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Effect of use and type of helmet on occurrence of traumatic brain injuries in motorcycle riders in Korea: a retrospective cohort study

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Purpose: The purpose of this study was to investigate (1) the association among helmet wearing, incidence rate of traumatic brain injury (TBI), and in-hospital mortality; TBI was diagnosed when the head Abbreviated Injury Scale (AIS) was ≥1, and as severe TBI when head AIS was ≥3; and (2) the association between helmet type and incidence rate of TBI, severe TBI, and in-hospital mortality of motorcycle accidents based on the newly revised Emergency Department-based Injury In-depth Surveillance (EDIIS) data.

Methods: Data collected from EDIIS between January 1, 2020 and December 31, 2020 were analyzed. The final study population comprised 1,910 patients, who were divided into two groups: helmet wearing group and unhelmeted group. In addition, the correlation between helmet type and motorcycle accident was determined in 596 patients who knew the exact type of helmet they wore. A total of 710 patients who wore helmet but did not know the type were excluded from this analysis. Multivariate logistic regression was performed in both the groups to investigate the factors affecting the primary (occurrence of TBIs) and secondary outcomes (severe TBI and in-hospital mortality).

Results: The prevalence of Injury Severity Scores, TBIs, and severe TBIs as well as in-hospital mortality were the highest in the unhelmeted group. Additionally, the results from the group that wore and knew the type of helmet worn indicated that wearing a full-face helmet decreased the incidence of TBIs in comparison to a half-face helmet.

Conclusions: The wearing of a helmet in motorcycle accidents is very important as it plays a role in reducing the occurrence of TBIs and severe TBIs and in-hospital mortality. The use of a full-face helmet lowered the incidence of TBIs.

Keywords: Helmet type; Motorcycle accidents; Traumatic brain injuries; Severe head Abbreviated Injury Scale; Hospital mortality

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INTRODUCTION

The growth of the delivery industry increased due to COVID-19 pandemic in Korea, and the Ministry of Land, Infrastructure and Transport (MOLIT) reported that the number of registered motorcycles in 2020 increased to 2,289,099 units [1]. According to the "Online shopping trends in May 2021," the demand for motorcycles can be estimated through the 62.2% increase in online food delivery services compared to the same period in the previous year [2]. With such rapidly increasing demand for motorcycles, the registration rate and the number of applicants for motor vehicle licenses have also increased significantly. The Korean National Police Agency and the Road Traffic Authority reported that there was a 12% increase in the number of applicants for motorcycle license test, from 54,986 in 2019 to 62,593 in 2020 [3]. With the increase in number of motorcycles, the incidence of motorcycle accidents has also increased. Eltorai et al. [4] reported that motorcycle accidents resulted in more serious injuries than automobiles. Data from the Korea Transportation Safety Authority indicates that head injuries are the main cause of death in road traffic accidents, accounting for 41.3% of all deaths [5]. Studies have shown that the use of helmet can prevent or significantly reduce the severity of injuries in motorcycle accidents, as well as reduce the mortality rate [6,7].

According to the *Motorcycle Safety Guide* provided by the Centers for Disease Control and Prevention (CDC) [8], helmets are classified into the following three types based on their shapes: half helmets, open-face helmets, and full helmets. International studies have proven the efficacy of full-face helmets in preventing a traumatic brain injury (TBI); however, the evidence is limited, with the number of study participants being just over 100 [9,10]. Furthermore, while domestic research have studied the relationship between the use of helmets and motorcycle accidents [4,11], none of the studies have focused on the type of helmet used, the information regarding which can be accessed from the revised Emergency Department-based Injury In-depth Surveillance (EDIIS) data. The objective of our study was to perform a nationwide data analysis to evaluate (1) the association between the use of helmet and the occurrence of TBI and (2) the association between the type of helmet and the occurrence of TBI. For this purpose, we hypothesized that, wearing a helmet will reduce the occurrence of TBI, and among the helmet types, the full-face type would be associated with least TBI, while the open-face type would be linked with the most TBI.

