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Helmet Usage Reduces Serious Head Injury Without Decreasing Concussion After Bicycle Riders Crash

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ABSTRACT

Background: The importance of bicycle helmets in reducing injuries is unclear. Our center receives a disproportionate number of bicycle crash victims. We sought to evaluate the types of injuries observed and the role of helmets in reducing head injuries.
Materials and methods: We evaluated demographic data and compared injuries between bicycle riders that crashed with and without helmets over a 9-year period. Categorical variables were compared using linear regression methods and nominal variables using ANOVA. Differences were considered significant for $P \leq 0.05$.
Results: There were 906 patients evaluated, 701 with helmets (77%) and 205 (23%) without helmets. The mean Injury Severity Score was 9.3 ± 6.4. The most common injuries were concussion ($n = 385$), rib fractures ($n = 154$), clavicle fractures ($n = 139$), facial fractures ($n = 102$), and cervical spine fractures ($n = 89$). There was no significant difference in the number of patients with a concussion in riders with or without helmets, [299/701, 42.6% *versus* 86/205, 42.0%, respectively, ($P =$ NS)]. In helmet *versus* no helmet riders, there were significantly fewer patients with facial fractures, [67/701, 9.5%, *versus* 35/205, 17.0%, respectively, ($P = 0.003$)], skull fractures [8/701, 1.1% *versus* 9/205, 4.4%, respectively, ($P = 0.003$)], and serious head injuries [6/701, 0.85% *versus* 8/205, 3.9%, respectively, ($P = 0.002$)].
Conclusions: Helmeted patients involved in bicycle crashes are less likely to sustain a serious head injury, a skull fracture, or facial fractures compared to riders without helmets.

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The most common injury in patients with a bicycle crash is a concussion. Helmets did not prevent concussion after bicycle rider's crash in our patient population.

Introduction

At our American College of Surgeons (ACS) verified Level III Trauma Center, we see a disproportionate number of bicycle crashes, as a percentage of total trauma patients, compared to other trauma centers.[1] On average, our center sees a six-fold increase in bicycle crashes as a percent of total trauma patients compared to other centers. The reasons for this increase is beyond the scope of this study although the popularity of bicycling among Marin County residents, and the number of visitors that rent bicycles, cross the Golden Gate Bridge from San Francisco, and then fail to realize the steep descent down to the town of Sausalito clearly contribute to this injury pattern. We evaluated the injuries seen in this population, the relationship of the injuries and the use of bicycle helmets, and the propensity to use bicycle helmets in riders in Marin County.

The importance of wearing a helmet is not debatable. Despite the importance of wearing bicycle helmets, in many reported series, less than one-quarter of riders injured in bicycle crashes are reported to have worn helmets, as low as 14% of teenagers in one large study.[2] Additionally, most studies do not differentiate between minor head injuries, concussion, and major head injuries like subdural hematomas, epidural hematomas, subarachnoid bleeds, and skull fractures. The role of helmets in preventing facial fractures also depends on how these injuries are described.

