

## RESEARCH ARTICLE

# Can helmet decrease mortality of craniocerebral trauma patients in a motorcycle accident?: A propensity score matching

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**Citation:** Choi WS, Cho J-S, Jang YS, Lim YS, Yang HJ, Woo J-H (2020) Can helmet decrease mortality of craniocerebral trauma patients in a motorcycle accident?: A propensity score matching. *PLoS ONE* 15(1): e0227691. <https://doi.org/10.1371/journal.pone.0227691>

**Editor:** Quan Yuan, Tsinghua University, CHINA

**Received:** August 26, 2019

**Accepted:** December 24, 2019

**Published:** January 13, 2020

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**Data Availability Statement:** Data cannot be shared publicly because data are owned by the Korea Center for Disease Control and Prevention (KCDC). Data are available from the Institutional Data Access/Ethics Committee of KCDC (contact via <https://is.cdc.go.kr/>) for researchers who meet the criteria for access to confidential data. The authors did not receive special access privileges to the data that others would not have.

**Funding:** The authors received no specific funding for this work.

## Abstract

A helmet is critical for preventing head injuries during motorcycle accidents. However, South Korean motorcyclists have a lower prevalence of wearing a helmet, compared to developed countries. Therefore, we aimed to evaluate whether helmet wearing was associated with the clinical outcomes in Korean motorcycle accidents. Data were obtained from the Emergency Department-based Injury In-depth Surveillance database 2011–2015. We considered the patients had experienced a motorcycle accident and were only diagnosed with a craniocerebral trauma (CCT). The primary outcome was mortality and the secondary outcomes were the severity and hospitalization duration. The patients were separated whether they were wearing a helmet and the outcomes were compared using multivariate logistic regression after propensity score matching (PSM). Among 1,254,250 patients in the database, 2,549 patients were included. After PSM, 1,016 patients in each group were matched. The univariate analyses revealed that helmet wearing was associated with lesser severity ( $P < 0.001$ ) and shorter hospitalization ( $P < 0.001$ ). The regression analysis revealed that mortality was also lower in a helmet-wearing group (odds ratio: 0.34, 95% confidence interval: 0.21–0.56). In conclusion, wearing a helmet may reduce the mortality from a CCT after a motorcycle accident and associated with lesser severity and shorter hospitalization.

## Introduction

Between 2010 and 2014, approximately 415 South Koreans died each year because of motorcycle accidents. This mortality rate is less than the overall Korean car accidental death rate, which is approximately 2,595 people per year. However, motorcycle deaths account for 386 deaths per 10,000 accidents, compared to 175 accidental deaths per 10,000 car accidents [1]. Motorcycle-related deaths typically involve a craniocerebral trauma (CCT), and a helmet is the

**Competing interests:** The authors have declared that no competing interests exist.

most important protective equipment for preventing or reducing the severity of CCTs [2][3]. Previous studies have examined the relationship between helmet wearing and mortality after motorcycle accidents. Some studies have reported that wearing a helmet was related to the low motorcycle-related mortality and other studies said that the legislation of helmet wearing for motorcyclists increased compliance and reduced the severity of accidents [4][5]. However, most previous studies evaluated mortality and severity independent of the affected body part, and it is difficult to accurately understand how wearing a helmet influences mortality and severity after a motorcycle-related CCT. Therefore, the present study aimed to evaluate whether wearing a helmet was associated with mortality, severity, and hospitalization duration among patients who only had a CCT diagnosis after a motorcycle accident.

## Methods

### Study design and subjects

This observational study evaluated patients with a motorcycle-related CCT who were entered into the Emergency Department-based Injury In-depth Surveillance (EDIIS) database between 2011 and 2015[6]. The database collects information from participating in emergency departments and is administered by the Korean Centers for Disease Control and Prevention (KCDC). The EDIIS database was launched in 2006 and was receiving data from 23 university hospitals by 2015. The present study evaluated data from 2011 to 2015.

The study population included patients who had only a motorcycle accident as the ‘mechanism of injury’ and a CCT diagnosis, which was searched using the International Classification of Diseases-10 code (ICD-10) (Table in [S1 Table](#)). We excluded patients who were  $\leq 14$  years old, cases in which it was unclear whether the patient had been wearing a helmet, and cases in which it was unclear whether the patient had consumed alcohol ([Fig 1](#)). The criteria for the CCT diagnosis are listed in the EDIIS guidelines (Table in [S1 Table](#)). Based on the results, we compared the demographic characteristics and clinical outcomes of patients who had worn a helmet (the HA group) and patients who had not worn a helmet (the NHA group).

