3%	NA	NA	100%	NA	NA	NA	NA
Blood test	3.4%	NA	NA	NA	NA	NA	NA	NA
Consultation needed	NA	48.7%	NA	NA	100%	NA	44.2%	NA
Hospitalization								
Discharged	94.2%	96.6%	NA	86%	85.37%	43.6%	16.3% under 4 h 39.5% more than 4 h	NA
Admitted to the hospital	5.7%	3.4%	NA	78%	14.63%	56.4% (m=3.7 days)	44.2%	NA
Surgery	NA	2.6%	NA	13.3%	12.2%	51.6%	44.2%	48.2%
Conservative	NA	NA	NA	NA	NA	38.5%	55.8%	52.8%
Work loss	NA	NA	NA	NA	NA	2.4 months	NA	NA

NA: Not applicable; m: mean; h: hour

Yılmaz et al. (2022) retrospectively analyzed cases presented to the emergency department due to e-scooter crashes. The study included 117 cases, with 35.9% female and 64.1% male patients ranging in age from 5 to 76 years (mean: 27.20±11.90). A total of 13.7% of the cases (n=16) were under 15. 41.9% of the crashes occurred on weekends. Of the injured individuals who reached the hospital, only 1.7% arrived by ambulance, while 98.3% went independently as outpatients. None of the patients showed alcohol in their blood; 23.3% were directed to X-rays, 38.5% to computed tomography (CT) scans, 1.7% to ultrasonography (USG) imaging, and 3.4% had blood tests. In 96.6% of the crashes, the rider was injured, and 3.4% were passengers. Helmet use was not recorded in any crash. The average speed was 24.36±6.28 km/h (ranging from 10 to 30 km/h), and 85.5% of the crashes occurred on the sidewalk, 85.5% on the beaches, 6% on the pavement, 3.4% on the road, 2.6% in the sidewalks and 2.6% in other locations on the road, and 2.6% in other locations. The most common injuries resulting from crashes were upper extremity injuries (49.6%), followed by lower extremity injuries (45.3%), head/face injuries (35%), thoracic injuries (8.5%), neck injuries (1.8%), and spinal injuries (1.8%). Among these cases, 4.3% (n=5) had lower extremity fractures, 9.4% (n=11) had upper extremity fractures, and 1.8% (n=2) had dental fractures. Moreover, 7.7% of cases (n=9) had soft tissue injuries to the head, and 0.9% had internal bleeding. When the relationship between injury severity and findings was examined, a moderate negative correlation was found between trauma severity and age. Among the included patients, 96.6% were discharged, whereas 3.4% were hospitalized. The study revealed that crashes resulted in minor patient injuries and identified injuries outside e-scooter users due to legal and technical reasons.

Büyükercan et al. (2023) examined orthopedic injuries resulting from e-scooter crashes, focusing on the pediatric population. The study retrospectively analyzed 99 patients admitted to the hospital emergency department with fractures. Almost half of the patients (49.4%) were under 18 years old, and the remaining were adults. Most crashes (58.5%) resulted from spontaneous falls, 37.3% involved collisions with vehicles, and 4.2% were due to striking stationary objects. Upper extremity fractures were more common (59.5%) than lower extremity fractures (27.2%). Crashes occurred most frequently between 18:00 and 00:00 (54.6%), followed by between 00:00 and 06:00 (31.3%). Pediatric patients tended to have more clavicle and humerus fractures, whereas adults had more radial and tibial fractures. Surgical treatment is more common for lower extremity fractures. This study highlighted that e-scooters are popular among pediatric populations and emphasized the importance of public education and awareness to prevent these injuries and associated workforce loss.

Similarly, in a study by Demir et al. (2023), the clinical and crash characteristics of 60 patients requiring surgical intervention were retrospectively analyzed. The majority of respondents were university students, with a slightly higher representation of males.

