Epidemiology and Injury Characteristic Between Bicycle and Motorcycle Under 19 Population: South Korea

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Research Article

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Abstract

Objectives

Bicycles and motorcycles are the main means of transportation and leisure for those under the age of 19 in South Korea. We aimed to identify epidemiology of injuries and to determine the injury characteristics and clinical outcomes of two-wheel vehicle-related accidents in individuals under the age of 19.

Materials and methods

This was a retrospective cohort and data, acquired from the National Emergency Department Information System, was collected from 401 emergency departments (EDs) between January 2016 and December 2018. We included injured patients aged < 19 years who experienced injuries while driving two-wheeled vehicles.

Results

We enrolled 54,342 two-wheel vehicle injury patients in the study (37,410 bicycle and 16,932 motorcycle-related), of which, males comprised 86.8% (bicycle) and 94.9% (motorcycle). External and extremity injuries were the most common injuries. ED mortality was 9 (0.0%) for bicycle injury and 53 (0.3%) in motorcycle injury.

3,346 (8.9%) patients with bicycle injuries and 4,096 (24.2%) with motorcycle injuries were hospitalised. Bicycle-related injuries included fractures in the clavicle (10.9%), humerus (13.4%), and forearm (25.4%). Motorcycle-related injuries included fractures in the pelvic ring (2.0%), acetabular (0.9%), femoral (10.2%), patellar (1.8%), tibiofibular (11.5%) and foot (7.5%).

The mean ISS score of hospitalised patients was 12.0 ± 12.6 in bicycle-related injury and 17.6 ± 15.4 in motorcycle-related injury. The number of hospitalised bicycle injury patients with ISS > 16 of was 922 (27.6%), and that of hospitalised motorcycle injury patients with ISS > 16 was 1,850 (45.2%). The mean length of hospital stay (LOS) was $191.5.8 \pm 224.2$ hours in bicycle injury, while the mean LOS for motorcycle injury was 359.6 ± 416.7 hours. Hospital mortality cases were 6 (0.2%) with bicycle injury and 49 (1.2%) with motorcycle injury.

Conclusions

In the under-19 population, two-wheel vehicle-related injuries had a low mortality rate and occurred predominantly in males. Motorcycle injuries were higher in patients aged over 16 and were associated with higher ISS (>16), ICU admissions, and mortality rates than bicycle injuries. Bicycle accidents mainly caused upper limb fractures, while motorcycle accidents mainly caused lower limb fractures. Preventive measures according to each means and age group are required.

1. Introduction

Bicycles and motorcycles are the main means of transportation and leisure for those under the age of 19 in South Korea. However, this use of two-wheeled vehicles often leads to injuries. Injury is a leading cause of death and morbidity in adolescents aged 19 or younger [1]. Traffic accidents are one of the most common causes for visits to emergency departments (ED) [2]. Among them, bicycle and motorcycle crashes show different characteristics from others, such as accidents in cars. Unlike car accidents, the body is exposed directly to the external environment in two-wheeler accidents. Because bicycles and motorcycles use only two wheels for balance, they can easily turn over. In addition, they have a high probability of accidents due to the influence of road surface and environment. As a result, fatal damage, such as the head and limb injuries, may be caused [3-5].

In South Korea, the adoption of cycling has steadily increased due to increased interest in leisure activities and the government's policy to encourage the use of bicycles by developing bicycle sharing systems and bicycle lanes [6]. The overall use of motorcycles is also gradually increasing due to the demand for food-delivery services. As the use of bicycles and motorcycles increases, the number of traffic accidents related to them is also increasing. From 2010 to 2019, the number of traffic accidents involving motorcycles and bicycles increased from 17,672 to 20,898 and from 11,439 to 13,693, respectively [7].

Patients who visit the ED due to motorcycle and bicycle-related traffic accidents have various severities of injuries, and may also require hospitalisation. Although some previous studies have reported motorcycle and bicycle-related injuries, most studied elderly patients or all age groups [8-10]. Bicycles and motorcycles are easier to use for paediatric and adolescent age groups compared to other transportation because a driver's license for cars is available only after the age of 20 years in South Korea. In addition, according to the World Health Organization, road traffic injuries, including motorcycle and bicycle accidents, are consistently one of the top three causes of death for young people [11]. Traffic accidents are the second leading cause of death in South Korea under the age of 10, and the third leading cause of death under the age of 10 [12].

Previous studies comparing bicycle and motorcycle-related accidents have shown differences in injury characteristics and outcomes [10, 13, 14]. To our knowledge, no study has been reported to evaluate the injury characteristics and outcomes in bicyclists and motorcyclists under the age of 19. Paediatric and adolescent injuries are an important public health concern because of their high global impact on deaths and disabilities [15].

The purpose of this research was to identify the general epidemiology of two-wheeled vehicle-related injuries and to determine the injury characteristics and clinical outcomes of motorcycle-and cycle-related accidents in individuals younger than 19 years of age.