### Data collection

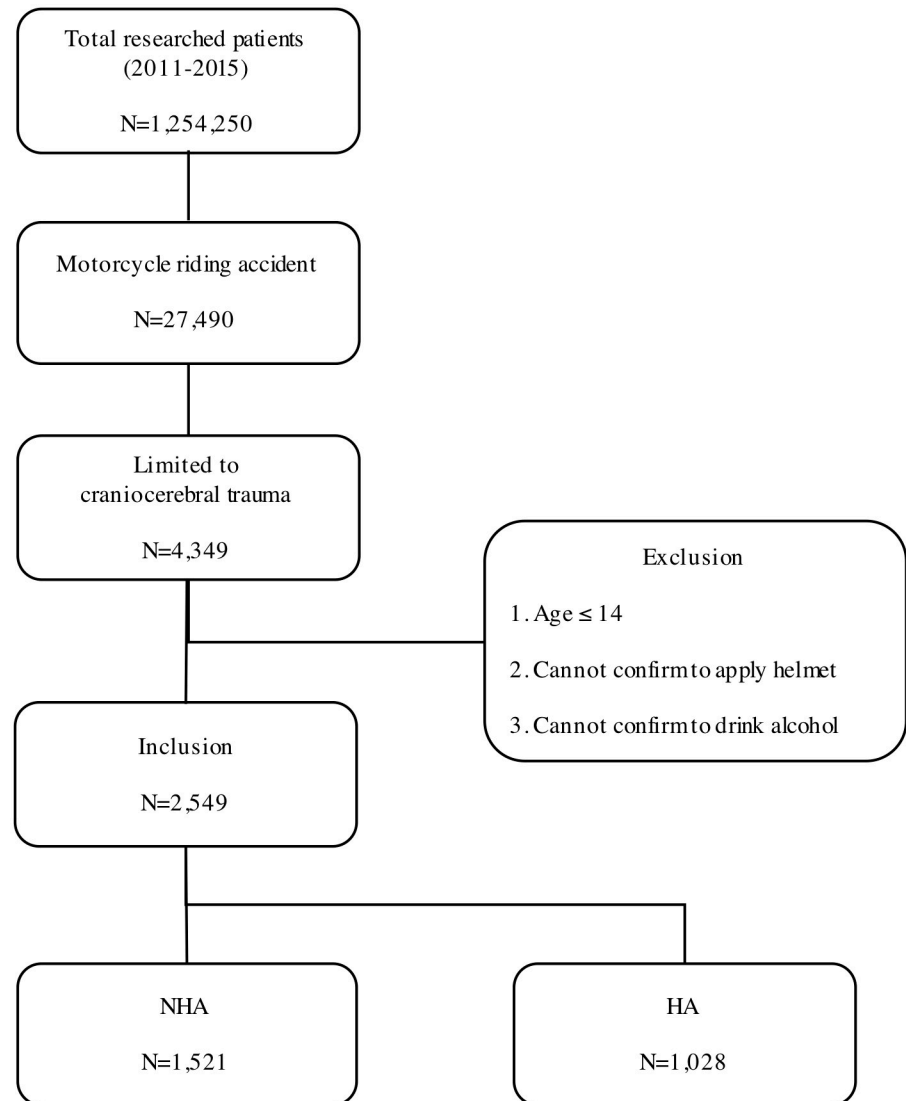
Twenty-three university hospitals have participated in the EDIIS project, and a coordinator collects data for each hospital. Prehospital data were gathered using prehospital medical records. Emergency room data were collected from the National Emergency Department Information System (NEDIS) and the patient’s medical records, admission records, and records from the patient’s admission to the intensive care unit and/or ward were collected from doctor and nurse’s medical record who were in charge of the patients.

### Ethical statement

This study’s design was reviewed and approved by the institutional review board of Gachon University Gil Hospital (GCIRB2016-242).

### Outcome measures

The primary outcome was defined as the relationship between mortality and wearing a helmet during the motorcycle accident. The secondary outcomes were defined as the relationship between wearing a helmet and the severity and/or hospitalization duration. Mortality was confirmed based on a record of death that was provided by the hospitals. Severity was calculated using the Excess Mortality Ratio-adjusted Injury Severity Score (EMR-ISS). The EMR-ISS is based on ICD-10 codes and is used to calculate the severity by summarizing the three highest



**Fig 1. Flow diagram of the study population.** NHA: Not worn a Helmet; HA: Worn a Helmet.

<https://doi.org/10.1371/journal.pone.0227691.g001>

squares of points (from 1 to 5) for various body parts (head, neck, torso, upper extremity, lower extremity, and non-traumatic injury [e.g., drowning]) [6][7]. Duration of hospitalization was defined as the time from the admission to the first instance of discharge, transfer, or death.

### Statistical analysis

Continuous variables were reported as mean and standard deviation or median and interquartile range (IQR). Student's *t*-test was used to analyze normally distributed continuous variables and the Wilcoxon rank-sum test was used to analyze non-normally distributed continuous variables. Categorized variables were analyzed using the chi-square test. Propensity score matching (PSM) were used to evaluate the relationship between wearing a helmet and mortality. We used logistic regression to create a multivariate model to control for underlying confounders. Variables inserted in the full model were determined to be  $p < 0.20$  in univariate analysis, or to be considered clinically important by the authors. We performed multivariate

logistic regression with backward elimination through likelihood-ratio tests and used the Hosmer-Lemeshow goodness-of-fit test to assess overall model performance of mortality. The PSM was used to adjust for differences in the HA and NHA groups' demographic and general characteristics, such as age, sex, education, type of insurance, route of hospital admission, alcohol consumption, driver or passenger status, and time of the accident. Differences with a *P*-value of  $<0.05$  were considered statistically significant, and all analyses were performed using STATA software (version 13.0).