The average age of the patients was 25.3 years (range, 6–62 years). E-scooter crashes were predominantly observed on weekdays, accounting for 75% of the cases. Non-contact crashes were the most common, constituting 68.3% of the incidents. The peak hours for crashes were between 12:00 and 18:00, representing 51.7% of the cases. All patients in the study sustained soft-tissue injuries (100%), with 13.3% requiring surgical intervention. Notably, extremity fractures were prevalent, occurring in 30% of both the lower and upper extremities, whereas maxillofacial fractures were observed in 25.5% of cases. The results of this analysis shed light on the severity of e-scooter-related injuries, particularly among young individuals, many whom students were. Notably, helmet use was conspicuously absent, and fatal crashes were infrequent. The most common injury was soft tissue trauma to the knee, wrist, and forehead, with a significant incidence of closed distal radius and nasal fractures. Additionally, it is pertinent to highlight the increased occurrence of non-contact crashes. These findings underscore the importance of safety measures and public awareness campaigns to mitigate the risk of such injuries, especially among young e-scooter users. The studies also emphasized the importance of public education and awareness to prevent such injuries and the associated workforce loss.

Study by Avıncı & Taş (2024) revealed that the number of patients admitted to the hospital due to e-scooter accident was 247, with 39% female and 61% male ranging between ages 13 to 44 in Diyarbakır after the first half of 2022. The average age was 22.93 ± 8.085 . Most of the patients had extremity-related trauma (78.05%, $n=160$), 19.51% had neck trauma ($n=40$), and 2.44% had vertebral trauma ($n=5$). Similarly, 75.61% had soft tissue-related trauma, whereas 24.39% had fracture in any region. All patients were discharged after treatment. Patients who received inpatient treatment from the hospital ($n=30$), 4.87% ($n=10$) were admitted to the intensive care unit, and 9.76% ($n=20$) were admitted to the relevant clinical service. This study demonstrates the need for protective gear to be advised and worn, and the policies outlined in numerous articles of comparable legislation must be put into action and closely observed.

Again in Diyarbakır (İğrek & Ulusoy 2023) in between January and July 2022, they reported 62 patient admissions to two different hospitals with 105 orthopedic injuries, comprising 72.5% males and 27.5% females, with a median age of 34.21 years. Fifty-six (90.3%) patients were riders and six were pedestrians. All associated e-scooters were rented. There were 44 fractures (41.9% of the total recorded injuries) including 8 (12.9%) open fractures. Surgery was required by 32 patients (51.6%) and 35 (56.4%) required hospital admission, leading to hospitalization for an average of 3.7 days. According to the study findings, the average duration of job loss among working patients after an injury is 2.4 months. This study appears to be the first to examine job loss in this context and in Türkiye, highlighting the potential economic burden that such injuries can impose on countries. Helmet use was detected in 6.4% of the e-scooter users, but no other protective equipment was detected in any of the patients. Furthermore, 19.3% of patients had a blood alcohol level of >10 mg/dl.

Between January 2022 and August 2022, 43 patients who were admitted to the emergency department after an e-scooter accident and developed extremity fractures were included. Patients were divided into 2 groups those treated surgically and conservatively. The mean age of the patients was 35.9 (16–61 years), and 46% were women ($n=20$). The study revealed that 65.3% of patients had upper extremity injuries, 34.7% had lower extremity injuries, and no patients had pelvic or spinal injuries (Kültür et al. 2023).

According to a study by Baca et al. (2025), among the 4481 upper extremity fractures, finger fractures (27.47%) and distal radius fractures (25.37%) were common, whereas e-scooter-related cases exhibited radius and ulna shaft fractures (23.07%). Of 2400 lower extremity fractures, toe fractures (30.2%) and metatarsal fractures (19.66%) predominated, with e-scooter-related injuries primarily involving metatarsal fractures (30%). The surgery rate in all patients was 8.92%, whereas the surgery rate for e-scooter injuries was 48.2%. The occurrence of lower extremity fractures was significantly greater in e-scooter-related injuries than in upper extremities ($p=0.011$). Collisions involving stationary or moving objects were linked to lower extremity injuries, whereas falls were primarily associated with upper extremity injuries. Treatment included surgery (48.2%) and conservative management (52.8%), with Open reduction and internal fixation surgery (35.7%) and Closed reduction-internal fixation surgery (10.7%) utilized (Baca et al, 2024).

The first fatal crash with a shared e-scooter in Türkiye was reported in the news for the first time in 2020 (Sözcü, 2020). The incident occurred late at night on a busy street in Istanbul. The incident involved a collision between a car and a 17-year-old boy who was riding an e-scooter. The collision resulted in the young man's death in the scene because he was dragged nearly 30 meters by the vehicle.

