ORIGINAL ARTICLE

ORTHOPEDIC INJURIES FOLLOWING THREE-WHEELED ELECTRIC MOTORCYCLE ACCIDENTS IN OLDER ADULTS: A RETROSPECTIVE STUDY

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Abstract

Introduction: Use of three-wheeled electric motorcycles is increasing in Turkey, particularly among older individuals residing in rural and summer residential areas. This study aimed to characterize the orthopedic injury patterns, treatment requirements, and clinical outcomes associated with three-wheeled electric motorcycle-related accidents.

Materials and Method: This single-center retrospective study included 33 patients who presented to the emergency department following three-wheeled electric motorcycle-related accidents between January 2023 and December 2025. Pedestrian injuries and accidents involving vehicles other than three-wheeled electric motorcycles were excluded. Patients were categorized as drivers or rear-seat passengers. Orthopedic injuries were analyzed by anatomical location, and treatment was classified as surgical or conservative; descriptive statistics and Fisher's exact test were used.

Results: Of 33 patients, 11 (33.3%) were male and 22 (66.7%) female. Mean age was 65.7 ± 5.1 years. Twenty-one patients (63.6%) were drivers and 12 (36.4%) rear-seat passengers. All sustained orthopedic injuries. Upper extremity injuries were identified in 28 patients (84.8%) and lower extremity in five (15.2%). The most common fractures were distal radial (n = 10, 30.3%), clavicle (n = 5, 15.2%), and proximal humeral fractures (n = 4, 12.1%). Surgical management was required in 15 (45.5%) and conservative treatment in 18 (54.5%). No patient required intensive care unit admission or died. Injury distribution and surgical requirement were similar in drivers and rear passengers (p = 0.328 and 0.469).

Conclusion: Three-wheeled electric motorcycles may pose a considerable risk of trauma, especially in older individuals, underscoring the need for vehicle-specific preventive strategies, educational programs, and regulatory measures.

Keywords: Off-Road Motor Vehicles; Geriatrics; Fractures, Bone.

INTRODUCTION

In recent years, the use of personal electric mobility devices has increased significantly globally. Electric bicycles are frequently preferred by elderly individuals, owing to their ease of use, low cost, and relatively low physical exertion requirements. In parallel, traffic accidents and traumatic injuries associated with electric vehicles have become increasingly important problems for healthcare systems. (1)

In studies comparing two-wheeled electric bicycles (2W-EBs), conventional bicycles, and motorcycles, 2W-EB users have been reported to be older than those of other 2W vehicles. Furthermore, it has been demonstrated that the injury patterns in this patient group are more similar to those in conventional bicycle accidents; however, the rates of intensive care unit (ICU) admission and serious orthopedic injuries are higher. (2)

Physiological changes in older age, such as balance problems, decreased reflex speed, and reduced bone mineral density, predispose individuals to serious orthopedic injuries and even low-energy trauma. (3) This is considered one of the primary reasons why elderly individuals sustained more severe injuries in 2W-EB vehicle accidents.

Studies investigating 2W-EB injuries have reported that fractures of the upper and lower extremities are a significant cause of morbidity and that these injuries often require orthopedic surgery. (4) Epidemiological studies examining 2W-EB vehicle accidents have also shown that the severity of injury, length of hospital stay, and mortality rates are higher in elderly than in younger individuals. (5) Similar orthopedic injury profiles have been described for other light electric mobility devices: studies on electric scooters report that falls are the most common mechanism and that upper-extremity fractures predominate, with a substantial proportion of patients requiring surgical treatment (6,7).

In one of the early studies concerning 2W-EB injuries, the majority of cases evaluated in an urban emergency department were middle-aged and elderly individuals, and the injuries frequently involved the extremities and the head and neck region. (8) The same study emphasized that a considerable proportion of 2W-EB accidents required hospitalization and that these vehicles could lead to unexpectedly severe trauma, particularly in elderly individuals. (8)

In large-scale studies evaluating patients with trauma, advanced age has been reported as an independent risk factor for injury severity in bicycle accidents and similar low-speed vehicle accidents; older individuals have longer hospital stays, higher complication rates, and a greater need for surgical treatment than younger individuals. (9)