## Results

During the 5-year study period, the EDIIS database contained records from 1,254,250 patients, although only 2,549 patients were considered eligible for our analyses. The 2,549 patients were categorized according to whether or not they had been wearing a helmet during the accident, and the two groups' characteristics are shown in [Table 1](#). The patients included a greater proportion of male patients, and male patients were significantly more common in the HA group, compared to the NHA group ( $P = 0.002$ ). In addition, the NHA group was noticeably younger than the HA group (mean age: 39.2 years vs. 41.9 years). The NHA group also included a greater proportion of individuals who had consumed alcohol. The NHA group also included a greater proportion of passengers, compared to the HA group (13.3% vs. 3.7%). The NHA tended to be riding their motorcycle between midnight and 6:00 AM. The two groups exhibit similar education levels and types of insurance.

The univariate analyses revealed differences between the two groups in most clinical variables ([Table 2](#)). For example, the NHA group exhibited lower values for systolic blood pressure (SBP), diastolic blood pressure (DBP), and Glasgow coma scale (GCS). The NHA group also exhibited higher values for heart rate (HR) and EMR-ISS. The NHA group exhibited a lower respiratory rate, although this difference was not significant. Finally, the NHA group exhibited a higher proportion of patients who died in the emergency room or who had prolonged hospitalization.

After we performed the PSM to adjust for the patients' demographic and general characteristics, we did not observe significant differences between the characteristics of the HA and NHA groups ([Table 3](#)). However, after the PSM, we found that there were no significant differences in the two groups' values for SBP and the DBP ([Table 4](#)). The NHA still exhibited a lower GCS, as well as higher values for HR and EMR-ISS. The NHA group also exhibited greater mortality and more prolonged hospitalizations.

We did multivariate logistic regression analyses using the original and PSM datasets ([Table 5](#)). Sex, age, Insurance, Method to come to the hospital, role of patients, alcohol ingestion, and time of accident were all used in the model. No interactions were found to have significant effects and were excluded from the final model. The final model was found to have adequate calibration ( $P = 0.99$  in original dataset,  $P = 1.00$  in PSM dataset). In both analyses, the HA exhibited a lower risk of mortality, compared to the NHA group (original dataset, odds ratio [OR]: 0.37, 95% confidence interval [CI]: 0.23–0.59; PSM dataset, OR: 0.34, 95% CI: 0.21–0.56). A greater risk of mortality was also associated with older age and patient transfer using an air ambulance. Other forms of patient transportation (e.g., a normal vehicle or walking) were associated with a lower risk of mortality. The original dataset revealed associations of a lower risk of mortality with other insurance types (e.g., private or vehicle insurance) and alcohol consumption. However, these associations were not observed when we analyzed the PSM dataset.

## Discussion

The present study aimed to evaluate whether helmet wearing was associated with mortality, severity, and hospitalization duration among patients who had only experienced a CCT after a

**Table 1. Baseline characteristics and demographics feature of patients before PSM.**

| Characteristics              | Total     |       | NHA       |       | HA        |       | P-value |
|------------------------------|-----------|-------|-----------|-------|-----------|-------|---------|
|                              | N         | 41    | N         | %     | N         | %     |         |
| Total                        | 2,549     | 100.0 | 1,521     | 100.0 | 1,028     | 100.0 |         |
| Gender                       |           |       |           |       |           |       | <0.001  |
| Male                         | 2,284     | 89.6  | 1,336     | 87.8  | 948       | 92.2  |         |
| Female                       | 265       | 10.4  | 185       | 12.2  | 80        | 7.8   |         |
| Age (Years)                  |           |       |           |       |           |       | 0.002   |
| Mean ± SD                    | 40.3±21.6 |       | 39.2±22.4 |       | 41.9±20.1 |       |         |
| Education                    | 478       |       | 306       |       | 172       |       | 0.571   |
| never go to school           | 25        | 5.2   | 13        | 4.2   | 12        | 7.0   |         |
| elementary school graduation | 79        | 16.5  | 55        | 18.0  | 24        | 14.0  |         |
| middle school graduation     | 105       | 22.0  | 73        | 23.9  | 32        | 18.6  |         |
| high school graduation       | 148       | 31.0  | 87        | 28.4  | 61        | 35.5  |         |
| technical college graduation | 5         | 1.1   | 3         | 1.0   | 2         | 1.2   |         |
| university graduation        | 39        | 8.2   | 26        | 8.5   | 13        | 7.6   |         |
| more than university         | 2         | 0.4   | 1         | 0.3   | 1         | 0.6   |         |
| unknown                      | 75        | 15.7  | 48        | 15.7  | 27        | 14.0  |         |
| Insurance                    |           |       |           |       |           |       | 0.099   |
| NHI                          | 861       | 33.8  | 535       | 35.2  | 326       | 31.7  |         |
| MAP                          | 67        | 2.6   | 44        | 2.9   | 23        | 2.2   |         |
| Etc                          | 1,619     | 63.5  | 940       | 61.8  | 679       | 66.1  |         |
| Unknown                      | 2         | 0.1   | 2         | 0.1   | 0         | 0.0   |         |
| Method to come to hospital   |           |       |           |       |           |       | 0.037   |
| Ground ambulance             | 1,959     | 76.9  | 1,204     | 79.2  | 755       | 73.4  |         |
| Air ambulance                | 8         | 0.3   | 6         | 0.4   | 2         | 0.2   |         |
| Etc                          | 580       | 22.8  | 310       | 20.4  | 270       | 26.3  |         |
| Unknown                      | 2         | 0.1   | 1         | 0.1   | 1         | 0.1   |         |
| Alcohol ingestion            |           |       |           |       |           |       | <0.001  |
| No                           | 2,164     | 84.9  | 1,236     | 81.3  | 928       | 90.3  |         |
| Yes—Only driver              | 369       | 14.5  | 269       | 17.7  | 100       | 9.7   |         |
| Yes—All rider                | 16        | 0.6   | 16        | 1.1   | 0         | 0.0   |         |
| Role of patient              |           |       |           |       |           |       | <0.001  |
| Driver                       | 2,309     | 90.6  | 1,319     | 86.7  | 990       | 96.3  |         |
| Passenger                    | 240       | 9.4   | 202       | 13.3  | 38        | 3.7   |         |
| Time of accident (24hr)      |           |       |           |       |           |       | <0.001  |
| 06–12                        | 505       | 19.8  | 296       | 19.5  | 209       | 20.3  |         |
| 12–18                        | 790       | 31.0  | 444       | 29.2  | 346       | 33.7  |         |
| 18–24                        | 717       | 28.1  | 401       | 26.4  | 316       | 30.7  |         |
| 00–06                        | 537       | 21.1  | 380       | 25.0  | 157       | 15.3  |         |