In April 2022, in Trabzon, a news report emerged of an incident where a child walking with his family on a sidewalk was struck by an e-scooter carrying two people in the opposite direction. The e-scooter riders and the child were unharmed because of the accident (61Medya 2022). In the same year, in June, another incident occurred in Trabzon, where a 20-year-old rider was severely injured after colliding with a wall. The crash resulted in cracks in various parts of the rider's brain and body, leading to surgical intervention and continued treatment in the intensive care unit. Claims said the crash was due to faulty e-scooter brakes, but no further details were given (Haber61 2022).

In July 2022, a 23-year-old female e-scooter rider was injured in Adana after being hit by a vehicle coming from the opposite direction and dragging her along the road. She was transported to the hospital by ambulance and was discharged after treatment

(Sözcü, 2022). In the same month in Istanbul, another 23-year-old female rider was injured when a vehicle approaching her from behind collided with her as she moved in the left. The rider died in hospital (Habertürk, 2022).

A 44-year-old psychologist fell from an e-scooter in Adana in August and hit his head, sustaining abrasions. He did not immediately seek medical attention but later experienced health deterioration and was hospitalized. It was determined that he had suffered a brain hemorrhage, and as a result, he died (TRT Haber, 2022).

In October 2022, two 18-year-old individuals were traveling together on an e-scooter when they were struck by a motorized vehicle and died (Sabah, 2022a). Most individuals seeking treatment at the emergency unit for jaw and dental trauma were registered as e-scooter crashes, and they presented with severe conditions, such as head-neck fractures, eye globe and jaw fractures, anterior dental fractures, and brain bleeding. While the exact number of cases was not specified, a 40-year-old female traveling on an e-scooter had her wheel stuck in a drain during her ride, causing her to fall forward and hit her jaw on the ground. She underwent orthodontic treatment for her teeth and extensive jaw surgery. Subsequently, during surgery, she experienced partial facial paralysis due to nerve damage. Treatment and recovery took seven months (Cumhuriyet, 2022b).

In addition, according to a report from the Hürriyet website (Hürriyet 2023), there were 2,446 e-scooter crashes in Türkiye in 2023, resulting in 21 deaths and 2,050 injuries. In comparison, 2022 saw 1,840 crashes, with 8 fatalities and 1,554 injuries. Therefore, the rising number of incidents highlights e-scooter crashes as an increasing public safety concern, emphasizing the need for immediate action and the implementation of emergency response plans.

4. Discussion

Our review of eight academic studies and eight media reports on e-scooter crashes in Türkiye identified several common themes. First, falls were the leading cause of accidents, with collisions being less frequent. This could be due to drivers' carelessness or defects on the road surface they are riding on. Most accidents occurred on sidewalks or intersections during the day, often on weekdays. Although using e-scooters on sidewalks is illegal, the concentration of accidents in these areas and their negative impact on pedestrians are significant findings. The majority of patients were young adults, with men being slightly more affected than women. Common injuries included upper and lower extremity fractures, followed by head and facial trauma, and soft tissue injuries. This is not surprising because accidents generally occur in the form of falls. Notably, helmet use was extremely low, recorded in only a small percentage of cases, and some studies have reported alcohol use among riders, although the percentage is quite low. Despite the frequent occurrence of accidents, most injuries were minor and were treated on an outpatient basis, although some required hospitalization or surgery, particularly for fractures. Media reports tended to focus on more severe incidents involving fatalities or significant injuries, often due to rule violations. Both the academic literature and media sources emphasize the growing concern over e-scooter safety, highlighting the need for stricter regulations, public safety campaigns, and better protective measures like helmet, knee pads, elbow pads, wrist guards, and reflective vests, to reduce injuries and fatalities.

