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Mountain Biking–Related Injuries Treated in Emergency Departments in the United States, 1994-2007

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Background: Injury research on mountain biking has been mostly limited to examining professional riders and off-road biking. Mountain bikes represent the largest segment of bike sales in the United States. Recreational mountain bike use is popular and understudied.

Purpose: To describe the scope, distribution, and trends of mountain bike–related injuries treated in US emergency departments.

Study Design: Descriptive epidemiologic study.

Methods: A retrospective analysis was conducted with data from the National Electronic Injury Surveillance System of the US Consumer Product Safety Commission for patients aged ≥8 years from 1994 through 2007. Sample weights provided by the system were used to calculate national estimates of mountain bike–related injuries based on 4624 cases. Bivariate comparisons between categorical variables were assessed with injury proportion ratios and 95% confidence intervals.

Results: Nationwide, an estimated 217,433 patients were treated for mountain bike–related injuries in US emergency departments from 1994 to 2007, an average of 15,531 injuries per year. The annual number of injuries decreased 56%, from a high of 23,177 in 1995 to 10,267 in 2007 (P < .001). The most common injuries were upper extremity fractures (10.6%) and shoulder fractures (8.3%). Patients aged 14 to 19 years sustained a greater proportion of traumatic brain injuries (8.4%) than did patients aged 8 to 13 years and ≥20 years combined (4.3%). A greater proportion of female riders (6.1%) than male riders (4.5%) were hospitalized.

Conclusion: Mountain bike–related injuries decreased from 1994 to 2007. Upper extremity fractures were the most common injury. Girls and women may be more likely than boys and men to sustain more severe injuries requiring hospitalization. Despite the decline over the past decade, more can be done to improve safety and reduce injuries in this popular recreational activity.

Keywords: National Electronic Injury Surveillance System; injury; mountain bike; outdoor; emergency department

Mountain biking, also known as off-road biking, began in the 1970s and grew to mainstream popularity in the early to mid-1990s, becoming a full Olympic sport in 2000.12 Mountain biking has continued to evolve as both a recreational sport and a professional sport. Organized races now include a variety of events, such as cross-country, short-track cross-country, ultraendurance, downhill, 4-cross, super D, and observed trials.31

Although 5.6 million people reported riding a mountain bike at least once in 2007 (a 35% decrease from its peak of 8.6 million in 1998), it is not known how many of these bikes are used off-road.1,2 In the 1980s and 1990s, mountain bikes accounted for the largest proportion of total bike sales in the United States, with sales peaking as high as 60% of all bikes sold. Mountain bike sales have decreased in the past decade, representing only 29% of bike sales in the United States in 2008.21 Despite this decline, mountain bikes are the largest specialty segment of the bike industry.21

Little is known about the epidemiology of mountain bike–related injuries on a national level.16 Much of the existing literature on mountain bike–related injuries has focused on elite mountain bikers,6,17,18,24 case studies and specific types of injuries,3,8-10,19,20,23,26 and small sample sizes.5,13,27 There are no published studies of national estimates of mountain bike–related injuries.

The objective of this study was to describe the scope, distribution, and trends of mountain bike–related injuries in the United States. This study examined mountain

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METHODS

Data Source

The National Electronic Injury Surveillance System (NEISS) of the US Consumer Product Safety Commission is a stratified probability sample of approximately 100 US hospital EDs (including 7 children’s hospital EDs) representing 6100 hospitals with 6 or more beds and a 24-hour ED. The sampling frame is stratified by hospital size and ordered by geographic location to minimize the statistical variance and ensure an adequate geographic distribution. This data set provides high-quality data on consumer product-related and sports and recreation activity-related injuries treated in EDs.28 At NEISS hospitals, ED medical charts are reviewed by professional coders, and data are recorded regarding patients’ age, sex, race, injury diagnosis, body part injured, products involved, locale, disposition, and a brief narrative describing the incident.22,28 The NEISS coders only code the primary injury or 1 major injury for each patient. Study data were obtained directly from the US Consumer Product Safety Commission for all patients who were treated for mountain bike-related injuries. This study was approved by the Institutional Review Board of The Research Institute of Nationwide Children’s Hospital.