Notes: NHA: Not worn a Helmet; HA: Worn a Helmet; NHI: National Health Insurance; MAP: Medical Aid Program

<https://doi.org/10.1371/journal.pone.0227691.t001>

motorcycle accident. When we compared the HA and NHA cases, we observed that HA status was associated with a lower risk of mortality after the PSM and multivariate logistic regression analyses for adjustment of the patients' demographic and general characteristics. In addition, through the univariate analyses, we found HA status was associated with less severe injuries and shorter hospitalizations. These results agree with the findings of previous studies [4] [8–12]. Jou et al. reported that mortality was more strongly associated with NHA status, compared

Table 2. Patient status and results of treatment before PSM.

| Results                    | Total           |      | NHA             |      | HA             |      | P-value |
|----------------------------|-----------------|------|-----------------|------|----------------|------|---------|
|                            | N               | %    | N               | %    | N              | %    |         |
| SBP (mmHg)                 | 2,076           |      | 1,206           |      | 870            |      |         |
| Mean ± SD                  | 132.4±27.1      |      | 131.0±28.5      |      | 134.4±25.0     |      | 0.005   |
| DBP (mmHg)                 | 2,076           |      | 1,206           |      | 870            |      |         |
| Mean ± SD                  | 78.8±16.7       |      | 77.8±17.3       |      | 80.1±15.6      |      | 0.002   |
| Heart rate                 | 2,077           |      | 1,207           |      | 870            |      |         |
| Mean ± SD                  | 83.0±17.8       |      | 83.8±19.2       |      | 81.9±15.5      |      | 0.017   |
| Respiratory rate           | 2,075           |      | 1,206           |      | 869            |      |         |
| Mean ± SD                  | 19.0±3.9        |      | 19.0±4.2        |      | 19.1±3.4       |      | 0.587   |
| Glasgow coma scale         | 1,659           |      | 989             |      | 670            |      |         |
| Mean ± SD                  | 14.1±2.7        |      | 13.9±2.9        |      | 14.4±2.3       |      | <0.001  |
| EMR-ISS                    | 1,822           |      | 1,080           |      | 742            |      |         |
| Mean ± SD                  | 18.7±15.8       |      | 20.2±17.2       |      | 16.5±13.1      |      | <0.001  |
| Results of ER treatment    | 2,549           |      | 1,521           |      | 1,028          |      | <0.001  |
| Discharge                  | 1,324           | 51.9 | 720             | 47.3 | 604            | 58.8 |         |
| Transfer                   | 275             | 10.8 | 181             | 11.9 | 94             | 9.1  |         |
| Admission                  | 905             | 35.5 | 586             | 38.5 | 319            | 31.0 |         |
| Death                      | 43              | 1.7  | 32              | 2.1  | 11             | 1.1  |         |
| Etc                        | 2               | 0.1  | 2               | 0.1  | 0              | 0.0  |         |
| Results of admission       | 905             |      | 586             |      | 319            |      | 0.059   |
| Discharge                  | 635             | 70.2 | 402             | 68.6 | 233            | 73.0 |         |
| Transfer to other hospital | 174             | 19.2 | 107             | 18.3 | 67             | 21.0 |         |
| Death                      | 72              | 8.0  | 58              | 10.0 | 14             | 4.4  |         |
| Etc                        | 24              | 2.7  | 19              | 3.2  | 5              | 1.6  |         |
| Admission date (days)      | 1,589           |      | 1,447           |      | 142            |      |         |
| Median (IQR)               | 13.0 (7.0–24.0) |      | 14.0 (8.0–25.0) |      | 6.0 (2.0–12.0) |      | <0.001  |
| Death in hospital          | 2,549           |      |                 |      |                |      | <0.001  |
| No                         | 2,434           | 95.5 | 1,431           | 94.1 | 1,003          | 97.6 |         |
| Yes                        | 115             | 4.5  | 90              | 5.9  | 25             | 2.4  |         |