METHODS

Ethics statements

This study was approved by the Korea Disease Control and Prevention Agency (KCDC) and the Institutional Review Board of Pusan National University Hospital (No. 2205-005-114). The need for informed consent was waived by the Institutional Review Board due to the use of de-identified data.

Study design and participants

This was a multicenter retrospective cohort study performed using the Korean EDIIS database. The study was described according to the STROBE (Strengthening the Reporting of Observational Studies in Epidemiology) statement (https://www.strobe-statement.org/). EDIIS is a nationwide database that comprises data of all injured patients who presented to the emergency department in Korea. The KCDC established EDIIS in 2006 using data collected from five hospitals. Currently, it includes data from 23 participating hospitals all across the country. EDIIS collects data which would aid in developing a national policy for injury prevention and also performs periodic quality control by analyzing errors.

We collected the data of patients registered in EDIIS between January 1, 2020, and December 31, 2020. The exclusion criteria were as follows: age <15 years ($n=4$), death on arrival ($n=1$), and patients with missing information regarding helmet ($n=112$). A total of 117 patients were excluded after implementing the criteria. The final study population comprised 1,910 patients who were divided into two groups: helmet wearing group and unhelmeted group. In addition, the correlation between helmet type and motorcycle accident was determined in 596 patients, who knew the exact type of helmet they wore. A total of 710 patients who wore a helmet but did not know the type were excluded from this analysis. Since a large number of patients were excluded due to lack of information regarding the type of helmet they wore, the basic characteristics of the group aware of the type of helmet and the group not aware of the type of helmet were analyzed to remove the possible bias.

Data collection and variable definition

The coordinator who collected information for the EDIIS database received regular training at the Coordinator Education and Quality Management Meeting, conducted by the KCDC four times a year. The coordinator collected the information from each patient, primarily via questioning the patient. If a patient

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was unable to provide the information, it was obtained from the patient's guardian or the paramedics (information witnessed directly by the paramedic at the scene and collected by the paramedics from other subjects who witnessed the accident).

The following baseline patient characteristics were extracted from EDIIS: age, sex, alcohol consumption, time of emergency department (ED) arrival, type of road, type of helmet, Injury Severity Score (ISS), head injury, and in-hospital mortality. Elderly was defined as individuals over the age of 65 years. Suspicion for alcohol consumption was noted, but if alcohol intake was unknown, it was classified as unused. ED visit dates were divided based on seasons: spring (March to May), summer (June to August), autumn (September to November), and winter (December to February). The time of ED visit was divided into dawn (00:00–05:59), morning (06:00–11:59), afternoon (12:00–17:59), and night (18:00– 23:59).

The type of helmet was classified into three categories based on their shape: half helmet, open-face helmet, and full helmet. This classification of helmets is used not only by the *Motorcycle Safety Guide* provided by the CDC [8], but also by the United Nations Economic Commission for Europe (UNECE) [12], which is currently used in more than 50 countries and is the world's most popular motorcycle helmet test standard. The KCDC also uses the same helmet classification [13]. The open-face helmet protects the ears, cheeks, and back of the head, but does not cover the area under the chin. The half-face helmet features the same front design as the open-face helmet, but lacks a lowered rear. The full-face helmets offer the maximum protection, protecting the eyes and face with a face shield and providing protection to the chin (Fig. 1). Road type was classified into three categories: alley, highway, and general road (i.e., all roads excluding alleys and highways). Opponent objects were classified into seven categories: pedestrian, two-wheel vehicle, four-wheel small vehicle (i.e., sedan and sport utility vehicle), four-wheel large vehicle (i.e., van, bus, and truck), a fixed object, unknown, and none. Severe injury was defined as an ISS of ≥16 points. TBI was defined when the head Abbreviated Injury Scale (AIS) was ≥1, and severe TBI was defined when head AIS was ≥3 [14]. In-hospital mortality was divided into two groups: alive and expired. The primary outcome was risk factors of TBI, and the secondary outcomes were factors associated with severe TBI and in-hospital mortality.