2. Material And Methods

2.1. Setting and Data Collection

This study used prospectively collected data from the National Emergency Department Information System (NEDIS) between January 2016 and December 2018. The NEDIS was started in 2003, and the number of participating emergency medical institutions has increased since. There are 36 regional emergency medical centres (Level 1), 117 local emergency medical centres (Level 2), and 119 local emergency medical rooms (Level 3) in South Korea. From 2016 to 2018, 399 (99.5%) emergency medical institutions participated in the NEDIS data collection [16]. The information of patients who visited emergency departments (EDs) was sent from each ED to the National Emergency Medical Centre database in real-time.

In this study, all patients under 19 years of age with traffic accident injuries were identified. In South Korea, driving licenses for cars are permitted for individuals over 20 years old, whereas driving licenses for motorcycle are permitted for individuals over 16 years old. We included patients who rode two-wheel vehicles; pedestrians hit by bicycles were excluded.

2.2. Variables and outcome Measures

NEDIS collected demographic and clinical data: age, sex, ED visit date, ED visit time, geographic location of EDs, insurance types, helmet use, means of visit, consciousness of patients in ED, systolic blood pressure, diastolic blood pressure, pulse rate, respiratory rate, diagnosis of patient in the ED, injury severity score (ISS), and dispositions after ED care (discharge, transfer to other hospital, admission to general ward (GW), or intensive care unit (ICU)). In the case of

admitted patients, the data of final diagnosis and medical results on discharge were sent. We divided ED visit date for spring (March to May), summer (June to August), autumn (September to November), and winter (December to February). The time was divided into dawn (00:00 to 05:59), morning (06:00 to 11:59), afternoon (12:00 to 17:59), and night (18:00 to 23:59).

We analysed the final diagnosis to categorise the injury (injury regions and fracture sites). Injury characteristics included the epidemiology and severity of injuries according to the Abbreviated Injury Scale (AIS) scores and Injury Severity Score (ISS) [17]. ED disposition, type of discharge on admission, duration of hospitalisation, and mortality were analysed as clinical outcomes.

2.3. Statistical Analysis

We compared and analysed the variables of the patients and injury-related characteristics between bicycle and motorcycle injuries. Categorical variables were analysed using the chi-square test. Student's t-test was used for continuous variables. We used the Statistical Package for the Social Sciences Statistics for Windows version 21 (International Business Machines Corporation, Armonk, NY, USA) for analyses, and 95% confidence intervals were considered statistically significant.

3. Results

From January 2016 to December 2018, the total number of two-wheel vehicle-related injuries under 19 population in the nationwide EDs included 37,410 bicycle-related cases and 16,932 motorcycle-related cases. (Figure 1)

In the under-19 population, bicycle patients were distributed among all ages, with peaks at 12–13 years. Motorcycle patients were mainly over 14 years of age, peaking at the age of 17, and the age graph of motorcycle users was much steeper than that of bicycle users. Motorcycle users increased geometrically above the age of 16 because the license for motorcycles in South Korea is permitted from the age of 16 years. (Figure 2)

3.1. Demographic characteristics of patients who visited the EDs with two-wheel vehicle related injury under 19 aged (Table 1)

The mean age of patients was 11.6 ± 4.0 years for bicycle injuries and 17.1 ± 1.9 years for motorcycle injuries. The incidence of injury was spring (30.4%), summer (36.3%), autumn (26.7%), and winter (6.6%) for bicycle injuries, and spring (24.2%), summer (28.3%), and autumn (27.9%), and winter (19.6%) for motorcycle injuries. Injury time was morning (3.7%), afternoon (11.4%), night (37.1%), and dawn (47.8%) for bicycle injuries and morning (20.9%), afternoon (8.5%), and night (20.6%), and dawn (50.1%) for motorcycle injuries. The use of helmets was 10.3% among patients with bicycle injuries and 46.7% among those with motorcycle injuries. Among the patients with bicycle-related injuries, 71.9% were treated with National Health Care Insurance, while 69.6% of those with motorcycle-related injuries were treated with traffic accident insurance. Amongst the patients, 25.1% of patients with bicycle injuries visited the ED by emergency call, while 62.0% of the patients with motorcycle injuries visited the ED by emergency call. Both bicycle and motorcycle accidents occurred more frequently in the urban areas (bicycle, 73.7%; motorcycle, 69.8%) than in the rural areas (bicycle, 26.3%; motorcycle, 30.2%). About 0.4% of bicycle injuries were alerted consciousness, while 3.2% of motorcycle injuries were alerted consciousness.