Notes: SBP: Systolic Blood Pressure; DBP: Diastolic Blood Pressure; EMR-ISS: Electrical Medical Records adjusted Injury Severity Score; ER: Emergency Room; SD: Standard Deviation; IQR: Interquartile Range

<https://doi.org/10.1371/journal.pone.0227691.t002>

to HA status (OR: 3.81, 95% CI: 3.4–4.27) [11]. Keng reported that helmets can reduce the probability of death by 71% [4]. These studies showed similar conclusions as our study. However, those data was based on the national police agency database that contains only deaths within 24 hours. The data included in our study are based on medical records, and mortality rates are based on death at the time of discharge from the hospital, allowing for a more accurate mortality analysis. Furthermore, these studies included study population independent of the injured body part by motorcycle accident, not only had CCT. Dutra et al. also analyzed head and neck injury severity using GCS, and found that NHA patients had significantly lower GCS values, compared to HA patients (GCS of <13: 13.4% vs. 50.0%,  $P < 0.001$ ) [12]. Similar to ours, this study only covered CCT, but no mortality analysis has been conducted, and the number of subjects was limited to 188.

Some previous studies have used time-series designs to compare mortality rates before and after legislation that required motorcyclists to wear helmets [13–18]. For example, Tsai and Hemenway reported a 14% decrease in overall motorcycle accident-related mortality and

Table 3. Baseline characteristics and demographics feature of patients after PSM.

| Characteristics              | Total     |       | NHA       |       | HA        |       | P-value |
|------------------------------|-----------|-------|-----------|-------|-----------|-------|---------|
|                              | N         | %     | N         | %     | N         | %     |         |
| Total                        | 2,032     | 100.0 | 1,016     | 100.0 | 1,016     | 100.0 |         |
| Gender                       |           |       |           |       |           |       | 0.934   |
| Male                         | 1,875     | 92.3  | 938       | 92.3  | 937       | 92.2  |         |
| Female                       | 157       | 7.7   | 78        | 7.7   | 79        | 7.8   |         |
| Age (Years)                  |           |       |           |       |           |       | 0.658   |
| Mean ± SD                    | 42.1±21.8 |       | 42.3±23.3 |       | 41.9±20.1 |       |         |
| Education                    | 370       |       | 201       |       | 169       |       | 0.301   |
| never go to school           | 23        | 6.2   | 11        | 5.5   | 12        | 7.1   |         |
| elementary school graduation | 64        | 17.3  | 41        | 20.4  | 23        | 13.7  |         |
| middle school graduation     | 84        | 22.7  | 52        | 25.9  | 32        | 18.9  |         |
| high school graduation       | 111       | 30.0  | 51        | 25.4  | 60        | 35.5  |         |
| technical college graduation | 4         | 1.1   | 2         | 1.0   | 2         | 1.2   |         |
| university graduation        | 25        | 6.8   | 12        | 6.0   | 13        | 7.7   |         |
| more than university         | 2         | 0.5   | 1         | 0.5   | 1         | 0.6   |         |
| unknown                      | 57        | 15.4  | 31        | 15.4  | 26        | 15.4  |         |
| Insurance                    |           |       |           |       |           |       | 0.121   |
| NHI                          | 675       | 33.2  | 357       | 35.1  | 318       | 31.3  |         |
| MAP                          | 51        | 2.5   | 28        | 2.8   | 23        | 2.3   |         |
| Etc                          | 1,306     | 64.3  | 631       | 62.1  | 675       | 66.4  |         |
| Unknown                      | 0         | 0.0   | 0         | 0.0   | 0         | 0.0   |         |
| Method to come to hospital   |           |       |           |       |           |       | 0.067   |
| Ground ambulance             | 1,528     | 75.2  | 780       | 76.8  | 748       | 73.6  |         |
| Air ambulance                | 6         | 0.3   | 4         | 0.4   | 2         | 0.2   |         |
| Etc                          | 498       | 24.5  | 232       | 22.8  | 266       | 26.2  |         |
| Unknown                      | 0         | 0.0   | 0         | 0.0   | 0         | 0.0   |         |
| Alcohol ingestion            |           |       |           |       |           |       | 0.209   |
| No                           | 1,836     | 90.4  | 919       | 90.5  | 917       | 90.3  |         |
| Yes—Only driver              | 193       | 9.5   | 94        | 9.3   | 99        | 9.7   |         |
| Yes—All rider                | 3         | 0.1   | 3         | 0.3   | 0         | 0.0   |         |
| Role of patient              |           |       |           |       |           |       | 0.571   |
| Driver                       | 1,951     | 96.0  | 978       | 96.3  | 973       | 95.8  |         |
| Passenger                    | 81        | 4.0   | 38        | 3.7   | 43        | 4.2   |         |
| Time of accident (24hr)      |           |       |           |       |           |       | 0.937   |
| 06–12                        | 424       | 20.9  | 216       | 21.3  | 208       | 20.5  |         |
| 12–18                        | 679       | 33.4  | 334       | 32.9  | 345       | 34.0  |         |
| 18–24                        | 610       | 30.0  | 304       | 29.9  | 306       | 30.1  |         |
| 00–06                        | 319       | 15.7  | 162       | 15.9  | 157       | 15.5  |         |