Case Selection Criteria

Case narratives were reviewed for injuries identified by the NEISS product code for mountain bikes (5033). To be included, the patient must have been operating the mountain bike at the time of injury. Cases that did not involve a mountain bike or cases in which the mountain bike was not actually being used or operated were excluded (eg, back strain from lifting mountain bike to store it, mountain bike tipped over on a child). Cases involving poisoning, dermatitis (eg, from poison ivy), or insect bites were excluded. Passengers (other than the rider) and bystanders were excluded. National estimates were based on weighted data for 4624 patients aged 8 years and older. The minimum age was selected to facilitate comparison with other mountain bike–related injury studies of nonelite riders.1,13 There were no case fatalities in the data set.

Variables

Data regarding patients’ age, body part injured, injury diagnosis, locale where the injury occurred, and disposition were grouped into categorical variables. Sex was used as coded by the NEISS. Patients were grouped into 4 age categories (8-13, 14-19, 20-39, and ≥40 years). The body parts injured were grouped into categories of head, face (including face, mouth, ears, and eyes), shoulder (NEISS code includes clavicle), upper extremities (including upper arm, elbow, lower arm, wrist, hand, and finger), lower extremities (including upper leg, knee, lower leg, ankle, foot, and toe), trunk (including upper and lower trunk, hip, neck, and pubic region), and other (including the NEISS code for other, 25% to 50% of the body, all parts of body, and internal injuries). Injury diagnosis was coded as soft tissue (including contusions, abrasions, hematomas), lacerations (including laceration, punctures, skin avulsions), fracture, dislocation, sprain or strain, traumatic brain injury (TBI; including cases with concussion, fractures to the head, and internal organ injuries to the head),32 and other (including crushing, foreign body, dental injury, nerve damage, internal organ, and the NEISS code for other). The variable locale (the location where injury took place) was grouped as home (including home and farm), sports and/or recreation place, street and/or highway, and other (including school and other public property). Disposition was categorized as hospitalized (patients who were admitted or transferred to another hospital) and not hospitalized (patients who were treated and released, held for observation for <24 hours, or left without being seen). A new variable, mechanism of injury, was created for this study. Each case narrative was reviewed by N.G.N. to categorize mechanism of injury. Mechanism of injury was grouped into 6 categories, including falls, thrown from bike (including going over the handlebars), contact with bike equipment, hit and/or struck an object, hit by and/or struck by an object, and other.

Statistical Analysis

Data were analyzed with SPSS 17.0 (SPSS Inc, Chicago, Illinois). Rates were calculated using population data from the US Census Bureau.28,30 Means were reported with standard deviations. Bivariate comparisons between categorical variables were assessed using injury proportion ratios (IPRs) with 95% confidence intervals (CIs). The SPSS Complex Samples module was used to account for the complex survey design, with P values ≤.05 and CIs not including 1.0 considered significant.29 An example of the IPR calculation—the formula for comparing the proportion of head injuries between boys and men and girls and women—was as follows: IPR = (no. of boys and men head injuries/total no. boys and men injuries)/(no. girls and women head injuries/total no. girls and women injuries). Trend significance of the number of mountain bike–related injuries over time was analyzed with linear regression. All data reported in this article are national estimates, unless specified as actual unweighted cases.

RESULTS

Demographic Factors and Overall Injury Trends

From 1994 through 2007, there were 4624 cases of mountain bike–related injuries in the NEISS for an estimated 217433 patients (95% CI, 97 128 to 337 728) treated in
The annual number of injuries decreased 56% from a high of 23,177 cases in 1995 to 10,267 in 2007 (P < .001) (Figure 1). The average overall rate of mountain bike–related injuries was 6.2 per 100,000 population. The annual injury rate decreased 45% from 6.9 injuries per 100,000 population in 1994 to 3.8 injuries per 100,000 population in 2007. Patients who sustained mountain bike–related injuries had a mean age of 29.8 ± 13.3 years (range, 8 to 97 years); 80.8% were boys or men. Patients aged 20 to 39 years accounted for the majority of cases (52.9%). Sports and/or recreation place was the most common locale where injuries occurred (67.4%).

