Original Article
J Trauma Inj 2022;35(1):3-11
https://doi.org/10.20408/jti.2021.0044

Journal of Trauma and Injury JTI
pISSN 2799-4317 • eISSN 2287-1683

Characteristics of injuries associated with electric personal mobility devices: a nationwide cross-sectional study in South Korea

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Purpose: The increasing use of electric personal mobility devices (ePMDs) has been accompanied by an increasing incidence of associated accidents. This study aimed to investigate the characteristics of ePMD-related injuries and their associated factors.

Methods: This cross-sectional study was conducted using data from the Emergency Department-based Injury In-depth Surveillance database from 2014 to 2018. All patients who were injured while operating an ePMD were eligible. The primary outcome was the rate of severe injury, defined as an excess mortality ratio-adjusted Injury Severity Score of ≥25. We calculated the adjusted odds ratios (AORs) of outcomes associated with ePMD-related injuries.

Results: Of 1,391,980 injured patients, 684 (0.05%) were eligible for inclusion in this study. Their median age was 28 years old, and most injuries were sustained by men (68.0%). The rate of ePMD-related injuries increased from 3.1 injuries per 100,000 population in 2014 to 100.3 per 100,000 population in 2018. A majority of the injuries occurred on the street (32.7%). The most commonly injured area was the head and face (49.6%), and the most common diagnosis was superficial injuries or contusions (32.9%). Being aged 55 years or older (AOR, 3.88; 95% confidence interval, 1.33–11.36) and operating an ePMD while intoxicated (AOR, 2.78; 95% confidence interval, 1.52–5.08) were associated with severe injuries.

Conclusions: The number of emergency room visits due to ePMD-related injuries is increasing. Old age and drunk driving are both associated with serious injuries. Active traffic enforcement and safety regulations regarding ePMDs should be implemented to prevent severe injuries caused by ePMD-related accidents.

Keywords: Injury Severity Score; Accidents; Traumatic brain injuries; Epidemiology; Wounds and injuries

Received: June 17, 2021
Revised: September 21, 2021
Accepted: October 14, 2021

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INTRODUCTION

Electric personal mobility devices (ePMDs) are electrically powered wheeled devices that provide personal transport. These devices provide simple, fast, and convenient transportation and are attracting considerable interest as a novel tool for short-haul transport and leisure activities [1].

The demand for ePMDs has increased rapidly in South Korea in recent years, and their increasing use has been accompanied by an increasing incidence of ePMD-related injuries [2-6]. However, the epidemiologic characteristics of ePMD-related injuries have only been studied in a few countries. In one study from Singapore, ePMD-related injuries were generally found not to be severe and were primarily external wounds and upper and lower limb injuries [7]. In a Swedish study, most of the reported ePMD-related injuries resulted from the driver hitting the ground due to device turnover [8]. Few studies on ePMD-related injuries have been conducted in South Korea, however.

Under South Korea's Road Traffic Act, ePMDs are classified as "motorized bicycles", and their operation is prohibited outside of roadways [9]. Furthermore, a driver's license and helmet are required for their use. However, many ePMD owners operate them outside of roadways to avoid collisions with motor vehicles and rarely wear helmets during use [10,11]. These behaviors can lead to severe injuries. This study aimed to examine the characteristics of ePMD-related injuries and identify risk factors associated with severe ePMD-related injuries in South Korea.

METHODS

The present study protocol was reviewed and approved by the Institutional Review Board of the Seoul National University Bundang Hospital (No. X-1903-528-902).

Study design

This cross-sectional study was performed using data from the Emergency Department-based Injury In-depth Surveillance (EDIIS) database sponsored by the Korea Disease Control and Prevention Agency (KDCA). The EDIIS is a prospective nationwide injury database that stores data on patients with injuries who present to the emergency rooms (ERs) of specific representative medical institutions in Korea.