Materials and methods

Marin Health Medical Center (MHMC, formerly known as Marin General Hospital) is the only Trauma Center in Marin County and is verified as a Level III Trauma Center by the American College of Surgeons (ACS). Verification was first received in 2009, and the center has been verified since 2009. The patients were entered into a relational database from January 1, 2007, through December 31, 2015. We evaluated demographic data and compared injuries between bicycle riders that crashed with and without helmets. The cause of the crash was not included in the evaluation. We did not differentiate between local riders and visitors, although it is important to consider that all bicycle rental agencies in the area require the renters to wear helmets. We did not include the number of rib fractures; rather, we just included any patient with one or more rib fractures. We likewise did not include the numbers of pelvic fractures in each patient nor whether or not the pelvic fractures were stable or unstable. Multiple fractures were considered as patients with different areas of fracture rather than multiple fractures in the same system. Any patient with concussive symptoms without CT evidence of an intracranial bleed or injury was considered to have a concussion. Concussive symptoms include confusion and amnesia, with or without loss of consciousness. Additional concussive symptoms include, though are not limited to, repetitive questioning, loss of memory for the event, other memory loss, including short- or long-term memory loss, headache, dizziness, and nausea and vomiting. Patients met the criteria for concussion, if they had one or more of the above symptoms of confusion and amnesia, repetitive questioning, memory loss, headache, and dizziness with or without nausea and vomiting. While we recognize that this is a subjective finding, it is also the accepted definition of concussion as there are no definitive findings on radiological studies. The patients are captured in our database from ICD coding of injuries. Patients were considered to have major head injuries with CT confirmed subdural hematoma, epidural hematoma, or subarachnoid, or intracerebral bleed. A skull fracture was considered a major head injury, although we separated out these injuries from parenchymal head injuries. We did not correlate speed with injuries. In only 175/906 (18%) of the patients was the speed recorded. We believe that because the speed is very subjective, it is not useful to identify speed as a variable. Most riders have no idea how fast they were riding when they crashed, particularly since more than 40% had a concussion. Additionally, because the range of speed entered in our database ranged from 5 to 40 miles per hour, and the distribution of speed was similar across the range reported, the significance in any difference would be questionable at best. In the studies that we reviewed for this project, we likewise did not find the speed of the bicycle rider as a variable when comparing injuries between riders with helmets and those without helmets. Additionally, we found no studies that compared the types of bicycles used by the riders as a comparison in the analysis of injuries sustained in helmeted riders. Categorical variables were compared using linear regression methods and nominal variables using ANOVA. Differences were considered significant for P values ≤ 0.05. The patients in our database are de-identified. Because the patients are de-identified, informed consent was waived. This study was approved by our Institutional Review Board.

Results

During the time period of evaluation, there were 7098 patients entered into our Trauma Registry. Of these patients, there were 906 (13%) patients evaluated that were injured riders after bicycle crashes. There were 683 men (75.4%) and 223 women (24.6%). The mean age was 42 $\pm$ 6 y, the mean initial Glasgow Coma Scale score was 14.7 $\pm$ 0.85, and the mean Injury Severity Score was 9.3 $\pm$ 6.4. The mean hospital length of stay (LOS) for admitted patients was 2.7 $\pm$ 3.8 d. The mean LOS for patients wearing helmets as compared to those not wearing helmets was 2.6 $\pm$ 2.6 *versus* 3.1 $\pm$ 6.2 d respectfully, (P = NS). There were 701 (77%) patients wearing helmets and 205 (23%) patients not wearing helmets. There were no significant differences in the age of the riders with or without helmets, 42 y *versus* 40 y. Additionally the numbers of riders on any type of anticoagulation was not significantly different, 3.1% *versus* 2.4% (22/701 *versus* 5/205). We did not include the type of bicycle in our database. There was no difference in the mechanism of injury between the groups. Table 1 shows the injuries in the patients from bicycle crashes without consideration of whether or not they were wearing a helmet. By far, the most common injury was a concussion, seen in 42% of our patients. Other common injuries included rib, clavicle, cervical, and facial fractures. In patients with fractures, 15% had multiple areas of fractures. Less common injuries included pelvic fractures, internal injuries, femur fractures, and spinal cord injuries. Skull fractures were seen on only 2% of patients and other major head injuries in 1.5% of patients. Table 2 demonstrates major injuries in riders wearing helmets as compared to those not wearing helmets. Interestingly, there were no differences seen in concussion injuries in bicycle riders that crash wearing helmets as compared to those not wearing helmets, 42% in both groups. Significant differences were seen in patients with facial fractures, 9.5% *versus* 17% ($P = 0.003$) in helmeted riders, as compared to riders without helmets. The number of skull fractures (1.1% *versus* 4.4%, [$P = 0.003$]respectively) and other major head injuries (0.85% *versus* 3.9%, [$P = 0.002$] respectively) were also significantly lower in bicycle riders that crash were wearing a helmet as compared to those not wearing a helmet.