Statistical analysis

Descriptive statistics were reported as median (interquartile range) for continuous variables according to the normality test using the Kolmogorov-Smirnov test. Categorical variables were expressed as frequencies (percentage).

Intergroup comparisons of baseline characteristics based on the use of helmet (unhelmeted vs. helmeted group) and helmet type (half-face vs. open-face vs. full-face helmet group) were performed. Mann-Whitney U-test or Kruskal-Wallis test were used for continuous variables, while chi-square test or Fisher exact test for categorical variables. In addition, to determine whether there was a bias between unknown and known helmet type groups, the same statistical methods mentioned above were used.

Significant variables in the univariate analysis (i.e., those with $P<0.10$) were entered into a stepwise backward multivariate logistic regression analysis to determine the independent risk factors of TBI, severe TBI and in-hospital mortality. For each independent risk factor, adjusted odds ratio (aOR) with 95% confidence (CI) were calculated. All statistical analyses were performed using IBM SPSS ver. 22.0 (IBM Corp), and $P<0.05$ was considered statistically significant.

Fig. 1. The different types of helmets. (A) Full-face helmet, (B) open-face helmet, and (C) half-face helmet.

RESULTS

Comparison of the unhelmeted and helmeted groups

During the study period, 2,027 patients injured as a result of motorcycle accidents were registered in the EDIIS registry. Among the 1,910 patients of the study population, 604 belonged to the unhelmeted group while 1,306 to the helmeted group (Table 1). In the >65 years age group, the ratio of individuals not wearing a helmet was 22.8%, which was significantly higher than 12.6% who wore a helmet. In addition, the proportion of women not wearing a helmet was 15.4%, which was significantly higher than 6.0% of men not wearing a helmet. It was observed that accidents occurred mainly at night in both the groups (32.3% vs. 42.3%, respectively). The ratio of alcohol intake was 18.2% versus 6.1%, which was significantly higher in the unhelmeted group. The most common opponent object observed was a four-wheel small car, and the proportions were 40.9% and 58.1% in the unhelmeted and helmeted group, respectively. The prevalence of ISS ≥16, TBIs, and severe TBIs, as well as in-hospital mortality were highest in the unhelmeted group (22.4%, 37.7%, 19.9%, and 7.5%, respectively).

Logistic regression to predict TBI

Table 2 shows the factors affecting TBIs based on the use or disuse of helmets, using the multivariate logistic regression analysis. In this analysis, the adjusted variables were age ≥65 years, season, admission time, alcohol consumption, opponent object, and the use of a helmet. The analysis showed that the factors affecting TBIs were being elderly (aOR, 1.012; 95% CI, 1.007–1.018) and consumption of alcohol (aOR, 2.643; 95% CI, 1.914–3.650). The incidence of TBIs were lower in winter compared to spring (aOR, 0.627; 95% CI, 0.506–0.862), and the accidents were more common at night than dawn (aOR, 0.756; 95% CI, 0.608–0.941). Wearing a helmet (aOR, 0.544; 95% CI, 0.436–0.678) lowered the incidence of TBIs. The analysis of factors affecting severe TBIs and in-hospital mortality showed that the factors which reduced the incidence of severe TBIs included time of accident, i.e., night compared to dawn (aOR, 0.703; 95% CI, 0.505–0.978); accident site, i.e., an alley compared to a highway (aOR, 0.285; 95% CI, 0.102–0.796); and use of helmet (aOR, 0.307; 95% CI, 0.226–0.419) (Table S1). Being elderly (aOR, 1.021; 95% CI, 1.014–1.028) and drinking alcohol (aOR, 1.692; 95% CI, 1.106–2.589) were more likely to cause severe TBIs. Furthermore, it was observed that in-hospital mortality increased for the elderly (aOR, 1.017; 95% CI,1 .007–1.028) and for four-wheel large vehicle opponent object compared to pedestrians (aOR, 2.518; 95% CI, 1.195–5.305), and decreased for those wearing helmets (aOR, 0.325; 95% CI, 0.203–0.519) (Table S2).