Data source

In total, 17 (in 2014), 20 (in 2015), and 23 (from 2016 to 2018) tertiary academic hospitals shared data on patients with injuries who presented to ERs using the EDIIS database. The EDIIS database includes demographic, injury prevention– related, and epidemiologic information as well as pre-hospital procedures, initial clinical findings from the ER visit, diagnoses (coded using the International Classification of Diseases, 10th Revision [ICD-10]), treatments, dispositions, and patient outcomes after admission. Individual incidents were described in written Korean. Primary information was obtained by physicians from each medical institution during clinical practice and by trained coordinators from the EDIIS project assigned to each hospital. The coordinators collected the data from a standardized registry. The data from each ER were registered on a web-based database hosted by the KDCA, and a quality improvement program was conducted regularly [12].

Selection of participants

Among all injuries reported in the EDIIS database between January 2014 and December 2018, only patients who were injured while operating an ePMD were included in this study. To identify ePMD-related injuries, we searched the database with ePMD-related keywords, including "electric scooter", "e-scooter", "electric kickboard", "e-kickboard", "hoverboard(s)", "electric unicycle", "e-unicycle", "Segway", "Lime scooter", and "Ninebot", and two researchers reviewed the incident descriptions. After reviewing each entry, data were excluded if 1) the injury was caused by an ePMD used as an aid for a disabled person, such as an electric wheelchair or mobility scooter, or 2) the accident was not related to the operation of the ePMD.

Variables and measurements

This study collected information for each injury on age, sex, injury date, device type, injury mechanism, injury location, the rider's state of intoxication, helmet use, diagnosis (ICD-10 code), and disposition. Age was classified as 0 to 14, 15 to 24, 25 to 34, 35 to 44, 45 to 54, and 55 years or older, based on previous studies [13]. An "e-scooter" was defined as a device powered by an electric motor with wheels and handlebars that is designed to be stood upon by the operator. An "electric unicycle" and "hoverboard" were defined as narrow, horizontal boards with one or two wheels, respectively, that move when the rider leans forward. Mechanisms of injury were categorized as falloff, collision with a motor vehicle, collision with a human, collision with another ePMD, or other. Possible injury locations were indoors, public property (a car-free public facility), street (a thoroughfare for cars), sidewalk (a foot traffic-only pathway), bike-way (a bicycle-only pathway), driveway/ parking lot, and alley (a road

https://doi.org/10.20408/jti.2021.0044

without sidewalks). Anatomical injury sites were categorized as head and face, neck, torso (including the thorax, abdomen, back, pelvis, and genitals), and upper and lower extremities (including the shoulders, upper arms, elbows, forearms, wrists, hips, thighs, knees, lower legs, ankles, and feet) according to the ICD-10 codes for the injury mortality diagnosis matrix by the Centers for Disease Control and Prevention of the United States [14].

To assess injury severity, the excess mortality ratio-adjusted Injury Severity Score (EMR-ISS) was calculated using ICD-10 codes. The EMR-ISS classifications used in this study were mild (scores 1–8), moderate (scores 9–24), severe (scores 25–74), or critical (scores ≥75 or death), as in a previous study [15].

Study outcomes

The primary outcome of the study was the incidence of severe injury. The secondary outcome was the incidence of acute traumatic brain injury, defined by ICD-10 codes of S02.0xx, S02.1, S06.2, and S06.3x [16]. The tertiary outcome was the rate of intensive care unit (ICU) admission.

Statistical analysis

All statistical analyses were performed using STATA version 14.2 (StataCorp LP, College Station, TX, USA). Continuous variables were presented as medians with interquartile ranges (IQR), and categorical variables were presented as frequencies with percentages. To identify statistically significant differences between the outcome groups, we used the Wilcoxon rank-sum test for continuous variables and the chi-square test or Fisher exact test for categorical variables. Odds ratios (ORs) with 95% confidence intervals (CI) were calculated using multivariate logistic regression analysis to evaluate the factors associated with the outcomes. The level of statistical significance was defined as a P-value of ≤0.05.

RESULTS

Incidence and characteristics of ePMD-related injuries

Of the 1,391,980 patients injured between 2014 and 2018, 1,472 patients (0.11%) had records that included ePMD-related keywords in their descriptions. After excluding ineligible cases, 684 cases (0.05%) were ultimately used in the final analysis. Among them, 505 cases (73.8%) were related to e-scooters and 179 cases (26.2%) were related to electric hoverboards (Fig. 1).