Discussion

The role helmet usage plays in reducing injuries after bicycle riders crash is clear from many published series.[2-9] The injuries seen, the reduction of severity of different areas injured, and the severity of injuries encountered is less clear. The most common injury in our patients was a concussion, and helmets usage in our patients did not prevent concussion. In our study, 40% of bicycle riders that crashed had a concussion. Another study reported a higher incidence of concussion in children that were wearing a helmet, 65% as compared to only 44% that were not wearing a helmet[(5)]. This difference was statistically significant, although the number of helmeted riders was only 15% (31 patients in total). In this study, the difference may be in how the concussion is reported as they reported concussion alone in helmeted riders as 65% as compared to 44% in non-helmeted riders, suggesting that the bicycle riders that crashed without a helmet had multiple injuries more often than the helmeted riders. Regardless, the helmeted riders had an incidence of concussion reported at 65%, which was much higher than in our series. Other studies have shown a reduction in head injuries[6,9,10] though most of these studies do not differentiate between minor and major head injuries. Some studies have shown no difference in head injury[5,6] when concussion was included as a head injury, although in the former study,[5] the helmeted patients were less likely to have a skull fracture although more likely to have a concussion. Overall the proportion of riders with head injuries was 68% *versus* 61% ($P = NS$) in helmeted *versus* nonhelmeted riders, respectively, with serious head injuries less common in helmeted riders. In these studies, a reduction in major head injury *versus* concussion was seen in helmeted bicycle riders that crash. Interestingly, in one study, helmets did reduce the incidence of concussion, 19% in helmeted patients as compared to 37% in patients not wearing a helmet. However, similar to our study, helmeted patients in this study, had a significantly lower incidence of skull fracture and intracranial hemorrhage as compared to bicycle riders that crash not wearing a helmet.[11] Another study showed an incidence of concussion in bicycle riders that crashed to be approximately 19%, and there was no difference whether or not the rider was wearing a helmet[(3)]. Major head injury was significantly less likely in helmeted riders in our study where helmeted riders had a less than 1% chance of major head injury as compared to almost 4% in riders not wearing a helmet. Likewise, skull fractures were seen in 1% *versus* 4.4%, respectively, in riders with and without helmets. What was most surprising

Table 1 – Injuries in bicycle riders that crash in Marin County irrespective of helmet usage. Skull fractures are shown separately from other major head injuries, which includes subdural and epidural hematoma, and subarachnoid and intracranial bleeds.

Injuries	n = (%)
Concussion	385 (42%)
Rib fracture	154 (17%)
Clavicle fracture	139 (15%)
Multiple fractures	139 (15%)
Facial fracture	102 (11%)
Cervical spine fracture	89 (10%)
Pelvic fracture	57 (6%)
Internal injuries	46 (5%)
Femur fractures	23 (3%)
Skull fractures	17 (2%)
Major head injury	14 (1.5%)
Spinal cord injuries	6 (0.6%)

Table 2 – Injuries in bicycle rider s that crash when wearing a helmet *versus* riders that crash not wearing a helmet. Linear regression was used to evaluate the relationship between the dependent variables shown and independent variables. We evaluated many data points, including Injury Severity Scores, age, types of injuries comparing bicycle riders that crashed with and without helmets. We then used ANOVA analysis to determine significance between the four injuries shown below.

Injury	Helmeted (n =)	Not helmeted (n =)	P-Value
Concussion	299/701 (42.6%)	86/205 (42.0%)	P = NS
Facial fractures	67/701 (9.5%)	35/205 (17.0%)	P = 0.003
Skull fractures	8/701 (1.1%)	9/205 (4.4%)	P = 0.003
Major head injury	6/701 (0.85%)	8/205 (3.9%)	P = 0.002