Notes: NHA: Not worn a Helmet; HA: Worn a Helmet; NHI: National Health Insurance; MAP: Medical Aid Program

<https://doi.org/10.1371/journal.pone.0227691.t003>

especially a 22% decrease in CCT-related mortality, after Taiwan passed a helmet wearing law in June 1997 [16]. In addition, Servadei et al. reported that the prevalence of helmet wearing increased from 20% to 96% and the incidence of CCT decreased by 31.4% after Italy passed a law in May 2003 requiring motorcyclists to wear helmets [18]. On the other hand, Banas and Knudson compared each state of United States of America that did and did not have helmet wearing laws in 2001 and found that there was a significant difference in univariate analysis

Table 4. Patient status and results of treatment after PSM, Mean ± SD.

| Results                    | Total            |      | NHA              |      | HA              |      | P-value |
|----------------------------|------------------|------|------------------|------|-----------------|------|---------|
|                            | N                | %    | N                | %    | N               | %    |         |
| SBP (mmHg)                 | 1,661            |      | 802              |      | 859             |      |         |
| Mean ± SD                  | 133.9±26.8       |      | 133.4±28.7       |      | 134.4±24.9      |      | 0.450   |
| DBP (mmHg)                 | 1,661            |      | 802              |      | 859             |      |         |
| Mean ± SD                  | 79.6±16.1        |      | 79.0±16.7        |      | 80.1±15.6       |      | 0.166   |
| Heart rate                 | 1,661            |      | 802              |      | 859             |      |         |
| Mean ± SD                  | 82.9±17.2        |      | 84.0±18.7        |      | 81.9±15.6       |      | 0.014   |
| Respiratory rate           | 1,659            |      | 801              |      | 858             |      |         |
| Mean ± SD                  | 19.1±3.9         |      | 19.0±4.4         |      | 19.1±3.4        |      | 0.989   |
| Glasgow coma scale         | 1,307            |      | 647              |      | 660             |      |         |
| Mean ± SD                  | 14.2±2.6         |      | 13.9±2.9         |      | 14.4±2.3        |      | 0.005   |
| EMR-ISS                    | 1,451            |      | 718              |      | 733             |      |         |
| Mean ± SD                  | 18.3±15.3        |      | 20.2±17.1        |      | 16.5±13.0       |      | <0.001  |
| Results of ER treatment    | 2,032            |      | 1,016            |      | 1,016           |      | <0.001  |
| Discharge                  | 1,079            | 53.1 | 482              | 47.4 | 597             | 58.8 |         |
| Transfer                   | 216              | 10.6 | 123              | 12.1 | 93              | 9.2  |         |
| Admission                  | 699              | 34.4 | 383              | 37.7 | 316             | 31.1 |         |
| Death                      | 37               | 1.8  | 27               | 2.7  | 10              | 1.0  |         |
| Etc                        | 1                | 0.1  | 1                | 0.1  | 0               | 0.0  |         |
| Results of admission       | 699              |      | 383              |      | 316             |      | 0.046   |
| Discharge                  | 487              | 69.7 | 256              | 66.8 | 231             | 73.1 |         |
| Transfer to other hospital | 140              | 20.0 | 74               | 19.3 | 66              | 20.9 |         |
| Death                      | 56               | 8.0  | 42               | 11.0 | 14              | 4.4  |         |
| Etc                        | 16               | 2.3  | 11               | 2.9  | 5               | 1.6  |         |
| Admission date (days)      | 691              |      | 635              |      | 56              |      |         |
| Median (IQR)               | 13.0 (7.0-,23.0) |      | 14.0 (8.0-,24.0) |      | 7.0 (3.0-,13.5) |      | <0.001  |
| Death in hospital          | 2,032            |      |                  |      |                 |      | <0.001  |
| No                         | 1,939            | 95.4 | 947              | 93.2 | 992             | 97.6 |         |
| Yes                        | 93               | 4.6  | 69               | 6.8  | 24              | 2.4  |         |

Notes: SBP: Systolic Blood Pressure; DBP: Diastolic Blood Pressure; EMR-ISS: Electrical Medical Records adjusted Injury Severity Score; ER: Emergency Room; SD: Standard Deviation; IQR: Interquartile Range

<https://doi.org/10.1371/journal.pone.0227691.t004>

between mortality and a helmet-wearing law, although the association was not significant in the multivariate analysis [19]. However, that study only included the amount of alcohol consumption and age as covariates in the multivariate analysis, which is not sufficient for the adjustment of the difference in patients' demographic and general characteristics.

