

ORIGINAL RESEARCH



Will the road traffic act reduce electric scooter injuries?: An observational study in Republic of Korea

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Abstract

This study investigated changes in clinical characteristics, including the severity of electric scooter-related damage, before and after revision of the Road Traffic Act that became effective on 13 May 2021. This retrospective single-center observational study was conducted at the Emergency Department (ED) of a tertiary university hospital in Incheon, Republic of Korea. The pre-revision period was set from 13 May 2020, to 30 November 2020, and the post-revision period from 13 May 2021, to 30 November 2021. Patients who visited the ED with E-scooter injuries during the study period were included. Data on patients' demographics, helmet use, alcohol use, Korean Triage and Acuity Scale, diagnosis and location of the injury, stay duration at ED and ED outcomes were collected and analyzed. The primary outcome was a change in Injury Severity Score between the pre-and post-revision periods. A total of 100 patients were included, and the results showed no significant difference between the two periods in Injury Severity Score (3.00 vs. 2.50, $p = 0.607$), helmet use (1.9% vs. 2.1%, $p = 1$), alcohol use (5.8% vs. 8.3%, $p = 0.708$) and stay duration at ED (157.00 vs. 183.00, $p = 0.964$). The facial area was the most common area of injury during both periods. Despite revision of the Road Traffic Act since May 2021, no significant difference was observed before and after the revision in the behavior of E-scooter users and severity of injuries. We believe that continuing public campaigns, encouraging the use of personal protective gear, promoting responsible attitudes and implementing stricter traffic laws might help reduce E-scooter-related injuries.

Keywords

Electric scooter; Emergency; Injury severity score; Road traffic act; Helmets; Alcohol

1. Introduction

“E-scooter” or “motorized scooter” is defined as any two-wheeled machine with handlebars and a floorboard, designed to stand upon when riding or a seat and footrests instead of the floorboard, powered by an electric motor [1]. Since the introduction of the E-scooter rental program system in 2018 by “KICKGOING” in the Republic of Korea, the number of users has been exponentially increasing.

Amendments to the Road Traffic Act related to E-scooters have been made twice. Before 10 December 2020, E-scooters were classified as motorized bicycles, permitting them to be driven on motorways and mandatory to wear motorcycle helmets. These laws put E-scooter users at risk, with some reluctant to wear personal protective equipment. Upon recognizing these issues, the government implemented the first revised Road Traffic Act on 10 December 2020, to stimulate the smart mobility industry and ensure the safety of E-scooter users. They classified motor bicycles with a maximum speed of 25 km/h and a weight of 30 kg or less as “personal mobility”. After the revision, E-scooter users could use bicycle helmets

and drive on bicycle roads. Additionally, people aged 13 years or older could use an E-scooter without a driver's license.

Although the Road Traffic Act and Act on the Promotion of Bicycle Use, implemented on 10 December 2020, further increased the number of E-scooter users, public safety concerns were raised after several E-scooter-related accidents were reported. These issues led to a second revision of the Road Traffic Act, made effective from 13 May 2021, to strengthen the users' safety. The second revised Road Traffic Act mandates a driver's license, penalties for not wearing a helmet, driving under the influence of alcohol, and carrying two people [2].

In September 2021, approximately 9700 personal mobility devices were observed rented by nine companies in Incheon, Republic of Korea [3]. A survey on the annual mortality rate from traffic accidents in the Republic of Korea showed that it has halved from 10.5 per 10,000 people in 2011 to 5.6 per 10,000 in 2021 (**Supplementary Table 1**). Although the statistics on overall traffic accidents are sufficiently reported, data and research on E-scooter-related accidents are still lacking despite concerns about E-scooter-related accidents in the Republic of Korea.