Consistent with these findings, a case-control study comparing 2W-EB use with traditional bicycles revealed that 2W-EB users had a poorer general health status; however, when variables such as health status and usage level were controlled, 2W-EB use alone was not associated with a greater risk of accidents or more severe injuries. (10) However, it has been reported that the risk of injury is increased among older female electric bicycle users, and that this group should be evaluated specifically. (10)

In Turkey, the use of three-wheeled electric motorcycles (3W-EM) (Figure 1) is widespread,



Figure 1. The image of the Three-Wheeled Electric Motorcycle was obtained from the address https://www.volta.com.tr/blog.



particularly among individuals aged 60 years and older, owing to the high demand for short-distance transportation in villages and summer residential areas. Ease of driving, perceived relative stability, low cost, and current absence of a mandatory driving license requirement play significant roles in the preference for these vehicles. However, the false sense of security provided by a three-wheeled vehicle may reduce risk awareness in the elderly and contribute to careless driving behaviors. The limited driver training and supervision associated with this absence of a licensing requirement may further compound these risks. Moreover, age-related physical and cognitive limitations—reflected in the higher mental workload and accident risk reported for elderly e-bike users in complex traffic situations—may increase the likelihood of accidents and injuries. (11)

This situation poses a new public health problem concerning not only individual transportation habits but also the safety of the elderly population and public health. Although numerous studies have been conducted on 2W-EB injuries, the epidemiological features of injuries caused by 3W-EM in the elderly population have not been sufficiently investigated. (1, 4, 5) This gap necessitates the clarification of the relationship between mobility habits and trauma risk in older individuals in Turkey.

While the literature has addressed injuries related to 2W-EBs as personal mobility devices, studies specifically examining injuries associated with 3W-EM accidents in individuals aged 60 years and over in Turkey are very limited. This retrospective study aimed to describe the injury patterns, types of orthopedic injuries, and clinical outcomes associated with the use of 3W-EM in older individuals in Turkey.

MATERIALS AND METHOD

This study was designed as a single-center, retrospective analysis. The medical records of patients admitted to our hospital's emergency department between January 2023 and December 2025 were reviewed retrospectively. All patients who presented to the emergency department because of a 3W-EM accident during the specified period were included in the study, and no age restriction was applied. Pedestrian accidents and trauma related to mobility devices other than 3W-EM were excluded.

Considering that the examined 3W-EM were designed to carry one driver in the front and two passengers in the rear, the patients involved in the accidents were classified according to their position in the vehicle as drivers or rear passengers. The injuries sustained by drivers and rear-seat passengers were included in this study.

Patient demographic characteristics (age and sex), position in the accident (driver or rear passenger), presentation method, and clinical findings were obtained from the patient files. However, crash-related details such as the accident mechanism, vehicle speed, and use of protective equipment (e.g., helmets) were not routinely recorded in the patient files, and standardized trauma severity scores such as the Injury Severity Score could therefore not be calculated; such variables have been associated with injury severity in the electric mobility literature (12). All patients underwent an initial assessment in the emergency department. Orthopedic injuries were evaluated based on physical examination findings and radiological investigations (plain radiographs and advanced imaging techniques when necessary). When a fracture was detected, the fracture type, anatomical location, and displacement status were recorded. The soft tissue injuries were evaluated for the presence of lacerations, abrasions, and contusions. Orthopedic injuries were classified according to their anatomical location into upper extremity, lower extremity, or axial skeletal injuries. The injuries involving multiple regions were observed separately. Open fractures, when present, were evaluated according to the Gustilo–Anderson classification (13).

Treatments were examined in two groups: conservative and surgical. Conservative treatments

included analgesia, plaster or splint application, and bandaging. In patients who underwent surgical treatment, methods such as plate and screw osteosynthesis, intramedullary nailing, partial hip arthroplasty, external fixation, and Kirschner wire osteosynthesis were used.

The length of hospital stay was recorded from patient files. Patients who received surgical treatment were followed up with admission to the orthopedic ward, whereas patients treated conservatively were discharged from the emergency department and directed to the outpatient clinic for follow-up appointments. A history of additional neurological diseases was also investigated in all patients.

Owing to the retrospective and descriptive nature of the study, continuous variables are presented as mean ± standard deviation and as median with range (minimum–maximum), and categorical variables are presented as numbers and percentages (%). Differences between the driver and rear-passenger groups were assessed using Fisher's exact test, which was preferred because of the small number of patients in several subgroups. A two-sided p value of less than 0.05 was considered statistically significant. Multivariable analysis was not undertaken, since the limited sample size and the small number of events would have produced unstable estimates and a high risk of overfitting. Statistical analyses were performed using IBM SPSS Statistics, version 25 (IBM Corp., Armonk, NY, USA).