In a study conducted in Germany examining the formation and relationship between injuries and micromobility clashes (Kleinertz, 2021), e-scooter and bicycle clashes were compared. Results from 89 e-scooter clashes (mean age: 39.9 ± 14 years) and 435 bicycle clashes (42.5 ± 17) that occurred within a year indicate that e-scooter clashes mainly occurred at night (37%) and under the influence of alcohol (28%). Among these cases, 54% reported head or facial trauma and 18% reported upper extremity injuries. In contrast, bicycle clashes had a lower incidence of occurring at night (14%) and under alcohol influence (6%), with 46% reporting head or facial trauma and 24% reporting upper extremity injuries. Helmet usage was not observed among e-scooter users, whereas 11% of bicycle riders wore helmets. Collisions involving pedestrians accounted for 65% of e-scooter clashes, whereas this rate was 57% for bicycle clashes. The number of cases requiring wound care after e-scooter clashes was 46%, while that for bicycle clashes was 27%. Hospitalization rates were similar in both groups (32%). After e-scooter clashes, 28% of the patients were referred for surgery, whereas the rate was 24% after bicycle clashes. There was no recorded need for intensive care after e-scooter clashes, whereas 2% of cases following bicycle clashes were admitted for intensive care. Only 1% of e-scooter and bicycle clashes required immediate intervention, whereas 7% required immediate intervention. According to the study, using any vehicle under alcohol consumption increases the risk and severity of clashes. Additionally, it is emphasized that the sharp corners of e-scooters, due to their structural characteristics, can cause injuries to the tibialis posterior muscle in the event of a clash.

When comparing e-scooter clashes in Germany to those in Türkiye, the predominance of head injuries (54% in Germany, 40% in Türkiye (Yavuz et al., 2022), and 35% in Türkiye (Yılmaz et al. 2022) stands out. In Germany, none of the drivers wore helmets, whereas in Türkiye, only 4.3% (Yavuz et al. 2022), 6.4% (İğrek & Ulusoy 2023), and 3% Kayaalp et al. (2023) of drivers wore helmets, and none wore helmets (Yılmaz et al., 2022). Given this, it is not surprising that e-scooter clashes occurred more frequently at night and under the influence of alcohol, while in Türkiye, only 2.9% (Yavuz et al. 2022) and 19.4% (İğrek & Ulusoy 2023) of cases involved alcohol or had no alcohol involvement (Yılmaz et al. 2022). This indicates that drivers in Türkiye avoid using e-scooters under the influence of alcohol more than those in Germany. Nevertheless, Yakar and Hancı (2022) published

a case study examining a 30-year-old female patient who was brought to the emergency department due to an e-scooter crash. Laboratory findings indicated alcohol and substance use by the patient, and radiological imaging revealed subdural hematoma, cerebral contusion, and lung contusion. In the initial assessment, the patient's Glasgow coma scale (GCS) score was 5 (indicating severe neurological damage). After a complex treatment process, the GCS remained unchanged, and the patient was discharged to a palliative care center with tracheostomy and home ventilator support. The authors argued that the risks of crashes that could result in outcomes like this one could be reduced in Türkiye through existing regulations related to e-scooter use. We would like to highlight mandatory helmet use and speed limit reductions, as well as organize informative campaigns for the public to discourage the use of e-scooters under the influence of alcohol.

In another study, research from around the world was compiled. The average age was slightly higher than in Türkiye (33.3 ± 3.5), with 58.3% of cases being male and 5.6% under 18 years old. Among the clashes, 74.4% occurred due to falls, and 68.1% of users did not wear helmets. In 39.2% of cases, fractures were reported, with 44.8% being upper extremity-related. Additionally, 22.2% of cases involved neck and head injuries, and 2.5% involved traumatic brain injuries. Moreover, 57.7% of cases were referred to radiology, 54.5% were discharged after initial interventions, and 17.2% were referred for surgery (Singh, 2022). Because of this compilation, which included studies from different parts of the world, it is recommended that equipment that protects the head, neck, and upper extremity areas be legally required. It is predicted that adding sensors and structural supports that reduce the risk of falling to vehicles will decrease the number of crashes related to falling. In contrast to research in Germany and Türkiye, reaching a helmet usage rate of 31.9% resulted in an obvious reduction in neck and head injuries from 40% to 22.2%. This demonstrates that using helmets for e-scooter users significantly reduces the risk of fatal outcomes. Furthermore, in the study conducted by Cakar et al. (2023), the authors examined a cohort of patients aged 18 years who were diagnosed with anterior cruciate ligament (ACL) injuries between January 2019 and June 2021. Their findings revealed that e-scooter crashes accounted for 7% of all ACL injuries during the study period, comprising 80 cases. A detailed analysis of e-scooter-related ACL tears showed that 72.8% ($n=58$) of these injuries occurred due to non-contact mechanisms, primarily resulting from falls while attempting to halt the scooter. In contrast, 27.2% ($n=22$) of the injuries were attributed to contact mechanisms, wherein patients fell after colliding with an object. Demographically, the patient population consisted of 52 males (65%) and 28 females (35%), with a mean age of 38.4 years (ranging from 19 to 52 years). Of these patients, 77.5% ($n=62$) were recommended for ACL reconstruction surgery using hamstring muscle grafts, while the remaining 22.5% ($n=18$) were managed through functional physical therapy. Remarkably, the study also revealed that 14 of 80 patients had concurrent upper extremity fractures in addition to ACL injuries. These findings highlight the prevalence of ACL injuries following e-scooter crashes and underscore the necessity for stricter regulations and improved safety measures, including the use of knee-specific protective equipment. Such injuries can lead to increased healthcare costs, including medical therapy and medication, and loss of work due to the recovery time required after reconstruction. Therefore, we emphasize the need for comprehensive regulations mandating the use of protective gear for both the head and knees to reduce the incidence of these injuries.