3.2. Comparison of injury patterns and clinical outcomes of patients under 19 years of age who visited the EDs with two-wheel vehicle related injury (Table 2)

Bicycle and motorcycle-related injuries were categorised according to AIS regions. There were 37,410 bicycle-related injuries recorded in the EDs. Of them, 6,316 (16.9%) patients had head and neck injuries, 2,492 (6.7%) had face injuries, 1,189 (3.2%) had chest injuries, 272 (0.7%) had abdomen and pelvis injuries, 21,144 (56.5%) had external injuries, 12,127 (32.4%) had upper extremities injuries, 11,161 (29.8%) had lower extremities injury, and 449 (1.2%) had spine injuries.

A total of 16,932 patients visited the ED with motorcycle-related injury, of which 4,729 (27.9%) had head and neck injuries, 1,826 (10.8%) had face injuries, 1,146 (6.8%) had chest injuries, 307 (1.8%) had abdomen and pelvis injuries, 10,257 (60.6%) had external injuries, 5,527 (32.6%) had upper extremities injuries, 9,627 (56.9%) had lower extremities injuries, and 747 (4.4%) had spine injuries.

Motorcycle injuries had more core bone fracture proportions of skull fracture (6.1%), facial fracture (20.9%), spine (2.7%), rib, sternum (2.3%) than bicycle injuries (3.6%, 16.4%, 0.8%, and 1.0%, respectively).

There were 11,629 fractures in bicycle injuries. Bicycle-related injuries included fractures in the clavicle (8.1%), humerus (5.7%), forearm (51.2%), hand (6.3%), pelvic ring (0.4%), femur (2.0%), patella (0.6%), tibia and/or fibula (0.7%), and foot (2.3%). There were 7,792 fractures in motorcycle injuries. Motorcycle-related injuries included fractures in the clavicle (4.9%), humerus (2.1%), forearm (37.0%), hand (5.3%), pelvic ring (1.2%), acetabulum (0.4%), femur (6.1%), patella (1.2%), tibia and/or fibula (3.0%), and foot (5.0%).

The mean ISS score was 5.0 ± 6.1 in bicycle injuries and 9.0 ± 10.4 in motor injuries ($P < 0.000$). ISS >16 was 2,172 (5.8%) patients with bicycle injuries and 30,278 (18.0%) with motorcycle injuries ($P < 0.000$).

Disposition of ED in bicycle injuries was discharge in 33,765 (90.3%), transfer in 258 (0.7%), ICU admission in 3,040 (8.1%), GW in admission 306 (0.8%), and death in 9 (0.0%) patients. Disposition of the ED in motorcycle injuries was discharge in 12,156 (71.8%), transfer in 574 (3.4%), ICU admission in 3,388 (20.0%), GW admission in 708 (4.2%), and death in 53 (0.3%).

This indicates that motorcycle injuries had a higher number of severe injuries that needed hospitalisation than bicycle injuries.

3.3. Injury patterns and clinical outcomes of patients who were hospitalised with two-wheeled vehicle related injury (Table 3)

We analysed two-wheel vehicle related injury patients who were hospitalised in the ICU and GW. There were 3,346 bicycle injuries and 4,096 motorcycle injuries.

Patients with bicycle injury who were hospitalised included 1,486 (44.4%) with head and neck injuries, 467 (14.0%) with face injuries, 218 (6.5%) with chest injuries, 209 (6.2%) with abdomen and pelvis injuries, 1,270 (38.0%) with external injuries were, 1,631 (48.7%) with upper extremities injuries, 1,057 (31.6%) with lower extremities injuries, 152 (4.5%) with spine injuries.

A total of 4,096 patients were hospitalised with motorcycle-related injuries. The incidence of head and neck injuries was 2,430 (59.3%); face injuries, 1,077 (26.3%); chest injuries, 587 (14.3%); abdomen and pelvis injuries, 342 (8.3%); external injuries, 1,857 (45.3%); upper extremity injuries, 1,520 (37.1%); lower extremity injuries, 3,111 (76.0%); spine injuries, 461 (11.3%).

Bicycle injuries included fractures in the skull (10.9%), face (16.1%), spine (2.2%), and sternum (2.1%). Motorcycle injuries included fractures in the skull (9.1%), face (22.1%), spine (4.9%), and sternum (3.1%).

A total of 2,564 patients with fractures were hospitalised after bicycle accidents. Bicycle-related injuries had fractures in the clavicle (10.9%), humerus (13.4%), forearm (25.4%), hand (4.3%), pelvic ring (0.9%), femur (2.8%), patella (0.5%), tibia and/or fibula (6.4%), and foot (2.8%). The 4,469 fractures in motorcycle-related accidents included fractures in the clavicle (4.4%), humerus (1.8%), forearm (14.0%), hand (5.6%), pelvic ring (2.0%), acetabulum (0.9%), femur (10.2%), patella (1.8%), tibia and/or fibula (11.5%), and foot (7.5%).