Fig. 2 shows the trends in ePMD-related injuries among the study population. The rate of ePMD-related injuries due to e-scooters or hoverboards increased from 3.1 ePMD-related ER visits per 100,000 population in 2014 to 100.3 per 100,000 population in 2018.

Table 1 shows demographic characteristics and clinical features according to ePMD type. The median age was 28 years old (IQR, 19–38 years old) and a higher proportion of men (68.0%) sustained injuries related to ePMDs. Patients who were injured while operating electric hoverboards tended to be younger than those who were injured while operating e-scooters. The distribution of the time of injury was different between the two groups. The rate of helmet use was low in both groups, at 3.4% for the e-scooter group and 2.2% for the hoverboard group (P = 0.210), and operation while intoxicated was more common in the e-scooter group than in the hoverboard group. Fall-off injuries were the most common injury mechanism, at 69.9% in the e-scooter group and 83.8% in the hoverboard group; however, collisions with vehicles or stationary objects were more fre-

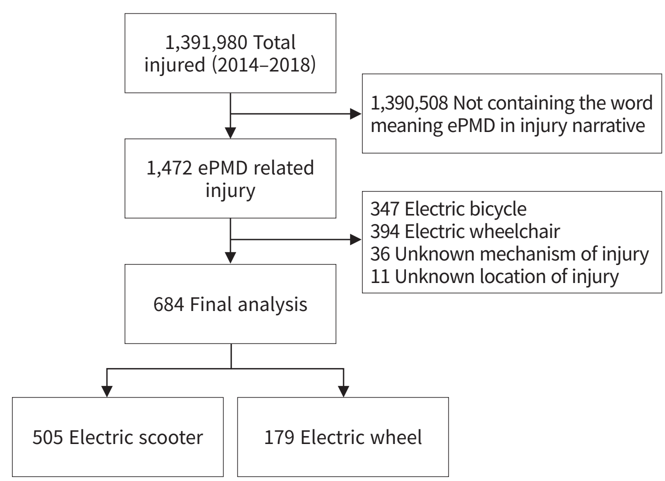
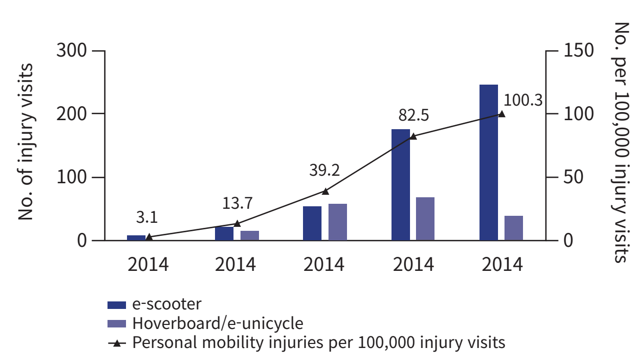


Fig. 1. Study population. ePMD, electric personal mobility devices.



Total injury visits	259,752	270,384	283,422	294,408	284,014
Participating hospitals	17	20	23	23	23

Fig. 2. Annual number of injuries related to electric personal mobility devices.

Table 1. Demographic findings and clinical outcomes of the study population by ePMD type