Mechanism of Injury
The majority of mountain bike–related injuries were attributed to falls (69.9%) or being thrown from the bike (14.1%). Falls resulted in a greater proportion of upper extremity injuries (31.7%) than all other mechanisms (16.6%) (IPR, 1.9; 95% CI, 1.7 to 2.2). Being thrown from the bike resulted in a greater proportion of shoulder and clavicle injuries (28.1%) than all other mechanisms (18.4%) (IPR, 1.5; 95% CI, 1.3 to 1.8), as well as a greater proportion of TBIs (8.0%) than all other mechanisms (3.7%) (IPR, 2.2; 95% CI, 1.7 to 2.8). Patients aged 8 to 13 years had a greater proportion of injuries caused by contact with the bike (8.6%) and being hit by something (4.4%) as compared with patients aged ≥14 years (4.7% and 1.3%, respectively) (IPR, 1.9; 95% CI, 1.3 to 2.7; IPR, 3.4; 95% CI, 1.9 to 6.4, respectively). Hitting an object while riding resulted in a higher proportion of face injuries (16.9%) and head injuries (11.1%) compared with all the other mechanisms (8.6% and 6.1%, respectively) (IPR, 2.0; 95% CI, 1.5 to 2.7; IPR, 1.8; 95% CI, 1.3 to 2.6, respectively).

Disposition
Overall, 4.8% of patients with mountain bike–related injuries were hospitalized. Of all hospitalizations, fractures accounted for 44.6%; other injuries, 20.4%; and TBIs, 16.1%. A greater proportion of girls and women (6.1%) than boys and men (4.5%) were hospitalized (IPR, 1.4; 95% CI, 1.1 to 1.7) (Figure 2). Patients aged ≥40 years (8.4%) had a higher proportion of hospitalization as...
compared with patients aged 8 to 39 years (3.7%) (IPR, 2.3; 95% CI, 1.8 to 2.9). Traumatic brain injuries and fractures were the diagnoses that required the highest proportion of hospitalizations (15.9%: IPR, 3.8; 95% CI, 2.6 to 5.4; 8.1%: IPR, 2.3; 95% CI, 1.8 to 2.9, respectively), whereas the head and trunk were the body parts injured that required the highest proportion of hospitalizations (12.7%: IPR, 3.0; 95% CI, 2.1 to 4.4; 12.4%: IPR, 3.5; 95% CI, 2.8 to 4.5, respectively). Examining mechanism of injury, being hit by something (19.1%: IPR, 4.1; 95% CI, 2.3 to 7.4) and being thrown from the bike (6.5%: IPR, 1.4; 95% CI, 1.1 to 1.8) resulted in the highest proportions of hospitalization.

DISCUSSION

This is the first study to examine a nationally representative sample of mountain bike–related injuries treated in US EDs. Between 1994 and 2007, mountain bike–related injuries declined. The most common injuries were upper extremity, shoulder, and clavicle fractures. Although boys and men accounted for the majority of injuries, girls and women were more likely to sustain an injury severe enough to require hospitalization. Mountain bike–related injuries most commonly occurred at places of sports and recreation. Falls were the most common mechanism of injury. Being thrown from the bike resulted in the greatest proportion of TBIs and a high proportion of hospitalizations. Adolescents aged 14 to 19 years sustained the greatest proportion of TBIs.