The mean ISS score for hospitalised patients was 12.0 ± 12.6 for bicycle injury and 17.6 ± 15.4 for motorcycle injury. ISS >16 was observed in 922 (27.6%) hospitalised patients after bicycle accident and 1,850 (45.2%) hospitalised patients after motorcycle accidents. The mean length of hospital stay (LOS) was 191.58 ± 224.2 hours for bicycle injury, while the mean LOS was 359.6 ± 416.7 hours for motorcycle injury. There were 6 (0.2%) hospital mortality cases with bicycle injury and 49 (1.2%) with motorcycle injury.

4. Discussion

This is the first nationwide study that analysed the characteristics of two-wheel vehicle injuries and clinical outcomes in individuals younger than 19 years in South Korea. This population-based study using the National Emergency Department Information System (NEDIS) evaluated the difference between bicycle-and motorcycle-related injuries presenting to EDs in South Korea between 2016 and 2018. This retrospective study presented the incidence of injury and fracture sites as well as the demographic characteristics of patients, and also categorised the injury region according to AIS and calculated ISS for all adolescent patients who visited the ED. We separately analysed the hospitalised patients' injury sites, fracture sites, ISS, and hospital length of stay. Previous studies have mainly focused on individual studies of bicycle or motorcycle crashes, or comparative studies targeting the elderly [8, 18], but this study compared the results of bicycle and motorcycle injuries among adolescents.

The Road Safety Report showed the road death by age group in 2018, which showed that the number of road deaths fell by 28% among 0–20 year-olds after road safety improvements [19]. Compared to other international road traffic and accident databases, adolescents have a relatively low mortality rate on Korean roads. Mortality rates ranged from 0.6 for 0–14 years to 3.7 for 21–24 years old. This may be because young people in Korea tend to drive late. In Korea, individuals above the age of 20 years can obtain driver's license for car; however, a motorcycle license is available from the age of 16 years. In this study, it can be seen that the rate of bicycle accidents and motorcycle accidents decreased and increased, respectively, when the patient age exceeded 15 years. After obtaining a motorcycle license, teenagers enjoy riding motorcycles rather than bicycles, which leads to them experiencing motorcycle-related injuries that are more severe than bicycle-related ones.

South Korea has four seasons, and this study shows that accidents occurred frequently from spring to autumn and decreased in winter. This may be due to the reduced use of two-wheel vehicles due to weather-related hinderances in winter compared to other seasons. Night and dawn periods had a large proportion of two-wheel vehicle accidents. The lack of light at night may make it difficult for other cars to notice two-wheeled vehicles or for drivers of two-wheeled vehicles to see the road surface or structures clearly [20]. In addition, there may also have been many accidents caused by drunk-driving at night and dawn. A previous study of alcohol-related motorcycle accidents also showed that the incidences of accidents due to drunken driving motorcycles were high at night and dawn [21].

Although there have been many previous studies that have proven the protective effects of helmets [22, 23], this study showed that only 10% of bicycle-injured and less than 50% of motorcycle-injured patients used helmets. A previous study on bicycle-related injury in the ED in South Korea during 2012–2014 showed that the use of helmet was nearly 20% [18], but decreased in 2016–2018 during the current study period. The helmet use rate of motorcycles was 85% in 2018 surveyed by the Korea Road Traffic Authority (KoROAD). There was a large difference between KoROAD and this

study in the ratio of individuals wearing helmets. There are two possible reasons for this. The first is that KoROAD's measurements were based on the road around traffic accident cases or on specific samples. The second reason is that this study may not reflect the overall helmet usage rate in the population as we only considered the helmet usage rate of patients using two-wheeled vehicles who visited the ED after injury. [19] If the actual motorcycle rider's helmet wearing rate was 85%, the helmet usage rate of the injury group visiting the ED was very low.

This study showed that 86.8% of bicycle-related injuries and 94.9% of motorcycle-related injuries were in males. Previous studies have shown that men had a higher proportion of injuries than females [24-26].

An ISS greater than 16 was more frequent in motorcycle than bicycle injuries, which means more severe injuries that need to be hospitalised in motorcycle injuries. We analysed two-wheeled vehicle related injury patients who were admitted to the ICU and GW. Bicycle injuries had more upper extremity injuries than motorcycle injuries. (32.4% vs. 29.8%), and less lower extremity injuries (32.6% vs. 56.9%) in the ED. Even in hospitalised patients, bicycle injuries have more upper extremity injuries than motorcycle injuries (48.7% vs. 37.1%), and less lower extremity injuries (31.6% vs. 76.0%).