Characteristics	Total (n=684)	E-scooter (n=505)	Hoverboard/e-unicycle (n=179)	P-value
Age (yr)				<0.001
0–14	133 (19.4)	73 (14.5)	60 (33.5)	
15–24	164 (24.0)	135 (26.7)	29 (16.2)	
25–34	157 (23.0)	125 (24.8)	32 (17.9)	
35–44	151 (22.1)	115 (22.8)	36 (20.1)	
45–54	57 (8.3)	44 (8.7)	13 (7.3)	
≥55	22 (3.2)	13 (2.8)	9 (5.0)	
Median (interquartile range)	-	29 (21–38)	26 (12–39)	0.026
Male sex	465 (68.0)	350 (69.3)	115 (64.2)	0.210
Year of injury				<0.001
2014	8 (1.2)	8 (1.6)	0	
2015	37 (5.4)	21 (4.2)	16 (8.9)	
2016	111 (16.2)	54 (10.7)	57 (31.8)	
2017	243 (35.5)	175 (34.7)	68 (38.0)	
2018	285 (41.6)	247 (48.9)	38 (21.2)	
Day of injury (weekend)	298 (43.6)	216 (42.8)	82 (45.8)	0.480
Time of injury				0.012
0–6 AM	180 (26.3)	147 (29.1)	33 (18.4)	
6–12 AM	35 (5.1)	29 (5.7)	6 (3.4)	
12–6 PM	204 (29.8)	146 (28.9)	58 (32.4)	
6–12 PM	265 (38.7)	183 (36.2)	82 (45.8)	
Helmet use	21 (3.1)	17 (3.4)	4 (2.2)	0.210
Drunk driving (alcohol)	70 (10.2)	64 (12.7)	6 (3.4)	<0.001
EMS use	267 (39.0)	226 (44.8)	41 (22.9)	<0.001
Mechanism of injury				0.002
Fall-off	503 (73.5)	353 (69.9)	150 (83.8)	
Collision with motor vehicles	76 (11.1)	68 (13.5)	8 (4.5)	
Collision with stationary objects	52 (7.6)	45 (8.9)	7 (3.9)	
Collision with humans	25 (3.7)	20 (4.0)	5 (2.8)	
Collision with another ePMD	13 (1.9)	10 (2.0)	3 (1.7)	
Other	15 (2.2)	9 (1.8)	6 (3.4)	
Location of injury				<0.001
Indoor	41 (6.0)	21 (4.2)	20 (11.2)	
Public property	109 (15.9)	65 (12.9)	44 (24.6)	
Street	224 (32.7)	180 (35.6)	44 (24.6)	
Sidewalk	137 (20.0)	109 (21.6)	28 (15.6)	
Bike-way	29 (4.2)	22 (4.4)	7 (3.9)	
Driveway/parking	8 (1.2)	6 (1.2)	2 (1.1)	
Alley	136 (19.9)	102 (20.2)	34 (19.0)	
Injury severity, EMR-ISS				<0.001
Mild	233 (34.1)	150 (29.7)	83 (46.4)	
Moderate	363 (53.1)	276 (54.7)	87 (48.6)	
Severe	82 (12.0)	74 (14.7)	8 (4.5)	
Critical	6 (0.9)	5 (1.0)	1 (0.6)	

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https://doi.org/10.20408/jti.2021.0044

Table 1. Continued

Characteristics	Total (n=684)	E-scooter (n=505)	Hoverboard/e-unicycle (n=179)	P-value
Operation (yes)	60 (8.8)	47 (9.3)	13 (7.3)	0.41
Anatomical location of injury[a)]				<0.001
Head and face	332 (49.6)	271 (55.0)	61 (34.5)	
Neck	11 (1.6)	7 (1.4)	4 (2.3)	
Torso	30 (4.5)	22 (4.5)	8 (4.5)	
Extremities	297 (44.3)	193 (39.1)	104 (58.8)	
Diagnosis[a)]				0.326
Fracture	264 (28.6)	200 (27.4)	64 (33.3)	
Dislocation	38 (4.1)	30 (4.1)	8 (4.2)	
Internal organ injuries	80 (8.7)	61 (8.4)	19 (9.9)	
Open wound	232 (25.2)	193 (26.4)	39 (20.3)	
Superficial injury or contusion	303 (32.9)	242 (33.2)	61 (31.8)	
Amputation, blood vessel injuries, or crushing	5 (0.5)	4 (0.6)	1 (0.5)	
Disposition				0.075
Discharge	584 (85.4)	422 (83.6)	162 (90.5)	
Transfer	15 (2.2)	12 (2.4)	3 (1.7)	
Admission	85 (12.4)	71 (14.1)	14 (7.8)	

Values are presented as number (%).
EMS, emergency medical services; ePMD, electric personal mobility devices; EMR-ISS, excess mortality ratio-adjusted Injury Severity Score.
[a)]In case of several parts of the injury, it was counted as duplicate.

quent in the e-scooter group than in the hoverboard group. A higher proportion of injuries in the e-scooter group had EMR-ISS classifications of moderate or severe, and the e-scooter group also had a higher ICU admission rate than the hoverboard group. One death was recorded in the e-scooter group.