Comparison of patients according to type of helmet in the group with known helmet type

Among the 1,309 patients who wore helmets, 596 were aware of the type of helmet while 710 were not. The 596 patients with clear helmet type were analyzed. Of these, 125, 185, and 286 patients wore half-face, open-face, and full-face helmets, respectively. Type of road and opponent object were the only two meaningful variables in terms of their basic characteristics. Furthermore, it was observed that majority of the accidents occurred on general roads at rates of 98.4%, 91.9%, and 98.6% in the half-face, open-face, and full-face groups, respectively; and four-wheel small vehicles as the opponent objects were responsible for most accidents at rates of 59.2%, 58.9%, and 58.4%, respectively (Table 3).

Logistic regression to predict TBI in the group with known helmet type

Table 4 shows the analysis of factors affecting TBIs in 596 patients who wore a helmet and were aware of the type. The factors that contributed to an increased incidence of TBIs were age above 65 years (aOR, 1.017; 95% CI, 1.005–1.028) and alcohol consumption (aOR, 2.423; 95% CI, 1.036–5.670). On the other hand, a correlation was observed that the incidence of TBIs decreased in the absence of an opponent object compared to when the opponent object were pedestrians (aOR, 0.496; 95% CI, 0.272–0.905) and when wearing a full-face helmet compared to a half-face helmet (aOR, 0.612; 95% CI, 0.396–0.944). Analysis of the factors affecting severity of TBIs and in-hospital mortality in this patient group (n = 596) showed that age of the patient and colliding object were the correlating factors (Tables S3, S4).

Comparison of unknown and known helmet groups

To exclude any statistical bias as a result of the missing data, comparison was done between the group that wore helmet of unknown type and group that wore a known type of helmet. No significant differences were observed in terms of the variables, except incidence of TBI. Although the incidence of TBI was significantly higher in the group with unknown helmet type, the incidence rate of TBI was still as low as 28.3%. This could be interpreted as use of helmets prevented TBI, even when the type of helmet was unknown.

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Table 1. Comparison between the unhelmeted and helmeted groups (n=1,910)

Characteristic	Unhelmeted (n=604)	Helmeted (n=1,306)	P-value
Age (yr)	33 (20–63)	37 (26–51)	0.047
≥65			<0.001
No	466 (77.2)	1,141 (87.4)	
Yes	138 (22.8)	165 (12.6)	
Sex			<0.001
Male	511 (84.6)	1,228 (94.0)	
Female	93 (15.4)	78 (6.0)	
Season			0.053
Spring	160 (26.5)	309 (23.7)	
Summer	152 (25.2)	363 (27.8)	
Autumn	172 (28.5)	423 (32.4)	
Winter	120 (19.9)	211 (16.2)	
Admission time			<0.001
Dawn (00:00–05:59)	149 (24.7)	179 (13.7)	
Morning (06:00–11:59)	106 (17.5)	184 (14.1)	
Afternoon (12:00–17:59)	154 (25.5)	391 (29.9)	
Night (18:00–23:59)	195 (32.3)	552 (42.3)	
Alcohol consumption			<0.001
No	494 (81.8)	1,226 (93.9)	
Yes	110 (18.2)	80 (6.1)	
Type of road			0.544
Highway	1 (0.2)	1 (0.1)	
General road	565 (93.9)	1,306 (92.9)	
Alley	32 (5.3)	86 (6.5)	
Unknown	4 (0.7)	6 (0.5)	
Opponent object			<0.001
Pedestrian	3 (0.5)	11 (0.8)	
Two-wheel vehicle	28 (4.6)	82 (6.3)	
Four-wheel small vehicle	247 (40.9)	759 (58.1)	
Four-wheel large vehicle	31 (5.1)	63 (4.8)	
Fixed object	41 (6.8)	58 (4.4)	
Unknown	11 (1.8)	18 (1.4)	
None	243 (40.2)	315 (24.1)	
Injury Severity Score ≥16			<0.001
No	469 (77.6)	1,131 (86.6)	
Yes	135 (22.4)	175 (13.4)	
TBI (head AIS ≥1)			<0.001
No	376 (62.3)	997 (76.3)	
Yes	228 (37.7)	309 (23.7)	
Severe TBI (head AIS ≥3)			<0.001
No	484 (80.1)	1,223 (93.6)	
Yes	120 (19.9)	83 (6.4)	
In-hospital mortality			<0.001
Alive	559 (92.5)	1,274 (97.5)	
Expired	45 (7.5)	32 (2.5)	