This was a retrospective study, and patient data were evaluated after anonymization. Approval was obtained from the relevant ethics committee for the study, or an ethics committee exemption was applied for retrospective studies.

Ethical Approval

This study was approved by the Clinical Research Ethics Committee of our hospital with the decision numbered 2026/35. Patient consent was not required owing to the retrospective design of the study. The data were analyzed anonymously. This study was conducted in accordance with the principles of the Declaration of Helsinki.

RESULTS

A total of 33 patients who presented to the emergency department with 3W-EM accidents between January 2023 and December 2025 were included in this study. Among the patients, 11 were male (33.3%), and 22 were female (66.7%). The mean age of the 33 patients included in this study was 65.7 ± 5.1 years, with a median age of 65 years. The patients' ages ranged from 60 to 80 years. When evaluated according to their position in the accident, 21 patients were identified as drivers (63.6%), and 12 were rear passengers (36.4%). Orthopedic injuries were detected in all 33 patients. (Table 1)

Analysis of the anatomical distribution of orthopedic injuries revealed a marked predominance of upper extremity injuries. (Table 2). Upper extremity injuries were observed in 28 patients (84.8%). The distribution of upper extremity injuries was as follows:

Table 1. Demographic, clinical, and treatment characteristics of the study population (n = 33)

Variable		Value
Total number of patients		33
Age, years, mean ± SD		65.7 ± 5.1
Age, years, median (range)		65 (60–80)
Sex	Male, n (%)	11 (33.3)
	Female, n (%)	22 (66.7)
Position in the accident	Driver (front seat), n (%)	21 (63.6)
	Rear passenger, n (%)	12 (36.4)
Orthopedic injury	Present, n (%)	33 (100.0)
	Absent, n (%)	0 (0.0)
Treatment modality	Surgical, n (%)	15 (45.5)
	Conservative, n (%)	18 (54.5)
Clinical course	Intensive care unit admission, n (%)	0 (0.0)
	In-hospital mortality, n (%)	0 (0.0)

Abbreviations and notes: Continuous variables are presented as mean ± standard deviation and as median (range); categorical variables are presented as n (%). ICU, intensive care unit; SD, standard deviation.



distal radial fractures in 10 patients (30.3%), clavicular fractures in five patients (15.2%), proximal humeral fractures in four patients (12.1%), humeral shaft fractures in three patients (9.1%), scapular fractures in two patients (6.1%), and other upper extremity injuries in four patients (12.1%). (Table 2)

Five patients (15.2%) were diagnosed with lower extremity injuries. The distribution of lower extremity injuries was as follows: proximal femoral fracture in two patients (6.1%) and other lower extremity injuries in three patients (9.1%). (Table 2)

Fifteen patients (45.5%) underwent surgical management, and 18 (54.5%) were treated conservatively. No patient required intensive care unit admission, and no in-hospital mortality occurred. Patients requiring surgical intervention were hospitalized and monitored at an orthopedic clinic. Conversely, patients treated conservatively were discharged from the emergency department and directed to the outpatient clinic for scheduled follow-up. (Table 1)

Surgical treatment was performed in 11 drivers (52.4%) and 4 rear passengers (33.3%), while conservative treatment was applied in 10 drivers (47.6%) and 8 rear passengers (66.7%); this difference was also not statistically significant (p=0.469) (Table 3).

Orthopedic injuries were observed in both drivers and rear passengers, and upper extremity injuries predominated in both groups. Upper extremity injuries were present in 19 of the 21 drivers (90.5%) and in 9 of the 12 rear passengers (75.0%), whereas lower extremity injuries were seen in 2 drivers (9.5%) and 3 rear passengers (25.0%); the difference between the two groups was not statistically significant (p = 0.328). (Table 4)

Table 2. Distribution of orthopedic injuries by fracture localization (n = 33)

Injury localization		n (%)
Upper extremity	Distal radius	10 (30.3)
	Clavicle	5 (15.2)
	Proximal humerus	4 (12.1)
	Humeral shaft	3 (9.1)
	Scapula	2 (6.1)
	Other upper extremity	4 (12.1)
	Subtotal	28 (84.8)
Lower extremity	Proximal femur	2 (6.1)
	Other lower extremity	3 (9.1)
	Subtotal	5 (15.2)
	Total	33 (100.0)

Abbreviations and notes: Values are presented as n (%) of the total cohort (n = 33). Upper and lower extremity categories are mutually exclusive.