Table 2 shows the clinical results and demographic findings by age group. Injuries related to e-scooters were more common than injuries related to hoverboards across all age groups. The rate of emergency medical service utilization was highest among those aged >55 years old. Those aged 0 to 14 years old experienced the most injuries on public property, while the majority of injuries occurred on the street or sidewalk for the other age groups.

Main outcomes

The results of the multivariate logistic regression models are shown in Table 3. The occurrence of severe injury, traumatic brain injury, and ICU admission was higher among those aged 55 and older. There were no cases of traumatic brain injury or ICU admission when the rider wore a helmet. The likelihood of a severe injury (i.e., with an EMR-ISS of ≥25) was higher for men and for patients who had consumed alcohol before riding (adjusted OR [AOR], 2.11; 95% CI, 1.14–3.90 for men and AOR, 2.78; 95% CI, 1.52–5.08 for those with alcohol consumption). Moreover, patients who sustained injuries on roads or streets (AOR, 2.68; 95% CI, 1.11–6.45) were more likely to be admitted to the ICU than patients injured elsewhere.

DISCUSSION

Thus far in South Korea, only one study on ePMD-related injuries has been conducted, and it only examined injuries at one center. The present study analyzed multicenter data collected from evenly distributed, representative medical institutions in South Korea to examine the demographics of patients injured by ePMDs [17].

As ePMD use has grown in popularity worldwide, the burden of ePMD-related injuries has similarly increased. In Singapore, the incidence of ePMD-related injuries increased by 68% over 3 years [7]. Similarly, we found that the rate of ePMD-related injuries in South Korea also increased rapidly, from 3.1 injuries per 100,000 population in 2014 to 100.3 injuries per 100,000 population in 2018. Despite this increase in ePMD-related injuries, there have been few changes in legislation and infrastructure in South Korea. The Korean Road Traffic Act has not yet been updated to distinguish this new means of personal transport from motorcycles, which has led to an increase in the number of citizens who defy traffic laws. This can lead to an increase in traffic

Table 2. Demographic findings and clinical outcomes of the study population by age group

Variable	0–14 Years (n=133)	15–34 Years (n=321)	35–54 Years (n=208)	≥55 Years (n=22)	P-value
Age (yr)	9 (7–11)	22 (22–30)	42 (38–46)	61.5 (60–65)	
Male sex	82 (61.7)	211 (65.7)	157 (75.5)	15 (68.2)	0.036
Type of ePMD					<0.001
E-scooter	73 (54.9)	260 (81.0)	159 (76.4)	13 (59.1)	
Hoverboard/e-unicycle	60 (45.1)	61 (19.0)	49 (23.6)	9 (40.9)	
Year of injury					0.700
2014	1 (0.8)	3 (0.9)	4 (1.9)	0	
2015	8 (6.0)	15 (4.7)	13 (6.2)	1 (4.5)	
2016	28 (21.1)	45 (14.0)	32 (15.4)	6 (27.3)	
2017	48 (36.1)	115 (35.8)	74 (35.6)	6 (27.3)	
2018	48 (36.1)	143 (44.5)	85 (40.9)	9 (40.9)	
Day of injury (weekend)	73 (54.9)	126 (39.3)	89 (42.8)	10 (45.5)	0.024
Time of injury					<0.001
0–6 AM	10 (7.5)	102 (31.8)	64 (30.8)	4 (18.2)	
6–12 AM	2 (1.5)	16 (5.0)	15 (7.2)	2 (9.1)	
12–6 PM	68 (51.1)	75 (23.4)	52 (25.0)	9 (40.9)	
6–12 PM	53 (39.8)	128 (39.9)	77 (37.0)	7 (31.8)	
Helmet use	7 (5.3)	7 (2.2)	7 (3.4)	0	0.290
Drunk driving (alcohol)	0	44 (13.7)	23 (11.1)	3 (13.6)	<0.001
EMS use	22 (16.5)	141 (43.9)	93 (44.7)	11 (50.0)	<0.001
Mechanism of injury					0.002
Fall-off	107 (80.5)	221 (68.8)	160 (76.9)	15 (68.2)	
Collision with vehicles	2 (1.5)	43 (13.4)	27 (13.0)	4 (18.2)	
Collision with stationary object	8 (6.0)	34 (10.6)	8 (3.8)	2 (9.1)	
Collision with humans	8 (6.0)	9 (2.8)	8 (3.8)	0	
Collision with another ePMD	2 (1.5)	8 (2.5)	2 (1.0)	1 (4.5)	
Other	6 (4.5)	6 (1.9)	3 (1.4)	0	
Location of injury					<0.001
Indoor	21 (4.5)	7 (2.4)	11 (5.9)	2 (9.1)	
Public property	37 (31.2)	42 (19.0)	27 (8.8)	3 (13.6)	
Street	21 (21.4)	123 (30.8)	75 (29.4)	5 (22.7)	
Sidewalk	25 (17.0)	64 (20.2)	43 (20.6)	5 (22.7)	
Bike-way	3 (0.9)	16 (5.9)	10 (2.9)	0	
Driveway/parking	3 (0.9)	5 (1.2)	0 (5.9)	0	
Alley	23 (24.1)	64 (20.6)	42 (26.5)	7 (31.8)	
Injury severity, EMR-ISS					0.036
Mild	55 (41.4)	106 (32.0)	66 (31.7)	6 (27.3)	
Moderate	72 (54.1)	171 (53.3)	110 (52.9)	10 (45.5)	
Severe	6 (4.5)	42 (13.1)	29 (13.9)	5 (22.7)	
Critical	0	2 (0.6)	3 (1.4)	1 (4.5)	
Operation (yes)	13 (9.8)	20 (6.2)	23 (11.1)	4 (18.2)	0.088
Disposition					<0.001
Discharge	122 (91.7)	282 (87.9)	165 (79.3)	15 (68.2)	
Transfer	0	10 (3.1)	5 (2.4)	0	
Admission	11 (8.3)	29 (9.0)	38 (18.3)	7 (31.8)	