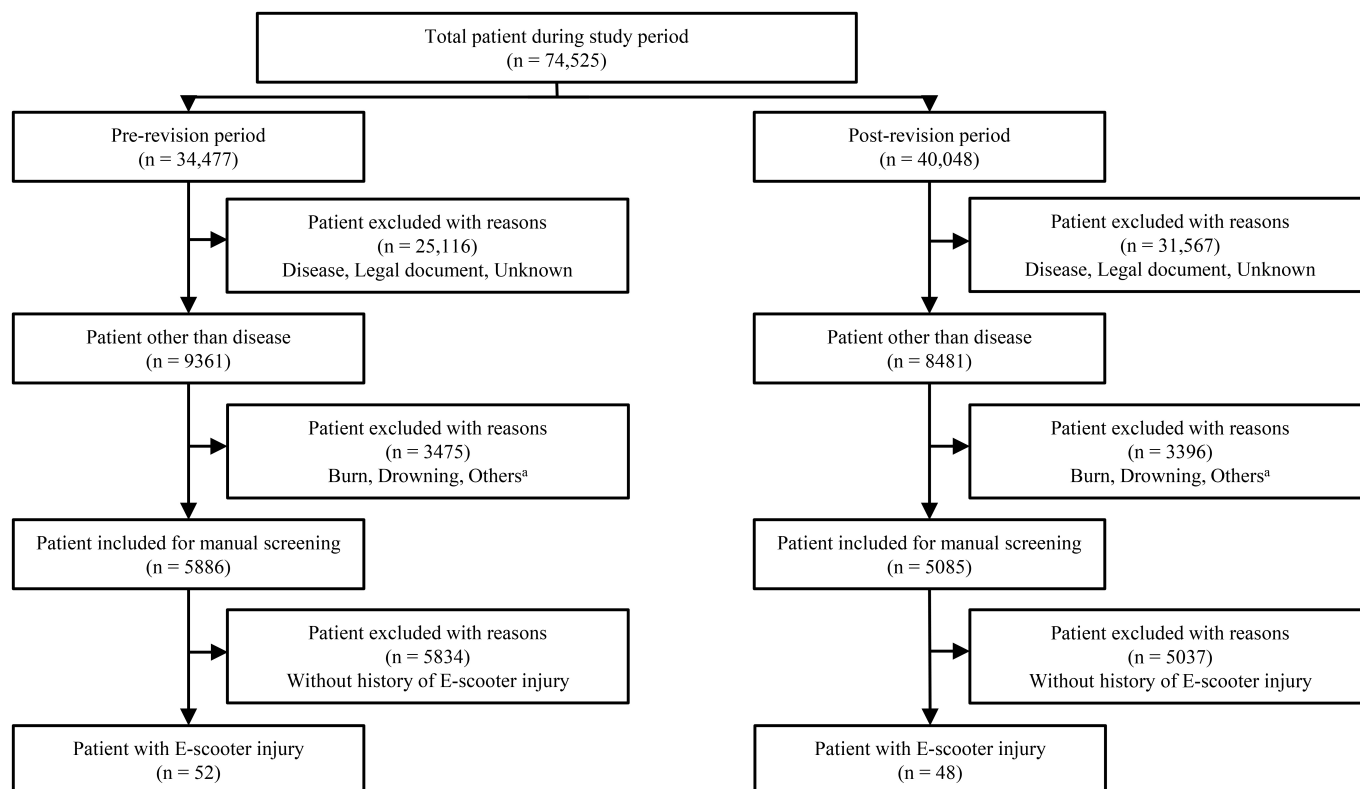


FIGURE 1. Flowchart of study population. ^a: others includes assault, machine, cut, firearm, chock.

Thus, this study was performed to determine the characteristics of E-scooter-related injuries and investigate the severity of injuries in an Emergency Department (ED) after the second revision of the Traffic Act on 13 May 2021 (**Supplementary Table 2**).

2. Materials and methods

2.1 Study settings and population

This single-center retrospective observational study was conducted at the Inha University Hospital, a tertiary university hospital located in Incheon, Republic of Korea. The ED of this hospital is a regional emergency medical center with approximately 70,000 patients visiting annually.

Pre-revision and post-revision periods were set to determine the change in severity of E-scooter-related injuries before and after the second revision of the Traffic Act. Additionally, these periods were also compared considering seasonal differences, which might have affected the characteristics of patients visiting the ED. The pre-revision period was set from 13 May 2020, to 30 November 2020, and the post-revision period from 13 May 2021, to 30 November 2021.

In the Republic of Korea, the National Emergency Department Information System (NEDIS) sends the information on patients visiting emergency medical centers from individual hospitals to the National Emergency Medical Center (NEMC), whereby the reasons for visiting the emergency departments are coded and classified. Additional injury mechanisms are coded if the patient's reasons for visiting the emergency room are classified as "other than disease" codes. However, there were no codes consistent with E-scooter-related accidents in

the database. Therefore, two emergency doctors reviewed and cross-validated the medical records of individual patients and assigned them to the final study population if medical records of E-scooter injury-related accidents were recorded.