A cohort study analyzing the demographics and injury outcomes of micromobility crashes in China, India, Japan, and the United States was conducted by Zhao (2022). Data on road crashes from the Global Burden of Disease Study by the World Health Organization for 1990-2019 were analyzed. According to the results, mortality and morbidity due to crashes increased in individuals younger than 25 years and older than 60 years. However, crashes are most frequently observed in users aged between 15 and 25. Although there has been a 25.59% decrease in overall traffic crash mortality since 1990, there have been increases of 39.08% and 44.06% in motorcycle and bicycle crash mortality, respectively. Notably, there has been a rapid increase in micromobility crashes, especially from 2015 to 2019. This increase can be attributed to the proliferation of shared e-scooters and e-bicycles in Japan and China as well as the number of two-wheeled motor vehicles in India. Although electric vehicles allow for faster travel, crashes involving electric vehicles tend to be more severe than those involving mechanical vehicles, requiring more extended hospitalization and treatment—for example, one of every ten e-scooter-bicycle collisions in India result in severe injury or death. The authors point out that due to the lack of standardization in the data collected from the four major countries included in the study, changes in regulations and legal requirements over the years, differences in infrastructure and environments in countries, unique individual and societal norms, cultural diversity, and varying driver behavior profiles, determining the overall impact of micromobility crashes and comparing countries is very challenging.

E-scooter crashes often occur at intersections and involve collisions (vehicle-to-vehicle collisions, e.g., motor vehicle-e-scooter or e-scooter-e-scooter collisions). Vehicle-to-vehicle crashes often occur when e-scooters approach the right side of moving cars. Therefore, it is essential to promote adherence to traffic rules and safe riding techniques to prevent crashes when using e-scooters. Increasing public awareness of correct and safe riding techniques is necessary.

In 2023, the Turkish Ministry of Transport and Infrastructure published a scientific study to identify the variables affecting e-scooter crashes and predicting the likelihood of crashes (İnaç 2023). The study used machine learning to use user and ride data from a shared e-scooter application in 15 cities. The results identified variables such as riding area, rental date, rental frequency (experience), travel duration, average speed, and travel distance as the most influential factors in completing a ride without a crash.

Different optimal values for these variables were found for female and male users. For women, the optimal values were a rental frequency of 100, a travel distance of 10.44 km, a travel duration of 48.33 minutes, and a riding speed of 13.38 km/h. For men, the corresponding values were 120, 11.49 km, 52.20 min, and 17.28 km/h, respectively. The study determined an average speed limit of 15.36 km/h for safe and trouble-free rides for both male and female e-scooter users.