Values are presented as median (interquartile range) or number (%).
TBI, traumatic brain injury; AIS, Abbreviated Injury Scale.

Table 2. Logistic regression to predict traumatic brain injuries (n=1,910)

Variable	Adjusted odds ratio	95% Confidence interval	P-value
Age ≥65 yr	1.012	1.006–1.017	<0.001
Season			
Spring	Reference		
Summer	1.152	0.862–1.541	0.339
Autumn	1.314	0.994–1.735	0.055
Winter	0.627	0.497–0.887	0.002
Admission time			
Dawn (00:00–05:59)	Reference		
Morning (06:00–11:59)	0.934	0.652–1.340	0.712
Afternoon (12:00–17:59)	0.967	0.697–1.343	0.843
Night (18:00–23:59)	0.756	0.608–0.941	0.012
Alcohol consumption			
No	Reference		
Yes	2.643	1.914–3.650	<0.001
Opponent object			
Pedestrian	Reference		
Two-wheel vehicle	0.371	0.188–1.280	0.116
Four-wheel small vehicle	0.596	0.190–1.869	0.375
Four-wheel large vehicle	0.758	0.225–2.558	0.655
Fixed object	0.749	0.223–2.517	0.641
Unknown	4.624	2.099–0.188	0.001
None	0.676	0.531–0.859	0.001
Use of helmet			
No	Reference		
Yes	0.544	0.436–0.678	<0.001

Variables included in multiple logistic regression: age ≥65 years, season, admission time, alcohol consumption, opponent object, and use of helmet.

DISCUSSION

This study aimed to identify the relationship between the use of helmets, occurrence of TBIs and severe TBIs, and in-hospital mortality in motorcycle accidents. The study also aimed to determine whether different types of helmets affected the occurrence of TBIs and severe TBIs and in-hospital mortality. Our study did not directly evaluate the injury-preventing function of helmets like the experiments conducted under uniform conditions, rather, retrospectively analyzed the EDIIS data. We observed that wearing a helmet reduced the occurrence of TBIs and severe TBIs and in-hospital mortality, which was consistent with the findings of other studies [6,7], which indicated that helmets mitigated head injuries in motorcycle accidents. Liu et al. [7] reported that wearing helmet decreased head injuries and mortality by 69% and 42%, respectively. These findings were very similar to our results, which showed that wearing a helmet reduced the incidence of TBIs (aOR, 0.544; 95% CI, 0.436–0.678) and in-hospital mortality (aOR, 0.325; 95% CI, 0.203–0.519).