Values are presented as median (interquartile range) or number (%).
ePMD, electric personal mobility devices; EMS, emergency medical services; EMR-ISS, the excess mortality ratio-adjusted Injury Severity Score.

https://doi.org/10.20408/jti.2021.0044

Table 3. Logistic regression of risk factors for severe injury, traumatic brain injury, and ICU admission related to electric personal mobility devices

Variable	Severe injury severity (EMR-ISS ≥25)				Traumatic brain injury				ICU admission			
	OR	95% CI	AOR[a]	95% CI	OR	95% CI	AOR[a]	95% CI	OR	95% CI	AOR[a]	95% CI
Age (yr)												
0–14	0.30	0.12–0.72	0.53	0.21–1.36	No case				0.47	0.10–2.20	0.99	0.19–5.16
15–34	Reference				Reference				Reference			
35–54	1.14	0.70–1.87	1.17	0.70–1.98	1.83	0.61–5.52	1.85	0.60–5.74	1.24	0.48–3.21	1.28	0.48–3.37
≥55	2.36	0.88–6.36	3.88	1.33–11.36	8.29	1.92–35.74	13.32	2.70–65.82	4.91	1.25–19.34	6.86	1.56–30.23
Male sex	2.50	1.42–4.53	2.11	1.14–3.90	2.07	0.58–7.34	1.37	0.36–5.26	3.24	0.95–11.01	2.20	0.62–7.85
Type of ePMD (hoverboard/e-unicycle)	0.29	0.14–0.58	0.32	0.15–0.67	0.18	0.24–1.39	0.22	0.03–1.71	0.26	0.06–1.12	0.34	0.08–1.49
Time of injury												
0–6 AM	4.27	0.98–18.61	3.61	0.80–16.22	1.58	0.19–13.06	1.66	0.19–14.40	0.87	0.18–4.20	0.86	0.17–4.37
6–12 AM	Reference				Reference				Reference			
12–6 PM	1.31	0.29–5.99	1.94	0.41–9.10	0.68	0.74–6.27	1.18	0.12–11.24	0.50	0.10–2.58	0.91	0.17–4.88
6–12 PM	2.43	0.56–10.58	2.98	0.66–13.36	0.39	0.04–3.85	0.59	0.06–6.06	0.38	0.74–1.97	0.54	0.10–2.89
Helmet use	0.33	0.44–2.50	0.40	0.05–3.13	No case				No case			
Drunk driving (alcohol)	4.86	2.79–8.46	2.78	1.52–5.08	2.07	0.57–4.45	1.27	0.31–5.20	1.90	0.63–5.75	1.42	0.43–4.76
Injury mechanism (fall-off)	1.17	0.69–1.97	1.40	0.80–2.44	1.08	0.34–3.40	1.30	0.39–4.31	0.66	0.28–1.60	0.84	0.34–2.11
Location of injury (road and street)	1.07	0.67–1.72	0.84	0.50–1.39	2.71	1.00–7.37	2.21	0.78–6.29	3.34	1.42–7.84	2.68	1.11–6.45