Table 3. Treatment modality according to accident position (n = 33)

Treatment modality	Driver (n = 21)	Rear passenger (n = 12)	Total (n = 33)	p value
Surgical, n (%)	11 (52.4)	4 (33.3)	15 (45.5)	0.469
Conservative, n (%)	10 (47.6)	8 (66.7)	18 (54.5)	—
Total, n (%)	21 (100.0)	12 (100.0)	33 (100.0)	

Abbreviations and notes: Values are presented as n (%). The comparison between the driver and rear-passenger groups was performed using Fisher's exact test.

Table 4. Anatomical distribution of orthopedic injuries according to accident position (n = 33)

Injury localization	Driver (n = 21)	Rear passenger (n = 12)	Total (n = 33)	p value
Upper extremity, n (%)	19 (90.5)	9 (75.0)	28 (84.8)	0.328
Lower extremity, n (%)	2 (9.5)	3 (25.0)	5 (15.2)	—
Total, n (%)	21 (100.0)	12 (100.0)	33 (100.0)	

Abbreviations and notes: Values are presented as n (%). The comparison between the driver and rear-passenger groups was performed using Fisher's exact test.

DISCUSSION

It has been frequently reported that 2W-EB users have distinct demographic and health differences from conventional bicycle and motorcycle users. (9) 2W-EB users were generally older than the other groups. A study in the Netherlands reported that the mean age of 2W-EB users was 66.9 years. (9) The authors also stated that 2W-EB users generally have poorer health status than conventional bicycle users, and that 2W-EBs enable these individuals to ride or continue riding. (10) Similarly, in our study, 3W-EMs were particularly preferred by elderly individuals, offering an alternative that facilitates daily mobility. However, our findings indicate that this gain in mobility is associated with high rates of orthopedic injury in both drivers and passengers following accidents, necessitating surgical treatment in nearly half of the cases. This suggests that the common perception of 3W-EMs as being "more stable and safe" should be questioned in terms of clinical outcomes.

In the literature, individuals' general health status (medication use, BMI, morbid conditions) is not associated with the likelihood of being involved in an accident or the severity of the injury and has not explained the increased risk in 2W-EB users. (10) However, those with balance or coordination issues and those using antiepileptic drugs were more frequently involved in accidents requiring emergency department treatment. In the retrospective inquiry of our patients, we did not encounter any data regarding balance and coordination problems due to an underlying disease or the use of antiepileptic medication.

In the literature, 40% of 2W-EB users among patients with trauma in the United States had a positive alcohol screen; however, in a Dutch study, the rate of alcohol consumption among conventional bicycle users was twice as high as that of 2W-EB users. (1, 9) Our study did not contain data regarding patients driving under the influence of alcohol or being present in a vehicle while intoxicated.

A study examining the emergency department experience in Switzerland revealed that the main causes of 2W-EB accidents were self-accidents (self-control loss) (8) rather than vehicle collisions. In our study, accidents involving 3W-EMs were also self-accidents.

A study in the Netherlands investigating the safety of 2W-EBs and the increased risk among elderly women suggested that elderly women carry a greater risk of injury with 2W-EBs, which is related to their greater likelihood of falling while mounting or dismounting a vehicle. (10) In our study, accidents occurred while the vehicle was in motion and not during mounting or dismounting.

The 2W-EB accidents carry significant risks, particularly craniocervical and traumatic brain injuries; in this context, they more closely resemble motorcycle accidents. (5) In our study, head trauma was not observed in any of the 3W-EM accidents. This is attributed to the fact that 3W-EMs were used at lower speeds. Furthermore, wearing a helmet is mandatory for all electric bicycle users abroad, but no such obligation currently exists in our country.

A study characterizing the orthopedic injury profile of 2W-EB patients in the US revealed that spinal fractures were the most common orthopedic injuries in the 2W-EB population. (1) We did not encounter spinal injuries in the 3W-EM accidents in our study. A study examining 2W-EB accidents in Switzerland reported that the most frequently fractured bone was the tibia and that these fractures were consistently intra-articular. (5) In our study, tibial fractures were detected in only two patients, and these fractures involved the distal tibial joint.