2.2 Data collection

The demographics and clinical data were collected through the electronic medical records (EMR), including information on sex, age, injuries, stay duration, Korean Triage and Acuity Scale (KTAS), procedure, disposition, ED transport, diagnosis, and treatment.

The KTAS was developed in 2012 to help reduce the overcrowding of the EDs at the hospital level and has been implemented in Korea since 2016. KTAS evaluates patients' critical first-look (airway, breathing, circulation, and disability) and scores their vital signs, pain score, hemorrhagic disease, injury mechanism, glucose level, dehydration and hypertension to categorize them into 5 levels (1 = resuscitation, 2 = emergency, 3 = urgent, 4 = less-urgent, and 5 = non-urgent) [4].

Alcohol intoxication was determined based on the emergency medical records in regard to the recorded alcohol consumption or a serum ethanol level of more than 10 mg/dL. Serum ethanol level was collected within ten minutes of visiting the ED through vein sampling.

2.3 Primary outcome and measurement

The primary outcome of this study was to compare the Injury Severity Score between pre-revision and post-revision periods. The abbreviated Injury Scale (AIS) codes (version 2005, updated 2008, licensed from the Association for the

Advancement of Automotive Medicine (AAAM) for academic purposes) of all diagnoses were recorded, and the Injury Severity Scores (ISS) were calculated. ISS is based on AIS. To calculate ISS, the three most severe injuries from six ISS regions were used, and each AIS code was sum squared (ISS regions: head and neck, face, chest, abdomen and pelvic contents, extremities or pelvic girdle, and external). AIS codes are AIS anatomical-based coding systems created by the AAAM to classify and describe injuries' severity (1 = minor, 2 = moderate, 3 = serious, 4 = severe and 5 = critical) [5]. An ISS higher than 15 is considered a major or severe trauma and is an excellent predictor of trauma-related mortality, morbidity, and hospitalization time [6].

2.4 Secondary outcome

The changes in pattern in E-Scooter injuries before and after implementing the revised law were the secondary endpoint of this study.

2.5 Statistical analysis

For continuous variables, the Kolmogorov-Smirnov normality test was performed. Variables with normal distribution were compared using the student's *t*-test and presented as mean and standard deviations. Those without normal distribution were compared using the Mann-Whitney U test and presented as median and interquartile range (IQR). Categorical variables were analyzed using the Pearson chi-square test or Fisher's exact test. All statistical significance was $p < 0.05$, using a two-sided test. The Statistical Package for the Social Sciences (version 25.0, SPSS, Inc., Chicago, IL, USA) on Windows version 22.0 was used for data analysis.

3. Results

3.1 Study population

A total of 74,525 patients visited the ED during the study period. Of them, 17,842 patients were classified as 'other than disease'. After excluding patients who visited the ED for burns, drowning and other non-E-scooter injury-related reasons, 100 patients (n = 52 in 2020, n = 48 in 2021) associated with E-scooter injuries were identified and selected as the final study subjects after reviewing their medical records (Fig. 1).

3.2 Clinical characteristics of the study population

The median age of the patients was 26 (IQR: 20.25–38.00) years. Of the whole cohort, 62 (62%) patients were male. Only two (2%) patients were found to have worn safety gear (helmet only; one patient each year). Moreover, 92 (92%) patients were in single-vehicle collisions, 6 (6%) were in car crashes, and 2 (2%) were pedestrians struck by E-scooters. Seven (7%) patients were driving under the influence (DUI; alcohol only). In the overall cohort, 47 (47%) patients were transported through emergency medical transportation, and 53 (53%) were self-admitted. Most patients were categorized as KTAS stage 4 (78; 78%), and 12 (12%) patients were admitted to the general wards. One patient was transferred due to personal reasons.

None of the patients were admitted to the intensive care unit within our study period. The median length of ED stay was 163 minutes (IQR, 100.25–243.25) (Table 1).

TABLE 1. Characteristics of the study participant.

	Total participants (n = 100)
Age, yr	26.00 (20.26–38.00)
Male	62 (62%)
Helmet use	2 (2%)
The state of being drink	7 (7%)
Type of accident	
Single-vehicle collision	92 (92%)
Car crash	6 (6%)
Pedestrian	2 (2%)
Type of transport	
Self visit	53 (53%)
EMT	47 (47%)
KTAS	
3	17 (17%)
4	78 (78%)
5	5 (5%)
Injury severity score	3.00 (1.00–4.00)
ED length of stay, min	163.00 (100.25–243.25)
ED outcome	
Discharge	87 (87%)
Admission to general wards	12 (12%)
Transfer out	1 (1%)

Data are presented as median (interquartile range) or number (%). EMT: Emergency medical transport; KTAS: Korean Triage and Acuity Scale; ED: Emergency department.