ICU, intensive care unit; EMR-ISS, the excess mortality ratio-adjusted Injury Severity Score; OR, odds ratio; CI, confidence interval; AOR, adjusted OR; ePMD, electric personal mobility devices.

[a] Adjusted for age, sex, type of ePMD, year of injury, time of injury, helmet use, drink-driving, mechanism of injury, and location of injury.

accidents and injuries resulting from the operation of ePMDs. Therefore, to prevent accidents and minimize injuries, the characteristics of ePMD-related injuries must be analyzed in order to create new regulations and infrastructure to address this issue.

We classified the most popular types of ePMDs into e-scooters and hoverboards or e-unicycles. Injuries related to e-scooters were more common than injuries related to hoverboards or e-unicycles in 2017 and 2018. Furthermore, injuries related to e-scooters were more likely to involve motor vehicle collisions than injuries related to hoverboards or e-unicycles, and they were also more likely to be severe and lead to hospital admission.

Wearing a helmet is one of the most important safety precautions required by law when operating an ePMD. One of the most remarkable findings in this study was the low rate of helmet use across all age groups. In this study, there were no cases of traumatic brain injury or admission to the ICU when the patient had been wearing a helmet. Given this finding, it is essential for riders to wear a helmet when operating ePMDs.

Injuries under the influence of alcohol accounted for approximately 10% of all cases, and intoxication was significantly related to severe injury. At present, operating an ePMD while intoxicated is illegal, and greater measures must be taken to enforce this law. The incidence of ePMD-related injuries on roads and streets was associated with admission to the ICU. Currently, the law in Korea requires ePMDs to be operated only on roadways. Considering that operation on sidewalks can also lead to accidents, particularly involving pedestrians, laws regarding the operation of ePMDs must be reevaluated for optimal safety. If necessary, new infrastructure for ePMDs should be considered in addition to roadways.

One limitation of this study is that the number of ePMD-related injuries was small (684 cases). However, as this study used data from representative regional medical institutions, most severe injuries that required specialized treatment were likely included in the EDIIS database. Therefore, we believe that the data are representative of the population of South Korea. Another limitation is that data related to fatalities may have been missing since, if the rider had already died, he or she would not have been transferred to one of the medical institutions from this study. Therefore, further studies on ePMD-related injuries based on pre-hospitalization data should be conducted to examine incidents in which riders are not hospitalized.

In conclusion, there has been a recent increase in ER visits in South Korea due to ePMD-related injuries. Wearing a helmet while operating an ePMD is essential, as doing so can reduce the risk of traumatic head injury and ICU treatment. Drunk driving increases the likelihood of serious injury, and active administrative enforcement targeting the illegal operation of ePMDs should be increased. Furthermore, regulations related to the operation of ePMDs should be updated to prevent serious injuries from ePMD-related accidents. The results of this study may help inform the development of policies to prevent ePMD-related injuries.

NOTES

Ethical statement

The present study protocol was reviewed and approved by the Institutional Review Board of the Seoul National University Bundang Hospital (No. X-1903-528-902). The requirement for written informed consent was waived by the Institutional Review Board.

Conflicts of interest

The authors have no conflicts of interest to declare.

Funding

None.

Author contributions

Conceptualization: MK, DS, JWP, YHK; Study design: MK, DS, JWP, YHK; Acquisition, analysis, or interpretation of data: MK, DS, JJ, SK; Statistical analysis: DS; Writing–original draft: MK, DS; Writing–review&editing: JHL, HK, YC, JWP, YHJ.
All authors read and approved the final copy of the manuscript.

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