The accident reports (collision reports) of 780 e-scooter collisions that occurred in 2021 in Türkiye were examined, and 771 accidents were included. The accident data were obtained from the Traffic Department of the Ministry of Interior (General Directorate of Security). Male e-scooter riders are involved in crashes and injured approximately 4 times more often than female riders. The average age for men injured in e-scooter accidents is 30.4, and the mean age of women was 27.2. For both men and women, most injuries occurred in the 15–20 years age group. Riders under the age of 18 years constitute a significant proportion of accidents (32.5%). Most e-scooter accidents occur on Mondays and during August. Most accidents occurred between 12:00 p.m. and 1:59 p.m. (15.7%) and between 4:00 p.m. and 5:59 p.m. (15.7%), mainly during the daytime. About half of the accidents occurred at intersections. In 10.5% of accidents, the accident occurred at a crosswalk. Approximately one-fifth of the accidents fall, and the most common type of collision was side collision (44.2%). Deaths and injuries caused by road traffic accidents are a public health problem in Türkiye and constitute a significant health burden. If necessary precautions are not taken, this burden is likely to increase (Arıkan Öztürk et al. 2024).

According to the initial regulations, e-scooters traveling on sidewalks now use roads like other vehicles. However, crashes involving e-scooters and other traffic elements can still occur. It is recommended that e-scooters travel on the left side of the traffic, i.e., in the opposite direction, to improve visibility for both e-scooter riders and other drivers. The absence of mirrors and turn signals on e-scooters, which could warn other drivers of the rider's moves, is considered a possible cause of crashes. Approaching e-scooters should reduce their speed and be alert to sudden, signal-less movements (Cumhuriyet 2022a).

According to the Electric Scooter Regulation, authorized operators must inform users that they must wear protective and visibility-enhancing equipment, such as helmets, knee pads, and reflective jackets. Failure to use this equipment is considered a violation of traffic rules, and users not wearing the required equipment may be subjected to fines for inspection. However, from the user's perspective, the fact that shared vehicles do not provide protective equipment is seen as a disadvantage. Therefore, despite discussions about placing protective equipment on or near shared e-scooters, this practice has yet to be implemented due to increased costs for service providers and users and the risk of theft of loose equipment. Users must also show more support when purchasing individual protective equipment because this involves additional costs. Moreover, one of the significant advantages of shared services is the ability to leave the vehicle as desired after use, thus offering the convenience of parking. Therefore, users who wish to avoid carrying protective equipment when their journey is complete may not benefit from this advantage (Sabah 2022b).

However, it should be noted that until a decision is made and implemented, the user bears the responsibility for obtaining and using equipment for safe riding. In any case, the adoption and conscious choice of helmet use are essential. Different designs and features of helmets suitable for various micromobility vehicles can be found in the market. Ideally, separate helmet models should be designed for different micromobility vehicles, considering their distinct riding characteristics and designs (Serra 2021, Wei 2023). For example, e-scooter crashes often involve falling forward onto the chin and upper face (Cumhuriyet 2022b). Therefore, it is appropriate to use a helmet with a chin guard rather than a helmet designed for bicycles.

Lastly, İnaç (2023) aimed to identify variables affecting e-scooter crashes and predict crash probability using machine learning methods based on data from e-scooter drivers in 15 provinces of Türkiye. The results indicate that gender, riding location, rental date, rental frequency, travel duration, average speed, and distance were the most influential factors in completing a ride without a crash. The travel duration had the most substantial impact on the ride, and it was noted that long journeys negatively affected drivers, leading to interruptions in their rides. The optimal values for these factors for female drivers were as follows: rental experience, 100; distance, 10.44 km; travel duration, 48.33 minutes; and travel speed, 13.38 km/h. For male drivers, the corresponding values were 120, 11.49 km, 52.20 min, and 17.28 km/h. It has been reported that the average speed limit for safe and smooth rides for both male and female e-scooter drivers is 15.36 km/h. E-scooter speed limits vary from country to country. According to the study results, reducing the speed limit from 30 km/h to 20 km/h can reduce the severity of injuries in injury-prone crashes by 23%. Although the rate of involvement in crashes among those under 18 years old was an average of 8.4%, the study found minimal interaction between age and driving. Another factor influencing crash outcomes is drivers' knowledge of traffic rules, regulations, and training. In conclusion, the study suggests that micromobility vehicles can smoothly integrate into traffic alongside other vehicles.

5. Conclusions

The findings of this review indicate that e-scooter crashes can impact individuals of all ages, as the studies included individuals aged 5–76 years. Additionally, the frequency of crashes varied by region, with some areas experiencing more crashes on weekdays and others experiencing higher rates on weekends. Males were more commonly involved in crashes than females, and the use of helmets was generally low among victims.