3.3 Injury pattern of the study population

The facial area (n = 56) was the most common area of injury, followed by the head (n = 53), upper extremity (n = 50), and lower extremity (n = 39). Only one patient had a head injury diagnosed with minimal subarachnoid hemorrhage and was hospitalized in a general ward. Four patients with scalp lacerations received primary sutures in the ED. Of the injury to the facial area, 21 cases were fractures, and nasal bone fractures were the most common with eight cases. Upper extremity fractures were found in 19 cases, and the most common ones were clavicle fractures, which were observed in six cases. Lower extremity fractures were observed in seven cases, and the most common fractures were in three cases with trimalleolar fractures (Table 2).

3.4 Comparison of patients' characteristics between pre-and post-revision periods

The number of patients who visited the ED with E-scooter injuries was 52 during the pre-revision period and 48 during

TABLE 2. Injury pattern of the total study population.

Body area	AIS	Diagnosis ^{a,b}	total study period
Head	1	Concussion without LOC	48
		Scalp laceration	53
	2	Concussion with LOC	4
		SAH	1
		Abrasion	24
Face	1	Laceration	33
		Contusion	13
	2	Eyelid laceration	2
		Nasal bone fracture	56
		Orbital wall fracture	4
		Maxillary fracture	3
		Zygoma fracture	2
		Mandible fracture	3
		Tripod fracture	1
		Chest	1
Abrasion	1		
Abdomen	1	Contusion	2
		Abrasion	1
Upper extremity	1	Abrasion	21
		Laceration	7
		Contusion	20
		Dislocation finger	1
		Dislocation elbow	1
	2	Scapular fracture	50
		Clavicle fracture	6
		Radius fracture	5
		Ulnar fracture	3
		Radioulnar	1
	1	Finger fracture	3
		Abrasion	17
		Laceration	5
		Contusion	21
		Sprain	2
Lower extremity	1	Tibia fracture	39
		Patella fracture	1
		Dislocation patella	1
	2	ACL rupture	1
		Trimalleolar fracture	3
		Toe fracture	1

^a: Injury counts are based on patients' diagnosis, some patient suffers from multiple injuries;

^b: Injuries include abrasion, contusion, fracture, laceration, ligament injury, concussion, dental, sprain.

AIS: Abbreviated Injury Scale; LOC: Loss of Consciousness; SAH: Subarchnoid Hemorrhage; ACL: Anterior Cruciate Ligament.

the post-revision period. We found no significant differences in age and sex between patients from these periods. It should be noted that we found only one subject wore personal protective equipment in each of the two periods. Three (5.8%) patients were DUI in the pre-revision period and four (8.3%) in the post-revision period. In both periods, a single-vehicle collision was the most typical type of accident. During the study period, there were no severe patients classified as KTAS 1 and 2, and no significant difference was observed in patients with KTAS stage 4 before and after the revision (Table 3).

3.5 Primary and other clinical outcomes

There was no statistically significant difference in ISS in patients visiting the ED before and after the revision due to the E-Scooter injury (3 vs. 2.5, $p = 0.607$). The median time of ED length of stay (EDLOS) was 157 minutes during the pre-revision period and 183 minutes during the post-revision period, but the difference was not statistically significant. In the analysis of ED outcomes reflecting the results of the emergency treatment, in both periods, the largest percentage were discharged patients, and the proportion of patients admitted to general wards decreased by half from 15.4% to 8.3%, but the difference was not statistically significant (Table 4).

3.6 Comparison of injury pattern between pre-and post-revision periods

In both periods, the most damaged area was facial injury, which occurred in 54 cases during the pre-revision period, 16 of whom showed a severity of AIS 2, and 39 during the post-revision period, of whom 5 showed a severity of AIS 2. Head injury occurred in 30 cases during the pre-revision period, of whom 2 showed a severity of AIS 2, and 27 during the post-revision period, of whom 3 showed a severity of AIS 2. Upper extremity injury occurred in 32 cases during the pre-revision period, 9 of whom showed a severity of AIS 2, and 37 during the post-revision period, of whom 10 were classified as AIS 2. Lower extremity injury occurred in 32 cases during the pre-revision period, 6 of whom showed a severity of AIS 2, and 22 during the post-revision period, 3 of whom showed a severity of AIS 2 (Table 5).