There was a report about the orthopaedic characteristics of bicycle injury in South Korea. It revealed that fractures of the forearm and shoulder were the most common orthopaedic injuries. This was a study of the entire age of a single institution [27]. The majority of childhood traffic accidents were mild and required only minor treatment [26]. In this study, there was a low mortality rate. However, motorcycle mortality was 7 times higher than that of bicycle injuries. We investigated both the disposition and clinical outcomes at both points during discharge from the ED and discharge after hospitalisation. The reason was that it was difficult to determine the overall mortality rate and the injury that would require hospitalisation if only the ED was reported. The national data used in this study were transmitted upon evacuation from the ED and upon discharge after hospitalisation. The average ISS was higher for motorcycle-related injuries, and patients with ISS > 16 were higher as well. This means that even if the same region is injured, the severity is higher in motorcycle-related accidents. Patients with motorcycle accidents were more severe than bicycles, so hospital LOS and mortality rates were also higher. Comparing the entire patient visiting the ED with the hospitalised patient, the frequency order of the injured area was different. Many of the hospitalised patients were injured in the head and neck, face, and lower extremities. These injuries require hospitalisation and affect the increase in ISS. Lower extremity injury was higher in motorcycle accidents than in bicycle accidents. It could have a negative impact on return to daily life and quality of life. Zibung et al. reported that more than 70% of bicycle trauma patients suffered physically for over six months after their crash, even though the trauma was mild. Cervical and facial injuries and ISS >15 were the risk factors for impaired quality of life. [28] Patients experiencing motorcycle accidents are more vulnerable to lower extremity injuries than those experiencing bicycle accidents. Kohler et al. reported that trauma to the lower extremities led to physical distress and ongoing social and economic costs, while injuries affecting mobility have widespread levels of injuries and economic consequences for the patient and affected family. [29] One year post injury in patients with lower extremity injury reported limitations in walking (46%), inability to return to work (22%), depression (39%), and post-traumatic stress disorder (18%). Long-lasting physical and psychological burdens may impede recovery and alter the lifestyle of patients with lower extremity injury. [30] In particular, major trauma in adolescents was associated with significant and marked deficits in quality of life throughout the 24-month follow-up period. [31]

We could suggest some beneficial ideas to adolescents who ride two-wheel vehicles, depending on our study. In South Korea, helmets have become compulsory for users of all motorised two-wheelers since 2007. Head and neck injuries may require hospitalisation and have a poor prognosis. However, the rate of wearing a helmet on motorcycles and bicycles have been low. Helmets should be recommended and mandatory for both bicycle and motorcycle riders. In addition, two-wheel vehicle riders are recommended to use body protectors. Upper and lower extremity injuries were the

most common injuries, so using arm, knee, and joint protectors may help to prevent extremity fractures. In addition, since most patients visit the ED at night, wearing protective gear with reflective lighting may help to prevent two-wheel vehicle crashes.

There are some limitations to our study. In this study, information on weather and road types were not taken into consideration. These factors could have affected the severity of injury. We also had no information on the patients' medical history and other laboratory tests that could affect the patient's outcome. Another limitation is that we did not investigate whether motorcycle usage was for leisure or livelihood. Information on several known and potential risk factors that could affect the severity, such as the speed at the time of the accident, the location of the accident, the weather, the license acquisition status, and engine displacement, could not be obtained. In addition, mopeds on the bike are not coded separately but are coded as bikes. Moreover, minor injuries could be treated at the outpatient clinic outside the ED, so this study could not represent all of the two-wheel vehicle injuries.

5. Conclusions

In the under 19 population, two-wheeled vehicle-related injuries had a very low mortality rate and occurred predominantly among males. Motorcycle injuries increased dramatically among individuals aged over 16 years, which is the required age for obtaining a license, and had a higher ISS (> 16), intensive care unit admission rate, and mortality rate than bicycle injuries. Bicycle accidents predominantly caused upper limb fractures, whereas motorcycle accidents predominantly caused lower limb fractures. Injuries in adolescents may have long-lasting physical and psychological problems. Preventive measures according to the means and the age group are required. In order to reduce injuries, adequate education regarding accidents and the importance of wearing protective devices should be provided to the youth when they obtain a motorcycle license.

Declarations

Ethics approval

This study was approved by the Institutional Review Board (IRB) of Ewha Womans' University Mok-dong hospital (IRB No. 2020-11-034) and was approved by the ethical principles of the Declaration of Helsinki. Informed consent was waived by the IRB because the study was retrospective in nature and patient information was anonymised before the analysis.

Consent to publish

NA

Availability of data and materials

The datasets used and/or analysed during the current study available from the corresponding author on reasonable request.

Competing interests

The authors declare that they have no competing interests.

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Author contributions

HY, SB wrote the first draft. JIL and DHL designed, performed the experiments, analyzed the data, prepared figures and/or tables. JIL and DHL are equally contributed to this work as corresponding authors. All authors approved the final draft.