A retrospective study conducted in Switzerland identified clavicular fractures as the most common type of fracture in 2W-EB accidents. (8) In our study, clavicular fractures were the second most common type of fracture (15.2%).

The 2W-EB accidents increased healthcare resource utilization in hospitals. Compared to



patients with Pedal bicycle, the 2W-EB users were more likely to present with critical trauma activation. (1) Furthermore, 2W-EB patients were admitted to the ICU more frequently than motorized bicycle patients. These findings indicate the potential for 2W-EB accidents to lead to high resource utilization within the healthcare system. However, in our study examining 3W-EM accidents, there was no need for intensive care. This difference may be explained by the lower speeds at which 3W-EMs were used; the injury mechanism being mostly limited to tipping and falling; and the rare occurrence of head, thorax, or abdominal trauma. Our findings suggest that despite leading to serious orthopedic injuries, the 3W-EM accidents exhibit a different clinical profile than the 2W-EB accidents concerning hemodynamic instability and life-threatening trauma.

In the literature, 19.0% to 52.2% of patients sustaining injuries in 2W-EB accidents required surgical intervention during hospitalization. (1) However, patients in the motorcycle group generally required more surgical intervention, especially for pelvic and femoral injuries, than 2W-EB patients did. (1, 14) In our study, orthopedic surgical treatment was performed in 45.5% of the patients.

In the inclusion and exclusion criteria set for trauma studies in the literature that focus on 2W-EBs, conventional bicycle, and motorcycle accidents, the examined accident data were primarily related to the rider of the vehicle. (14) Patients hit by bicycles or pillion passengers were excluded. Additionally, accidents that occurred when vehicles were mounted or dismounted were excluded. Our study examined the trauma to both riders and rear passengers. Traumas that occurred while the vehicle was mounted or dismounted were excluded from the study. (5) In our study, 12 patients (36.4%) were injured despite being at the rear. Consequently, the rear passengers are also at risk. In our cohort, upper extremity injuries predominated in both drivers (90.5%) and rear passengers (75.0%), and this distribution did not differ significantly between the two groups ($p = 0.328$; Table 4); the need for surgical treatment was likewise comparable (52.4% vs. 33.3%, $p = 0.469$; Table 3). These findings indicate that rear-seat occupants face a risk of orthopedic injury comparable to that of drivers.

A study examining orthopedic injuries in patients involved in 2W-EB accidents reported that radius fractures were detected in 5.0% of patients. (1) In our study, the rate of distal radial fracture was 30.3%. The most common type of injury in our study was the distal radial fracture, which may be associated with the biomechanical characteristics of 3W-EM accidents. In these vehicles, the mechanisms of tipping and falling are predominant rather than collision, and the reflexive extension of the hand during a fall (Fall On Outstretched Hand mechanism) leads to axial loading on the distal radius. (15) The transfer of energy to the distal extremities instead of the head and trunk in relatively low-speed accidents may explain the more frequent occurrence of distal radial fractures. Furthermore, the patient profile in our study consisted largely of elderly individuals, and the possible loss of bone mineral density can be considered an additional factor that increases the risk of distal radial fractures, even in individuals with low-energy trauma. We did not examine patients for bone mineral density loss in the present study.

The predominance of upper extremity injuries, and of distal radial fractures in particular, may further be understood in light of the structural characteristics and seating configuration of 3W-EMs. Unlike enclosed vehicles, these tricycles provide no restraint system or protective frame, and both the front driver and the rear-bench passengers remain exposed during sudden deceleration or loss of vehicle stability; instinctive bracing with an outstretched hand then channels the impact to the distal upper extremity (Table 2). A comparable upper-limb predominance has been described across the electric micromobility literature, where falls rather than collisions dominate the injury mechanism (6, 16). Because an upper extremity fragility fracture is

itself a recognized predictor of subsequent fractures in older adults, the distal radial fractures observed in our cohort may also carry prognostic importance beyond the acute injury (17).