The present study has two strengths, compared to previous studies. First, we included patients who had only craniocerebral trauma. Helmet wearing can minimize damage by protecting an individual's head during a motorcycle accident. In contrast, most previous studies included all patients regardless of their injured body parts, and these studies may have included patients who died because of traumatic injury of other body parts, which is a limitation inaccurate analysis about the effect of wearing a helmet in motorcycle accident. Second, we used PSM to adjust for the patients' demographic and clinical characteristics. The unmatched univariate analyses had significant differences in various factors, including age, alcohol consumption, and time of the accident. Previous studies have detected these associations,



Table 5. Logistic regression analysis on mortality in original and PSM dataset.

|   | Original dataset (N = 2,536) |           |         | PSM dataset (N = 2,032) |           |         |
|---|------------------------------|-----------|---------|-------------------------|-----------|---------|
|   | OR                           | 95%CI     | P value | OR                      | 95%CI     | P value |
| Helmet apply (ref = non)                                | 0.37                         | 0.23–0.59 | <0.001  | 0.34                    | 0.21–0.56 | <0.001  |
| Sex (ref = male)  | 1.01                         | 0.54–1.87 | 0.984   | 0.80                    | 0.36–1.78 | 0.589   |
| Age   | 1.03                         | 1.02–1.04 | <0.001  | 1.03                    | 1.01–1.04 | <0.001  |
| Insurance (ref = NHI)                                   |                              |           |         |                         |           |         |
| MAP   | 0.81                         | 0.19–3.56 | 0.786   | 1.02                    | 0.23–4.58 | 0.977   |
| Etc   | 1.66                         | 1.06–2.62 | 0.028   | 1.55                    | 0.93–2.56 | 0.090   |
| Method to come to the hospital (ref = Ground ambulance) |                              |           |         |                         |           |         |
| Air ambulance   | 7.96                         | 1.75–36.2 | 0.007   | 15.32                   | 2.84–82.5 | 0.001   |
| Etc   | 0.21                         | 0.09–0.48 | <0.001  | 0.11                    | 0.04–0.37 | <0.001  |
| Role of patient (ref = driver)                          | 1.06                         | 0.53–2.15 | 0.865   | 1.38                    | 0.45–4.20 | 0.569   |
| Alcohol ingestion (ref = non)                           | 0.48                         | 0.24–0.94 | 0.033   | 0.52                    | 0.20–1.32 | 0.167   |
| Time of accident(ref = 06–12)                           |                              |           |         |                         |           |         |
| 12–18   | 0.98                         | 0.60–1.60 | 0.946   | 0.80                    | 0.48–1.35 | 0.401   |
| 18–24   | 0.62                         | 0.32–1.20 | 0.153   | 0.55                    | 0.27–1.10 | 0.091   |
| 00–06   | 1.38                         | 0.73–2.60 | 0.318   | 0.88                    | 0.40–1.93 | 0.751   |

Notes: NHI: National Health Insurance; MAP: Medical Aid Program; ER: Emergency Room

<https://doi.org/10.1371/journal.pone.0227691.t005>

2011 study by Yu et al. revealed differences in age, education level, speed at the accident, and alcohol consumption when they compared the HA and NHA groups [20]. Although they adjusted for those differences using multiple logistic regressions, our study had designed with more powerful analysis by using PSM for adjustment of variables which can influence the result except wearing helmets.

South Korea has a law that requires motorcyclists to wear a helmet or other protective equipment. However, the 2014 Road Safe Annual Report indicated that only 78% of South Korean motorcyclists wore helmets, and this result was much lower than the rates of approximately 100% in European countries [21]. Therefore, both legislation and practical interventions are needed to increase the prevalence of helmet wearing in South Korea. Especially, teenagers have a very low rate of helmet wearing, and education efforts should target this age group.

The present study had several limitations. First, the data were retrospectively collected from various university hospitals and this approach is prone to selection bias, as we could not have enrolled enough data from vulnerable rural areas. Second, we could not analyze some variables that are relevant when evaluating motorcycle accidents. For example, we did not have access to data regarding the type of helmet or the motorcycle’s speed at the accident. Third, we only evaluated mortality data from hospitals that are included in the EDIIS database, and we could not analyze mortality among patients who were transferred after acute management. Finally, we only evaluated mortality and severity as clinical outcomes, and we are unable to comment on the survivors’ quality of life.

### Conclusion

Wearing a helmet may help reduce the risk of mortality from a CCT after a motorcycle accident. Furthermore, wearing a helmet was associated with reduced severity and shorter hospitalization.

## Supporting information

**S1 Table. Included ICD-10 diagnostic code of CCT.**  
(DOCX)

## Acknowledgments

The authors are grateful to the Korea Center for Disease Control and Prevention for supporting data of Emergency Department-based Injury In-depth Surveillance (EDIIS).