In conclusion, the lack of protective structures in e-scooters makes their users vulnerable to crashes. Crashes can lead to undesirable health outcomes, such as minor scratches and bruises, fractures, neurological damage, jaw and head trauma, and even death. The individual consequences of crashes manifest as disabilities, job loss, reduced quality of life, the need for care, treatment expenses, and psychological and social issues. Societally, allocating healthcare resources to treat these outcomes may hinder investments in other areas that could improve public health. Despite these risks and consequences, e-scooters remain a popular and practical mode of transportation. The most appropriate step to reduce the risks to vulnerable users is to improve and enforce relevant legal regulations.

This study has several limitations. First, as a narrative rather than a systematic review, it may be prone to selection bias. Second, considerable variability exists in the findings and outcome measures across the included studies, making it difficult to draw robust, standardized conclusions. Some studies have focused solely on patients with fractures (Büyükercan et al. 2023, Kültür et al. 2023, Baca et al. 2024), those admitted exclusively to orthopedic departments (İğrek & Ulusoy 2023, Kültür et al. 2023) or those comparing all patients in a department with those involved in e-scooter accidents (Baca et al. 2023), potentially overlooking other injury types and broader patient outcomes. Consequently, we were unable to review all injured patients or comprehensively evaluate the general characteristics of crash-related injuries from e-scooters, which limited the scope of our findings. Additionally, some news reports lacked detailed information on crash characteristics or health outcomes, thereby restricting their use in this review. Despite these limitations, this study represents the first comprehensive effort to consolidate the characteristics of e-scooter crashes and health outcomes. The accumulation of more comprehensive data on e-scooter crashes and health outcomes will enable the development and application of consistent metrics. This will enable more robust comparisons across studies, leading to clearer insights and more actionable conclusions in the field. Finally, longitudinal studies that track e-scooter usage and related incidents over time are valuable for assessing trends and evaluating the impact of regulatory and safety interventions.

Based on our analysis, we propose the following recommendations for reducing e-scooter crash risks and mitigating the severity of consequences:

- Increasing users' awareness about safe driving techniques, rules, and regulations and raising awareness of risky behaviors. Sharing resources about this information openly and freely, organizing educational programs, and transitioning to a driver's license system.
- Organize driving training programs to enhance user driving experiences in controlled environments or simulations.
- Conduct appropriate environmental and infrastructure regulations based on expert opinions.
- Periodically reviewing vehicles' physical conditions and, if available, stations (e.g., annually).
- Determining the variety and quantity of vehicles based on demand and potential usage, revisiting these decisions annually.
- Adding components to vehicles that enhance their visibility on the road and implementing systems that allow users to signal and reduce the risk of falling.
- Updating legal obligations and measures such as speed limits and age restrictions based on scientific research findings.
- Expand the rules to be followed during rides, including issues such as cell phone usage, listening to music, and obeying traffic signals.
- Taking additional precautions and using warning signs in areas with a higher incidence of crashes.
- Enforcement of regulations in addition to deterrent bans.
- Regularly discussing regulations and measures with experts and updating them according to emerging needs.
- Making investments and regulations to establish a safe micromobility network and ensuring the safety of all road users, including pedestrians.

Additionally, evaluating the following recommendations would be beneficial for assessing e-scooter crashes and their impacts in a more objective manner and observing the results of improvements:

- Provide training for law enforcement officers, emergency service workers, and other stakeholders regarding crash documentation.
- Designating a separate unit or authority for in-hospital documentation.
- Adopting a standardized and effective method for recording the formation and outcomes of all crashes in the country and developing a corresponding database.

- Ensuring that data on crashes collected by authorized agencies are reported appropriately at specified intervals so that experts in the field can also benefit from the data.
- Developing policies supporting research addressing the risks, formation, health outcomes, and expenses associated with crashes fosters research in this area.
- Developing algorithms for emergency interventions based on research findings and other data related to crash formation and health outcomes.
- Investigating the proportion of healthcare spending attributable to micromobility crashes, addressing this issue through public health experts, and developing health policies to reduce micromobility crashes.

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