The injury distribution we observed parallels findings from other small electric mobility vehicles. Studies of electric scooters likewise identify falls as the dominant mechanism and report a heavy burden of extremity fractures, although the anatomical emphasis varies: some series describe a predominance of upper-limb fractures (7), whereas others, particularly among adult riders, report frequent lower-leg, ankle, and foot injuries (18). A three-year emergency department series from Rome similarly documented a substantial volume of e-scooter trauma, with a meaningful proportion of patients requiring hospitalization (19). Taken together, these observations suggest that limited protective structures and exposed seating arrangements, rather than vehicle category alone, shape the characteristic extremity-dominant trauma of light electric vehicles.

One study has reported that older and untrained individuals may have slower reaction times and reduced control over the 2W-EB. Given that 2W-EBs become faster owing to motor assistance, this situation was stated to create a risk. (11) Another analysis suggested that the high rate of self-accidents among the 2W-EB users was due to advanced age, possibly longer reaction times, and less control over their relatively higher speed. (14) Therefore, the literature suggests that although the 2W-EBs support the mobility of the elderly and vulnerable groups, their slow reactions and balance capabilities create an increased risk of accidents and serious injuries for these groups. The fact that our patients were in an advanced age group aligns with the information reported in these publications.

The strength of this study lies in its focus on 3W-EMs, which have not been adequately addressed in the literature. Most current studies have examined 2W-EB accidents, and this study provides unique data on different vehicle types. The inclusion of rear-seat passengers in addition to drivers allowed for a more comprehensive presentation of injury patterns.

From a clinical standpoint, awareness of this characteristic injury profile can help emergency physicians and orthopedic surgeons prioritize their diagnostic evaluation and management. In an older patient presenting after a 3W-EM accident, a focused yet thorough assessment of the upper extremity—particularly the distal radius, clavicle, and proximal humerus (Table 2)—is warranted, while remaining alert to the less frequent but clinically important lower-extremity fractures such as proximal femoral injuries. Anticipating that nearly half of these patients may require surgical management also supports early orthopedic involvement and appropriate planning of hospital resources (6).

These observations reinforce the need for preventive measures tailored specifically to 3W-EMs, spanning three complementary domains. First, vehicle design could be improved through measures such as enhanced lateral stability, restraint or secure hand-hold systems for rear passengers, and protective framing. Second, regulatory measures—including a defined licensing or training requirement and, as advocated for related micromobility devices, mandatory helmet use and speed limitation—warrant consideration (19, 20). Third, public awareness initiatives directed at older users and their families could help counter the false sense of security associated with the three-wheeled configuration. Evidence from e-bike riders, among whom helmet use has been linked to better clinical outcomes, further supports the value of such protective and regulatory interventions (12).

However, this study has certain limitations. The single-center and retrospective design, coupled with the small sample size, restricts the generalizability of the findings. The retrospective design also precludes any causal inference. Owing to the limited sample size and the small number



of events, multivariable analysis could not be reliably performed, and the comparisons between drivers and rear passengers should be regarded as exploratory. In addition, important crash-related variables—such as the precise accident mechanism, travel speed, and use of protective equipment—were not systematically documented in the records, and standardized trauma severity scores (e.g., the Abbreviated Injury Scale or the Injury Severity Score) commonly applied in the micromobility literature could therefore not be calculated (12, 18). Functional outcomes and post-treatment complication rates were likewise not consistently available, a limitation also recognized in the broader e-scooter literature (6). Future prospective, multicenter studies that incorporate detailed crash characteristics and standardized trauma severity assessments will be needed to confirm these findings, clarify the underlying injury mechanisms, and guide the development of targeted preventive strategies.

CONCLUSION

This study suggests that 3W-EM accidents, despite being widely perceived as safer, can lead to serious orthopedic injuries in both drivers and passengers. The injuries predominantly affect the upper extremities, and the prevalence of distal radial fractures may reflect injury mechanisms related to the structure and use of these vehicles. The need for surgical treatment in a considerable proportion of cases indicates that such injuries can carry a meaningful clinical burden.

Although these observations derive from a single-center cohort, they suggest that, while 3W-EMs offer an alternative that enhances mobility for elderly individuals, they may pose a considerable risk of trauma under current usage conditions. Therefore, protective measures for driver and passenger safety, educational programs, and legal regulations need to be reevaluated specifically for this vehicle type. Future multicenter and prospective studies, incorporating detailed crash characteristics and standardized injury severity assessment, will contribute to a more detailed elucidation of injury mechanisms and the development of preventive strategies.

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