comparing the patients in our large single-center study as compared to other studies was the low number of helmeted patients in other studies, as low as 0% in one study,[12] and 5% in another study.[7] The average number of helmeted patients is only 15% in most studies.[5,10] In our study, 77% of the bicycle riders that crashed were helmeted, which is considerably higher than any previous study we found. In contrast to some studies we also found that facial fractures were significantly reduced in helmeted riders, 9.5%, as compared to 17% in riders without helmets. Some studies differentiate between the areas of facial injuries,[3] although we did not study differences in the area of facial fracture, upper *versus* lower. We also did not attempt to use bicycle speed as a variable due to the complexity of trying to determine the actual speed from the Emergency Medical Services (EMS) report. We also did not evaluate the role of alcohol use in crash victims, although alcohol is not a large contributor to bicycle injuries in our patient population. Likewise, we did not differentiate between riders in crashes with automobiles as compared to nonautomobile-related bicycle crashes. There was no difference between the groups when considering the use of any anticoagulant, although this would not change the type of injury, only the consequence of the injury. And finally, we did not include upper extremity injuries as upper extremity injuries are less common and likely would not be affected by helmet use. One study evaluated the effect of facial injuries in bicycle riders and demonstrated an impaired quality of life in riders that crash which have associated facial injuries.[13] We have not evaluated any quality of life effects in our patients after bicycle crashes. Because we have a large population of patients with concussion, we believe that an additional study evaluating the long-term effects of concussion would be useful.

One limitation of this study would be that we cannot evaluate the role of speed in the injuries seen. It is intuitive that the faster a rider is moving the more likely it would be that they would sustain more significant injuries. In most instances it is not possible to obtain true bicycle speed, as it is an estimate and relies on the rider to report an accurate speed. In that 40% of the patients had a concussion, relying on speed is not an accurate way to analyze the speed as a variable in the injury data. We also found that other reports of helmet usage did not report speed as a variable.

In summary, in our large single series of bicycle riders that crash evaluated at an ACS Level III Trauma Center, we found that wearing a helmet did not reduce the number of patients with minor head injuries (concussion). We did find that the helmeted riders did have a significantly fewer facial fractures, skull fractures, and major head injuries. We strongly support the use of helmets for bicycle riders to help reduce serious injury when bicycle riders crash.

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Disclosures

The authors report no proprietary or commercial interest in any product mentioned or concept discussed in this article.

REFERENCES

1. *Data, trauma quality programs*. Chicago, IL: American College of Surgeons; 2019.
2. Axelsson A, Stigson H. Characteristics of bicycle crashes among children and the effect of bicycle helmets. *Traffic Inj Prev*. 2019:1–6.
3. Benjamin T, Hills N, Knott P, Murr A, Seth R. Association between conventional bicycle helmet use and facial fractures. *JAMA Otolaryn Head Neck Surg*. 2019;154:140–145.
4. Thompson DC, Rivara FP, Thompson R. Helmets for preventing head and facial injuries in bicyclists. *Cochrane Database Syst Rev*. 2000:CD001855.
5. Shafi S, Gilbert J, Loghmanee F, et al. Impact of bicycle helmet safety legislation on children admitted to a regional pediatric trauma center. *J Pediatr Surg*. 1998;33:317–321.
6. Hoya A. Bicycle helmets-To wear or not to wear? A meta-analyses of the effects of bicycle helmets on injuries. *Accid Anal Prev*. 2018;117:85–97.
7. Williams C, Weston R, Feinglass J, Crandall M. Pediatric bicycle helmet legislation and crash-related traumatic brain injury in Illinois, 1999-2009. *J Surg Res*. 2018;222:231–237.
8. Sethi M, Heidenberg J, Wall S, et al. Bicycle helmets are highly protective against traumatice brain injury within a dense urban setting. *Injury*. 2015;46:2483–2490.
9. Zibung E, Riddez L, Nordenvall C. Helmet use in bicycle trauma patients: a population-based study. *Eur J Trauma Emerg Surg*. 2015;41:517–521.
10. Axelsson A, Stigson H. Characteristics of bicycle crashes among children and the effect of bicycle helmets. *Traffic Inj Prev*. 2019:1–6.
11. Bergenstal J, Davis SM, Sikora R, Paulson D, Whiteman C. Pediatric bicycle injury prevention and the effect of helmet usage: the West Virginia experience. *W V Med J*. 2012;108:78–81.
12. Ashbaugh SJ, Macknin ML, VanderBrug MS. The Ohio bicycle injury study. *Clin Pediatr (Phila)*. 1995;34:256–260.
13. Zibung E, Riddez L, Nordenvall C. Impaired quality of life after bicycle trauma. *Injury*. 2016;47:1078–1082.