4. Discussion

Generally, amendments to traffic laws are made to reduce traffic injuries [7]. However, this study found no statistically significant difference in the injury severity of the two groups before and after the law revision.

The emergence of new vehicles may lead to related accidents, and amendments in relevant laws are required to increase the safety of the users [8]. As the number of people using E-scooter has increased in the Republic of Korea, E-scooter rental business via mobile phone applications began in several companies, and E-scooter-related injury increased further. A nationwide cross-sectional study published in the Republic of Korea showed that related damage to electric personal mobility increased from 8 cases in 2014 to 285 cases in 2018 [9].

To reduce the risk of E-scooter-related injury, the Repub-

TABLE 3. Comparison of patient’s characteristics between pre-and post-revision periods.

Variables	Pre-revision period (n = 52)	Post-revision period (n = 48)	p-value
Sex			
Male	31 (59.60%)	31 (64.60%)	0.609
Female	21 (40.40%)	17 (36.40%)	
Age	31 (20.00–41.50)	24 (21.00–36.00)	0.136
Helmet use	1 (1.90%)	1 (2.10%)	1.000
Type of accident			
Single-vehicle collision	48 (92.30%)	44 (91.67%)	0.375
Car crash	2 (3.80%)	4 (8.33%)	
Pedestrian	2 (3.80%)	0 (0.00%)	
Alcohol	3 (5.80%)	4 (8.30%)	0.708
Type of Transport			
Self visit	26 (50%)	27 (56.3%)	0.532
EMT	26 (50%)	21 (43.8%)	
KTAS			
3	8 (15%)	9 (18.8%)	0.444
4	40 (76.9%)	38 (79.2%)	
5	4 (7.7%)	1 (2.1%)	

Data are presented as median (interquartile range) or number (%).

EMT: Emergency medical transport, KTAS: Korean Triage and Acuity Scale.

TABLE 4. Comparison of clinical outcomes between pre-and post-revision periods.

Clinical Outcomes	Pre-revision period (n = 52)	Post-revision period (n = 48)	p-value
Injury severity score	3.00 (1.50–4.00)	2.50 (1.00–4.00)	0.607
ED length of stay (min)	157.00 (106.00–245.00)	183.00 (97.50–239.00)	0.967
ED outcome			
Discharged	44.00 (84.6%)	43.00 (89.6%)	0.362
Admitted to general wards	8.00 (15.4%)	4.00 (8.3%)	
Transfer	0	1.00 (2.1%)	

Data are presented as median (interquartile range) or number (%).

ED: Emergency department.

lic of Korea implemented a revised law on 13 May 2021, urging mandatory wearing of personal protective equipment and prohibiting unlicensed driving, drunk driving, two-person boarding and driving on a pedestrian road. We hypothesized that the revision of the law would have reduced the severity of E-scooter-related injury; however, our results showed no statistically significant difference in ISS for severity evaluation before and after the law (3 vs. 2.5, $p = 0.607$).

According to previous studies, the risk factor for E-Scooter injury is speeding (>30 km/h), riding without a helmet, and drunk driving [10]. Head and facial injuries are typical E-Scooter injuries, with 53 head injuries and 56 facial injuries recorded in this study. According to a study by Sone *et al.* [11], helmets prevented brain injury and lowered mortality and morbidity rates. Although the revised law required wearing helmets, there was no statistically significant difference in

helmet use between the pre- and post-revision groups in our study (1 vs. 1, $p = 1.0$). These results could be related to two factors. First, because helmets were not mandatory during early E-scooter use/renting, people have been used to not wearing helmets and might find it inconvenient to carry or rent helmets separately, leading to a low helmet-wearing rate. Second, during the 2019 coronavirus disease pandemic, users may have been reluctant to wear shared helmets due to the fear of infection transmission.

Existing literature showed an increase in mortality in vehicle-related accidents caused by intoxication, and in 2019, about 320,000 people worldwide died from alcohol-related accidents [12–14]. Although the revised law prohibits DUI of alcohol, the difference in the percentage of alcohol before and after the revision of the law in injured patients visiting the ED was not statistically significant (3 vs. 4, $p = 0.706$).

TABLE 5. Comparison of injury patterns between pre-and post-revision periods.