Our study showed reduced incidence of TBI in the full-face helmet group. This was consistent with the findings of Tabary et al. [9]. However, the P-value in our study was 0.027, which was significant compared to the very limited evidence used in the aforementioned study. In addition, the report by Tabary et al. [9] showed that wider the area covered by the helmet including the face, lower was the degree of damage. We agree with the fact that the position of helmet at the time of the accident is an important factor for TBIs [15]. One study reported that protection of chin is an important differentiating factor between full-face helmets and other helmet types [16]. This study by Richter et al. [16] reported a high prevalence of damage to the chin guard region. Additionally, Otte [17] identified the distribution of impact locations on motorcycle helmets for all types of collisions and found that the rate reached 34.6% for the chin guard. On this basis, the *Motorcy-*

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Table 3. Comparison of patients according to type of helmet in the group with known helmet type (n=596)

Characteristic	Helmet group			P-value
	Half-face (n=125)	Open-face (n=185)	Full-face (n=286)	
Age (yr)	39.0 (24.3–57.0)	35.0 (25.0–52.0)	37.5 (26.0–49.8)	0.743
≥65				0.201
No	101 (80.8)	162 (87.6)	248 (86.7)	
Yes	24 (19.2)	23 (12.4)	38 (13.3)	
Sex				0.825
Male	118 (94.4)	177 (95.7)	272 (95.1)	
Female	7 (5.6)	8 (4.3)	14 (4.9)	
Season				0.042
Spring	29 (23.2)	36 (19.5)	87 (30.4)	
Summer	36 (28.8)	56 (30.3)	69 (24.1)	
Autumn	31 (24.8)	59 (31.9)	63 (22.0)	
Winter	29 (23.2)	34 (18.4)	67 (23.4)	
Admission time				0.900
Dawn (00:00–05:59)	17 (13.6)	27 (14.6)	39 (13.6)	
Morning (06:00–11:59)	18 (14.4)	24 (13.0)	33 (11.5)	
Afternoon (12:00–17:59)	36 (28.8)	48 (25.9)	90 (31.5)	
Night (18:00–23:59)	54 (43.2)	86 (46.5)	124 (43.4)	
Alcohol consumption				0.094
No	119 (95.2)	171 (92.4)	277 (96.9)	
Yes	6 (4.8)	14 (7.6)	9 (3.1)	
Type of road				<0.001
Highway	0	0	0	
General road	123 (98.4)	170 (91.9)	282 (98.6)	
Alley	2 (1.6)	15 (8.1)	4 (1.4)	
Unknown	0	0	0	
Opponent object				<0.001
Pedestrian	0	3 (1.6)	4 (1.4)	
Two-wheel vehicle	14 (11.2)	9 (4.9)	29 (10.1)	
Four-wheel small vehicle	74 (59.2)	109 (58.9)	167 (58.4)	
Four-wheel large vehicle	7 (5.6)	10 (5.4)	17 (5.9)	
Fixed object	2 (1.6)	13 (7.0)	11 (3.8)	
Unknown	1 (0.8)	0	2 (0.7)	
None	27 (21.6)	41 (22.2)	56 (19.6)	
Injury Severity Score ≥16				0.462
No	110 (88.0)	156 (84.3)	238 (83.2)	
Yes	15 (12.0)	29 (15.7)	48 (16.8)	
TBI (head AIS ≥1)				0.056
No	100 (80.0)	143 (77.3)	245 (85.7)	
Yes	25 (20.0)	42 (22.7)	41 (14.3)	
Severe TBI (head AIS ≥3)				0.924
No	117 (93.6)	175 (94.6)	268 (93.7)	
Yes	8 (6.4)	10 (5.4)	18 (6.3)	
In-hospital mortality				0.057
Alive	125 (100)	179 (96.8)	275 (96.2)	
Expired	0	6 (1.0)	11 (3.8)	

Values are presented as median (interquartile range) or number (%).
TBI, traumatic brain injury; AIS, Abbreviated Injury Scale.