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## References

1. Korean National Police Agency. Traffic Accident Chart 2011–2015 [cited on 14 October 2019]. [http://taas.koroad.or.kr/sta/acs/exs/engTypical.do?menuId=WEB\\_EMP\\_TAS\\_SDB\\_PCAT](http://taas.koroad.or.kr/sta/acs/exs/engTypical.do?menuId=WEB_EMP_TAS_SDB_PCAT)
2. National Highway Traffic Safety Administration. Traffic Safety Factors. 2006. [cited 14 October 2019]. <https://www.nhtsa.gov/sites/nhtsa.dot.gov/files/documents/2015-11756.pdf>
3. World Health Organization. Helmets: a road safety manual for decision-makers and practitioners. 2006 [cited 14 October 2019]. <https://www.who.int/mediacentre/news/releases/2006/pr44/en/>
4. Keng SH. Helmet use and motorcycle fatalities in Taiwan. *Accident; Analysis and Prevention*. 2005; 37(2):349–55. <https://doi.org/10.1016/j.aap.2004.09.006> PMID: 15667822.
5. Byrnes M, Gerberich S. Motorcycle helmet use and legislation: a systematic review of the literature. *Minnesota Medicine*. 2012; 95(1):60–5. PMID: 22355917.
6. Cha MI, Kim GW, Kim CH, Choa M, Choi DH, Kim I, et al. A study on the disaster medical response during the Mauna Ocean Resort gymnasium collapse. *Clinical and experimental emergency medicine*. 2016; 3(3):165–74. <https://doi.org/10.15441/ceem.15.106> PMID: 27752635.
7. Kim J, Shin SD, Im TH, Kug Jong L, Ko SB, Park JO, et al. Development and validation of the Excess Mortality Ratio-adjusted Injury Severity Score Using the International Classification of Diseases 10th Edition. *Academic emergency medicine*. 2009; 16(5):454–64. <https://doi.org/10.1111/j.1553-2712.2009.00412.x> PMID: 19388920.
8. Tsai YJ, Wang JD, Huang WF. Case-control study of the effectiveness of different types of helmets for the prevention of head injuries among motorcycle riders in Taipei, Taiwan. *American Journal of epidemiology*. 1995; 142(9):974–81. <https://doi.org/10.1093/oxfordjournals.aje.a117746> PMID: 7572979.
9. Shankar V, Mannering F. An exploratory multinomial logit analysis of single-vehicle motorcycle accident severity. *Journal of Safety Research*. 1996; 27(3):183–94. [https://doi.org/10.1016/0022-4375\(96\)00010-2](https://doi.org/10.1016/0022-4375(96)00010-2).

10. Richter M, Otte D, Lehmann U, Chinn B, Schuller E, Doyle D, et al. Head injury mechanisms in helmet-protected motorcyclists: prospective multicenter study. *The Journal of trauma*. 2001; 51(5):949–58. <https://doi.org/10.1097/00005373-200111000-00021> PMID: 11706346.
11. Jou RC, Yeh TH, Chen RS. Risk factors in motorcyclist fatalities in Taiwan. *Traffic Injury Prevention*. 2012; 13(2):155–62. <https://doi.org/10.1080/15389588.2011.641166> PMID: 22458794.
12. Dutra VdC, Caregnato RCA, Figueiredo MRB, Schneider DdS. Craniocerebral trauma in motorcyclists: relation of helmet use and trauma severity. *Acta Paulista de Enfermagem*. 2014; 27:485–91.
13. Chenier TC, Evans L. Motorcyclist fatalities and the repeal of mandatory helmet wearing laws. *Accident; analysis and prevention*. 1987; 19(2):133–9. [https://doi.org/10.1016/0001-4575\(87\)90032-7](https://doi.org/10.1016/0001-4575(87)90032-7) PMID: 3580090.
14. Sosin DM, Sacks JJ. Motorcycle helmet-use laws and head injury prevention. *JAMA*. 1992; 267(12):1649–51. PMID: 1542175.
15. Kraus JF, Peek C, Williams A. Compliance with the 1992 California motorcycle helmet use law. *American journal of Public Health*. 1995; 85(1):96–9. <https://doi.org/10.2105/ajph.85.1.96> PMID: 7832270.
16. Tsai MC, Hemenway D. Effect of the mandatory helmet law in Taiwan. *Injury Prevention: Journal of the International Society for Child and Adolescent Injury Prevention*. 1999; 5(4):290–1. <https://doi.org/10.1136/ip.5.4.290> PMID: 10628919.
17. Ferrando J, Plasencia A, Oros M, Borrell C, Kraus JF. Impact of a helmet law on two wheel motor vehicle crash mortality in a southern European urban area. *Injury Prevention: Journal of the International Society for Child and Adolescent Injury Prevention*. 2000; 6(3):184–8. <https://doi.org/10.1136/ip.6.3.184> PMID: 11003182.
18. Servadei F, Begliomini C, Gardini E, Giustini M, Taggi F, Kraus J. Effect of Italy's motorcycle helmet law on traumatic brain injuries. *Inj Prev*. 2003; 9(3):257–60. <https://doi.org/10.1136/ip.9.3.257> PMID: 12966016.
19. Branas CC, Knudson MM. Helmet laws and motorcycle rider death rates. *Accident; analysis Prevention*. 2001; 33(5):641–8. [https://doi.org/10.1016/s0001-4575\(00\)00078-6](https://doi.org/10.1016/s0001-4575(00)00078-6) PMID: 11491244.
20. Yu WY, Chen CY, Chiu WT, Lin MR. Effectiveness of different types of motorcycle helmets and effects of their improper use on head injuries. *International journal of Epidemiology*. 2011; 40(3):794–803. <https://doi.org/10.1093/ije/dyr040> PMID: 21389036.
21. OECD/ITF. Road Safety Annual Report 2015. [cited 1 November 2016]. [https://www.itf-oecd.org/sites/default/files/docs/15irtad\\_summary.pdf](https://www.itf-oecd.org/sites/default/files/docs/15irtad_summary.pdf)