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References

1. Kaplan J, Thacker S: Working to prevent and control injuries in the year 2000: the injury fact book for the year 2000. *Atlanta, GA: National Center for Injury Prevention and Control, Centers for Disease Control and Prevention* 2000.
2. DiMaggio CJ, Avraham JB, Lee DC, Frangos SG, Wall SP: The Epidemiology of Emergency Department Trauma Discharges in the United States. *Acad Emerg Med* 2017, 24(10):1244-1256.
3. Güngör F, Oktay C, Topaktaş Z, Akçimen M: [Analysis of motorcycle accident victims presenting to the emergency department]. *Ulus Travma Acil Cerrahi Derg* 2009, 15(4):390-395.
4. Youl Won K, Sung Hwa L, Soon Chang P, Young Mo C, Il Jae W, Byung Kwan B, Sung Wook P, Sang Kyoon H, Dae Woo K, Hyung Bin K: Early Predictors of Severe Injury in Motorcycle Crashes. *Journal of the Korean Society of Emergency Medicine* 2017, 28(4):327-333.
5. Su Jeong S, Hyun Wook R, Jung Bae P, Kang Suk S, Jae Myung J, Dong Chan P, You Ho M: Characteristics and Risk Factors of Bicycle Injury. *Journal of the Korean Society of Emergency Medicine* 2010, 21(3):328-334.
6. Report of cycling infrastructure by local government. *The Korea Transport Institute* 2019.
7. Report of traffic Accidents statistics. *Korea Transportation Safety Authority* 2019.
8. Cheong HS, Tham KY, Chiu LQ: Injury patterns in elderly cyclists and motorcyclists presenting to a tertiary trauma centre in Singapore. *Singapore Med J* 2020.
9. Hsieh CH, Liu HT, Hsu SY, Hsieh HY, Chen YC: Motorcycle-related hospitalizations of the elderly. *Biomed J* 2017, 40(2):121-128.
10. Liu HT, Rau CS, Liang CC, Wu SC, Hsu SY, Hsieh HY, Hsieh CH: Bicycle-related hospitalizations at a Taiwanese level I Trauma Center. *BMC Public Health* 2015, 15:722.
11. Global status report on road safety 2018. *World health organization*.
12. The statistics of Cause of Death [<http://kostat.go.kr/wnsearch/search.jsp>]
13. Pai CW, Lin HY, Tsai SH, Chen PL: Comparison of traffic-injury related hospitalisation between bicyclists and motorcyclists in Taiwan. *PLoS One* 2018, 13(1):e0191221.
14. Pai CW, Chen YC, Lin HY, Chen PL: A population-based case-control study of hospitalisation due to head injuries among bicyclists and motorcyclists in Taiwan. *BMJ Open* 2017, 7(11):e018574.
15. Chandran A, Hyder AA, Peek-Asa C: The global burden of unintentional injuries and an agenda for progress. *Epidemiologic reviews* 2010, 32(1):110-120.
16. Statistical yearbook of emergency medical service [https://www.e-gen.or.kr/nemc/statistics_annual_report.do]

17. MacKenzie EJ, Shapiro S, Eastham JN: The Abbreviated Injury Scale and Injury Severity Score: levels of inter-and intrarater reliability. *Medical care* 1985;823-835.
18. Kim YJ, Seo DW, Lee JH, Lee YS, Oh BJ, Lim KS, Kim WY: Trends in the incidence and outcomes of bicycle-related injury in the emergency department: A nationwide population-based study in South Korea, 2012-2014. *PLoS One* 2017, 12(7):e0181362.
19. Forum IT: International Transport Forum: Road Safety Annual Report 2019; Korea. In: . 2020.
20. Ikpeze TC, Glaun G, McCalla D, Elfar JC: Geriatric cyclists: assessing risks, safety, and benefits. *Geriatric orthopaedic surgery & rehabilitation* 2018, 9:2151458517748742.
21. Liu HT, Liang CC, Rau CS, Hsu SY, Hsieh CH: Alcohol-related hospitalizations of adult motorcycle riders. *World J Emerg Surg* 2015, 10(1):2.
22. Olivier J, Creighton P: Bicycle injuries and helmet use: a systematic review and meta-analysis. *Int J Epidemiol* 2017, 46(1):278-292.
23. Park GJ, Shin J, Kim SC, Na DS, Lee HJ, Kim H, Lee SW, In YN: Protective effect of helmet use on cervical injury in motorcycle crashes: A case-control study. *Injury* 2019, 50(3):657-662.
24. Klin B, Rosenfeld-Yehoshua N, Abu-Kishk I, Efrati Y, Kozler E, Jeroukhimov I, Eshel G, Lotan G: Bicycle-related injuries in children: disturbing profile of a growing problem. *Injury* 2009, 40(9):1011-1013.
25. Hefny AF, Eid HO, Grivna M, Abu-Zidan FM: Bicycle-related injuries requiring hospitalization in the United Arab Emirates. *Injury* 2012, 43(9):1547-1550.
26. Nurmi M, Järvelä S, Mattila VM, Luoto TM, Pauniahho S-L: Paediatric traffic accidents—current epidemiological trends at a Finnish university hospital. *Injury* 2020, 51(10):2179-2185.
27. Heo YM, Yi JW, Oh BH, Jun JB, Cho HJ, Kim TG: Study on the orthopedic characteristics of bicycle injury patients. *The Korean journal of sports medicine* 2018, 36(1):1-6.
28. Zibung E, Riddez L, Nordenvall C: Impaired quality of life after bicycle trauma. *Injury* 2016, 47(5):1078-1082.
29. Kohler RE, Tomlinson J, Chilunjika TE, Young S, Hosseinipour M, Lee CN: "Life is at a standstill" Quality of life after lower extremity trauma in Malawi. *Quality of life research* 2017, 26(4):1027-1035.
30. Read KM, Kufera JA, Dischinger PC, Kerns TJ, Ho SM, Burgess AR, Burch CA: Life-altering outcomes after lower extremity injury sustained in motor vehicle crashes. *Journal of Trauma and Acute Care Surgery* 2004, 57(4):815-823.
31. Holbrook TL, Hoyt DB, Coimbra R, Potenza B, Sise MJ, Sack DI, Anderson JP: Trauma in adolescents causes long-term marked deficits in quality of life: adolescent children do not recover preinjury quality of life or function up to two years postinjury compared to national norms. *Journal of Trauma and Acute Care Surgery* 2007, 62(3):577-583.