Table 4. Logistic regression to predict traumatic brain injuries in the group with known helmet type (n=596)

Variable	Adjusted odds ratio	95% Confidence interval	P-value
Age ≥65 yr	1.017	1.005–1.028	0.004
Alcohol consumption			
No	Reference		
Yes	2.423	1.036–5.670	0.041
Opponent object			
Pedestrian	Reference		
Two-wheel vehicle	0.517	0.084–3.176	0.477
Four-wheel small vehicle	0.519	0.098–2.772	0.440
Four-wheel large vehicle	0.551	0.086–3.546	0.531
Fixed object	0.337	0.047–2.440	0.282
Unknown	1.453	0.077–27.248	0.803
None	0.496	0.272–0.905	0.022
Type of helmet			
Half-face	Reference		
Open-face	1.243	0.707–2.182	0.450
Full-face	0.612	0.396–0.944	0.027

Variables included in multiple logistic regression: age ≥65 years, sex, season, admission time, alcohol consumption, opponent object, type of road, and type of helmet.

cle Safety Guide provided by the CDC emphasizes the importance of full-face helmets. Similarly, Tabary et al. [9] also reported that full-face type helmets remained fixed in the most intact position at the scene after the accident, and this benefit had the most significant effect on mortality in motorcycle traffic accidents. This fact is also supported by findings on the relationship between helmet loss during accident and fatal injury [16]. The UNECE regulation [12], currently used in more than 50 countries and the world's most popular motorcycle helmet test standard, provides safety regulations for helmet users. However, the usefulness of this certification is debated as it does not test for penetration and has no test for chin guards [18]. Motorcyclists who purchase helmets should be made aware that only full-face helmets achieve their true function, that is ensuring safety. The Eastern Association for the Surgery of Trauma (EAST) Guidelines Committee Injury Prevention Task Force of the United States conducted a study on the effectiveness of full-face helmets to develop practice management guidelines for the use of motorcycle helmets [19]. This meta-analysis was published in 2022, which concluded that full-face helmets prevented TBIs and recommended their use in motorcyclists [19]. Although the full-face helmet is not a specific advanced case, it was found that if the helmet law was repealed in the United States, the use of helmets decreased significantly, and consequently death and TBI increased [6]. Conversely, the use of helmets has been found to increase with the enactment of the helmet wearing law, and it is expected that the incidence of TBI would decrease with promulgation of laws regarding the use of full-face helmets.

Interestingly, with respect to sex, the current study found a higher proportion of unhelmeted female patients (93 of 171, 29.4% vs. 511 of 1,739, 54.4%) (Table 1). Although the reason for this disparity remains unknown, these findings highlight the need to increase the awareness and use of helmets in women. Meanwhile, although several studies found that alcohol use was an influencing factor for mortality or severe injury in motorcycle traffic accidents [20,21], our result indicated that alcohol consumption was a risk factor for the occurrence of TBIs and severe TBIs. Jeong et al. [11] reported that alcohol consumption was associated with high risk of TBI because of the tendency to not to wear a helmet when intoxicated. However, our results support that the use of correct type of helmet, rather than alcohol intake itself, reduced injuries and affected the severity of injury. Future research are needed to establish the direct effect of alcohol consumption on the severity of injury.

This study had some limitations. First, the possibility of bias could not be ruled out owing to the retrospective study design. Second, although the EDIIS is a nationwide system, there may have been a bias in patient recruitment since the participating medical institutions were relatively high-level emergency departments. Third, the missing data in the group that wore unknown type of helmet exceeded the number in the group that wore accurate type of helmet. However, to compensate for the statistical

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Table 5. Comparison between the unknown and known type of helmet groups (n=1,306)