Body area	AIS	Diagnosis ^{a,b}	Pre-revision period	Post-revision period	
Head	1	Concussion without LOC	27	21	
		Scalp laceration	1	3	
	2	Concussion with LOC	30	27	3
		SAH	1	0	
		Abrasion	15	9	
Face	1	Laceration	18	15	
		Contusion	4	9	
	2	Eyelid laceration	1	1	
		Nasal bone fracture	54	39	2
		Orbital wall fracture	4	0	
		Maxillary fracture	2	1	
		Zygoma fracture	1	1	
		Mandible fracture	2	1	
	Chest	1	Tripod fracture	1	0
			Contusion	0	2
Abdomen	1	Abrasion	1	0	
		Contusion	0	1	
		Abrasion	8	13	
		Laceration	5	2	
Upper extremity	1	Contusion	9	11	
		Dislocation finger	1	0	
	2	Dislocation elbow	0	1	
		Scapular fracture	32	37	1
		Clavicle fracture	3	3	
		Radius fracture	3	2	
		Ulnar fracture	1	2	
		Radioulnar	1	0	
	Lower extremity	1	Finger fracture	1	2
			Abrasion	11	6
		2	Laceration	3	2
			Contusion	10	11
Sprain			2	0	
Tibia fracture			32	22	0
Lower extremity	1	Patella fracture	0	1	
		Dislocation patella	0	1	
	2	ACL rupture	0	1	
		Trimalleolar fracture	3	0	
		Toe fracture	1	0	

^a: Injury counts are based on patients' diagnosis, some patient suffers from multiple injuries;

^b: Injuries include abrasion, contusion, fracture, laceration, ligament injury, concussion, dental, sprain.

AIS: Abbreviated Injury Scale; LOC: Loss of Consciousness; SAH: Subarchnoid Hemorrhage; ACL: Anterior Cruciate Ligament.

We also observed that the ISS scores did not decrease after the law revision, but the number of moderate injuries (facial injury) decreased from 16 to 5 after the revision of the law. Although it can be estimated that the revision of the law has been useful in preventing E-scooter injuries to some extent, it is thought that additional policies such as more stringent surveillance and law enforcement should be applied to effectively reduce ISS.

This study had several limitations. First, there is a possibility of recall bias due to the study's retrospective nature. Second, to ensure the inclusion of a maximum number of patients, it was not possible to predict the proportion of injured patients from all users because the data was not for all E-scooter users but for E-scooter patients who visited the ED. However, instead, we tried to reasonably evaluate the effectiveness of the revised law by using ISS to determine the severity of damage and as the primary outcome. To overcome these shortcomings, a prospective study analyzing nationwide data should be conducted in the future.

5. Conclusion

This study showed that the number of facial injuries decreased after implementing the second revision of the E-scooter-related Road Traffic Act. However, E-scooter-related injury in the pre- and post-revision group was not statistically different in ISS, rate of alcohol use and helmet use, indicating low effectiveness of the revised law and urging the need for stricter monitoring and enforcement as well as additional revision of the traffic law, if necessary.

AVAILABILITY OF DATA AND MATERIALS

The data are contained within this article and supplementary material.

AUTHOR CONTRIBUTIONS

YWJ—designed the study, wrote original draft and analyzed the data. YHS—designed the study, wrote original draft. SK—designed the study, analyzed the data, supervised, reviewed and edited. All authors read and approved the final manuscript.

ETHICS APPROVAL AND CONSENT TO PARTICIPATE

The study protocol was reviewed and approved by the Institutional Review Board of Inha University College of Medicine (IRB No.: 2022-05-033-000). The need for informed consent was waived due to the retrospective nature of this study. The study was conducted in compliance with the principles of the Declaration of Helsinki.

ACKNOWLEDGMENT

Thanks to all the peer reviewers for their opinions and suggestions.

FUNDING

This research was supported by INHA University Hospital Research Grant.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

SUPPLEMENTARY MATERIAL

Supplementary material associated with this article can be found, in the online version, at <https://oss.signavitae.com/mre-signavitae/article/1593427120022798336/attachment/Supplementary%20material.docx>.

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How to cite this article: Yong Wook Jeong, Young Ho Seo, Soo Kang. Will the road traffic act reduce electric scooter injuries?: An observational study in Republic of Korea. Signa Vitae. 2023; 19(5): 97-103. doi: 10.22514/sv.2022.079.