Tables

Table 1. Demographic characteristics of patients who visited the emergency department with two-wheeled vehicle-related injury

Variable	Bicycle		Motorcycle		Total	<i>p-value</i>
Number of injury cases	37,410	68.8%	16,932	31.2%	54,342	
Age	11.6±4.0		17.1±1.9		13.3±4.3	0.000
Sex, male	32,478	86.8%	16,076	94.9%	48,554	0.000
Season of injury						0.000
Spring	11,373	30.4%	4,099	24.2%	15,472	
Summer	13,585	36.3%	4,793	28.3%	18,378	
Autumn	9,997	26.7%	4,724	27.9%	14,721	
Winter	2,455	6.6%	3,316	19.6%	5,771	
Time of injury						0.000
Morning (06:00~11:59)	1,379	3.7%	3,534	20.9%	4,913	
Afternoon (12:00~17:59)	4,279	11.4%	1,435	8.5%	5,714	
Night (18:00~23:59)	13,883	37.1%	3,484	20.6%	17,367	
Dawn (00:00~05:59)	17,869	47.8%	8,479	50.1%	26,348	
Helmet use						0.000
Yes	3,856	10.3%	7,903	46.7%	11,759	
No	33,554	89.7%	9,029	53.3%	42,583	
Insurance type						0.0001
National health care	26,893	71.9%	4,120	24.3%	31,013	
Traffic accident insurance	9,202	24.6%	11,792	69.6%	20,994	
Industrial accident insurance	2	0.0%	70	0.4%	72	
Medicaid	883	2.4%	441	2.6%	1,324	
Others	430	1.1%	509	3.0%	939	
Means of visit						0.0001
911	9,371	25.1%	10,499	62.0%	19,870	
hospital based ambulance	358	1.0%	595	3.5%	953	
Self-visit	27,456	73.4%	5,730	33.8%	33,186	
Others	255	0.7%	108	0.6%	363	
Area						0.0001
Urban area	27,561	73.7%	11,825	69.8%	39,386	
<i>number of urban injuries /100,000 population</i>	133.2		57.2			
Rural area	9,849	26.3%	5,107	30.2%	14,956	

<i>number of rural injuries /100,000 population</i>	111.2		57.6			
Conciousness						0.0001
Alert	37,254	99.6%	16,394	96.8%	53,648	
Altered	156	0.4%	538	3.2%	694	
Systolic blood pressure (mmHg)	103.4±16.8		126..4±27.6		124.6±43.9	0.0001
Diastolic blood pressure (mmHg)	68.8±11.0		75.5±19.4		74.9±30.1	0.109
Pulse rate (beats/min)	86.0±25.8		86.2±19.8		84.4±20.8	0.0001
Respiration rate (/min)	19.3±6.6		19.2±8.4		19.4±6.0	0.606
Body temperature (°C)	36.1±2.6		36.4±3.4		36.4±2.8	0.0001

Table 2. Injury patterns and clinical outcomes of patients who visited the emergency department with two-wheeled vehicle-related injury