Characteristic	Helmet type		P-value
	Unknown (n=710)	Known (n=596)	
Age (yr)	36 (26–50)	37 (26–52)	0.449
≥65			0.112
No	630 (88.7)	511 (85.7)	
Yes	80 (11.3)	85 (14.3)	
Sex			0.129
Male	661 (93.1)	567 (95.1)	
Female	49 (6.9)	29 (4.9)	
Season			<0.001
Spring	157 (22.1)	152 (25.5)	
Summer	202 (28.5)	161 (27.0)	
Autumn	270 (38.0)	153 (25.7)	
Winter	81 (11.4)	130 (21.8)	
Admission time			0.381
Dawn (00:00–05:59)	96 (13.5)	83 (13.9))	
Morning (06:00–11:59)	109 (15.4)	75 (12.6)	
Afternoon (12:00–17:59)	217 (30.6)	174 (29.2)	
Night (18:00–23:59)	288 (40.6)	264 (44.3)	
Alcohol consumption			0.084
No	659 (92.8)	567 (95.1)	
Yes	51 (7.2)	29 (4.9)	
Type of road			<0.001
Highway	1 (0.1)	0	
General road	638 (89.9)	575 (96.5)	
Alley	65 (9.1)	21 (3.5)	
Unknown	6 (0.9)	0	
Opponent object			<0.001
Pedestrian	4 (0.6)	7 (1.2)	
Two-wheel vehicle	30 (4.2)	52 (8.7)	
Four-wheel small vehicle	409 (57.6)	350 (58.7)	
Four-wheel large vehicle	29 (4.1)	34 (5.7)	
Fixed object	32 (4.5)	26 (4.4)	
Unknown	15 (2.1)	3 (0.5)	
None	191 (26.9)	124 (20.8)	
Injury Severity Score ≥16			0.051
No	627 (88.3)	504 (84.6)	
Yes	83 (11.7)	92 (15.4)	
TBI (head AIS ≥1)			<0.001
No	509 (71.7)	488 (81.9)	
Yes	201 (28.3)	108 (18.1)	
Severe TBI (head AIS ≥3)			0.733
No	663 (93.4)	560 (94.0)	
Yes	47 (6.6)	36 (6.0)	
In-hospital mortality			0.473
Alive	695 (97.9)	579 (97.1)	
Expired	15 (2.1)	17 (2.9)	

Values are presented as median (interquartile range) or number (%).
TBI, traumatic brain injury; AIS, Abbreviated Injury Scale.

bias resulting from this difference, we performed an analysis, the description of which is presented separately in Table 5. Fourth, the number of variables for each type of helmet was small, although the number of patients included in our study was much higher compared to foreign studies. Finally, since the predefined variables of EDIIS lack specificity for evaluation of all important factors, our findings may have limited generalizability and validity. Future studies encompassing more hospitals of all levels and more detailed patient information would help address these limitations and provide information that is more representative of the entire Korean population.

In conclusion, the use of a helmet is very important as it plays a significant role in reducing the occurrence of TBIs and severe TBIs and in-hospital mortality in motorcycle accidents. Although the study did not rank the types of helmets for better protection, we found that the use of a full-face helmet lowered the incidence of TBIs. It is recommended that in future studies, ranking by type of helmet be established with an increased number of variables for each type of helmet, which would be helpful in supplementing education and laws for motorcyclists.

SUPPLEMENTARY MATERIALS

Table S1. Logistic regression to predict severe traumatic brain injuries (n = 1,910)
Table S2. Logistic regression to predict in-hospital mortality (n = 1,910)
Table S3. Logistic regression to predict severe traumatic brain injuries (n = 596)
Table S4. Logistic regression to predict in-hospital mortality (n = 596)
Supplementary materials are available from https://doi.org/10.20408/jti.2022.0029.

NOTES

Conflicts of interest

The authors have no conflicts of interest to declare.

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Data sharing statement

The data of this article are available from the corresponding author upon reasonable request.

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Author contributions

Conceptualization: YC, SRY; Data curation: SS; Formal analysis: SWP; Funding acquisition: YC; Methodology: SJC; Writing–original draft: SS, YC, SWP; Writing–review & editing: IJW, WTY, SJC, SRY. All authors read and approved the final manuscript.

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