Variable		Bicycle		Motorcycle		Total		<i>p-value</i>
		N	%	N	%	N	%	
Number of patients in ED		37,410		16,932		54,342		
Region of injury	Head and neck	6,316	16.9%	4,729	27.9%	11,045	20.3%	
	Face	2,492	6.7%	1,826	10.8%	4,318	7.9%	
	Chest	1,189	3.2%	1,146	6.8%	2,335	4.3%	
	Abdomen and pelvic contents	272	0.7%	307	1.8%	579	1.1%	
	External	21,144	56.5%	10,257	60.6%	31,401	57.8%	
	Extrimities and pelvic girdle	54	0.1%	124	0.7%	178	0.3%	
	Upper extremities	12,127	32.4%	5,527	32.6%	17,654	32.5%	
	Lower extremities	11,161	29.8%	9,627	56.9%	20,788	38.3%	
	Spine	449	1.2%	747	4.4%	1,196	2.2%	
		15	0.0%	25	0.1%	40	0.1%	
Number of fractures		11,629		7,792		19,421		
Fracture site	Skull	418	3.6%	474	6.1%	892	4.6%	
	Facial	1,909	16.4%	1,631	20.9%	3,540	18.2%	
	Spine	96	0.8%	207	2.7%	303	1.6%	
	Rib, sternum	120	1.0%	176	2.3%	296	1.5%	
	Scapula	90	0.8%	75	1.0%	165	0.8%	
	Clavicle	939	8.1%	379	4.9%	1,318	6.8%	
	Humerus	660	5.7%	166	2.1%	826	4.3%	
	Forearm	5,953	51.2%	2,886	37.0%	8,839	45.5%	
	Hand	736	6.3%	416	5.3%	1,152	5.9%	
	Pelvic ring	44	0.4%	91	1.2%	135	0.7%	
	Acetabulum	4	0.0%	30	0.4%	34	0.2%	
	Femur	238	2.0%	477	6.1%	715	3.7%	
	Patella	74	0.6%	97	1.2%	171	0.9%	
	Tibia/fibula	85	0.7%	237	3.0%	322	1.7%	

	Foot	263	2.3%	450	5.8%	713	3.7%	
ISS (mean±SD)		5.0±6.1		9.0±10.4		6.2±7.9		0.000
ISS>16		2,172	5.8%	3,078	18%	5,250	9.70%	0.000
ED disposition	Discharge	33,765	90.3%	12,156	71.8%	45,921	84.5%	
	Transfer	258	0.7%	574	3.4%	832	1.5%	
	ICU admission	3,040	8.1%	3,388	20.0%	6,428	11.8%	
	GW admission	306	0.8%	708	4.2%	1,014	1.9%	
	Death	9	0.0%	53	0.3%	62	0.1%	
	Others	27	0.1%	50	0.3%	77	0.1%	

Table 3. Injury patterns and clinical outcomes of patients who were hospitalised after two-wheeled vehicle related injury

Variable		Bicycle		Motorcycle		Total		p-value
Number of Hospitalization patients		3,346		4,096		7,442		
Region of injury	Head and neck	1,486	44.4%	2,430	59.3%	3,916	52.6%	0.000
	Face	467	14.0%	1,077	26.3%	1,544	20.7%	
	Chest	218	6.5%	587	14.3%	805	10.8%	
	Abdomen and pelvic contents	209	6.2%	342	8.3%	551	7.4%	
	External	1,270	38.0%	1,857	45.3%	3,127	42.0%	
	Extremities and pelvic girdle	28	0.8%	131	3.2%	159	2.1%	
	Upper extremities	1,631	48.7%	1,520	37.1%	3,151	42.3%	
	Lower extremities	1,057	31.6%	3,111	76.0%	4,168	56.0%	
	Spine	152	4.5%	461	11.3%	613	8.2%	
	Unspecified	6	0.2%	16	0.4%	22	0.3%	
Number of Fractures		2,564		4,469		7,033		0.000
Fracture site								
	Skull	280	10.9%	407	9.1%	687	9.8%	
	Facial	414	16.1%	989	22.1%	1,403	19.9%	
	Spine	57	2.2%	219	4.9%	276	3.9%	
	Rib, sternum	54	2.1%	139	3.1%	193	2.7%	
	Scapula	30	1.2%	52	1.2%	82	1.2%	
	Clavicle	279	10.9%	195	4.4%	474	6.7%	
	Humerus	344	13.4%	79	1.8%	423	6.0%	
	Forearm	652	25.4%	626	14.0%	1,278	18.2%	
	Hand	109	4.3%	250	5.6%	359	5.1%	
	Pelvic ring	23	0.9%	88	2.0%	111	1.6%	
	Acetabulum	3	0.1%	39	0.9%	42	0.6%	
	Femur	71	2.8%	454	10.2%	525	7.5%	

	Patella	12	0.5%	82	1.8%	94	1.3%	
	Tibia/fibula	163	6.4%	513	11.5%	676	9.6%	
	Foot	73	2.8%	337	7.5%	410	5.8%	
ISS (mean±SD)		12.0±12.6		17.6±15.4		15.0±14.5		0.000
ISS>16		922	27.6%	1,850	45.2%	2,772	37.2%	
Clinical outcomes								
	Hospital LOS (hours)	191.5.8±224.2		359.6±416.7		283.7±353.4		0.000
	In-hospital mortality	6	0.2%	49	1.2%	55	0.7%	0.000

Figures

Figure 1

Flow gram

Figure 2

Incidence of two-wheeled vehicle injury by age