Our study found that the annual number of mountain bike–related injuries in the United States decreased by more than one half since 1995. It is likely that some, although not all, of this decline is due to decreased participation. The Superstudy of Sports Participation reported that between 1993 and 2007 there was a 24% decrease in participation, from 7.4 million riders to 5.6 million (these data were not available for 1994). Improved design features of mountain bikes, such as disc brakes and dual-suspension systems, have become increasingly common in the past decade. These features may have contributed to the decline in injuries associated with the sport; as such, technology contributes to greater rider control. We observed a 40% drop in mountain bike–related injuries between 2002 and 2003 (approximately 7000 injuries), a decline that was sustained in the following years. The reasons for this sharp decline are unclear.

In terms of sex differences, a greater proportion of girls and women were hospitalized than boys and men. Carmont noted a similar injury pattern and attributed it to girls and women weighing less and, as a result, being more likely to fall over the handlebars, thereby causing more serious injury. Our findings, however, do not show a difference in this mechanism between the sexes. Other sex differences have been identified in the literature, most of which focused on elite mountain bikers. Our study, which included recreational mountain bike use, had contrary findings. For example, although previous publications found that fractures were more common among girls and women, our study found that fractures were equally distributed between the sexes. Lower extremity injuries were one of the most common injuries (19.6%) but were more common among girls and women, our study found that fractures were equally distributed between the sexes. Lower extremity injuries in mountain biking may be related to contact with low objects and undergrowth while riding off-road, contact with the gears or chain on the bike, delay in release from clip-in pedals, and the force of planting the foot on the ground to stop a fall.

Overall, upper extremity, shoulder, and clavicle fractures were the most common injuries, which is consistent with previously published studies. Mountain bike–related
injury research reports a high degree of helmet use among mountain bikers (80% to 90%), which may account for the relatively low proportion of head injuries found in our study and others.\textsuperscript{6, 10, 16} The proportion of TBIs (5.9%) observed in this study is in line with the 3% to 13% range reported in the literature.\textsuperscript{16} However, we did find that injuries of all types to the head, neck, and face accounted for 16% of all injuries, which is higher than in other studies.\textsuperscript{11, 13}

Injuries to the head and TBIs in adolescents aged 14 to 19 years were double that of patients aged 8 to 13 years and ≥20 years. Infrequent use of protective equipment, including helmets, has been documented among adolescents participating in other styles of biking and other “extreme” sports, such as skateboarding, in-line skating, and snowboarding.\textsuperscript{7, 14} This increased proportion of head injuries may be due to lower helmet use among this age group compared with older and younger mountain bikers.

Falls were the most common mechanism of injury. In previous studies of elite mountain bikers, the most common direction to fall was forward, over the handle bars.\textsuperscript{6} In our study, falls over the handle bars were considered “being thrown from the bike” and accounted for only 14% of injuries. Being thrown from the bike was the mechanism with the second-largest proportion of hospitalizations, a finding that supports previous studies that showed that falling over the handlebars results in more serious injury.\textsuperscript{4, 6, 15, 17} Our study found that injuries due to this mechanism have a significantly greater proportion of shoulder and clavicle injuries and TBIs. Similar results are found in previously published reports.\textsuperscript{6}

Being hit by an object was the injury mechanism that resulted in the greatest proportion of hospitalizations. The youngest age group (8 to 13 years) had the greatest proportion of injuries caused by this mechanism. In the majority of these cases, a motor vehicle was the object that hit the biker (data not shown). This mechanism has not been found in other mountain bike–related injury studies, because it is typically not a factor in professional off-road activity, whereas recreational use of mountain bikes occurs off and on the road, thus increasing the risk of being hit by a motor vehicle. Being hit by an object accounted for 1.4% of cases.

Limitations

This study has several limitations. The total number of mountain bike–related injuries was most likely underestimated because the NEISS captures only injuries treated in EDs. Some mountain bike–related injuries may be treated at home or by a community-based health care facility. Additionally, the mechanism of injury was gleaned from case narratives and is thus subject to reporting or interpretation error and not available for all cases. Our study does not address mountain bike–related injury fatalities, because NEISS is generally not regarded as being useful for identifying fatal injuries. Information specific to type of terrain, helmet use, competitive versus recreational use, and level of mountain biking experience could not be determined from these data. Despite these limitations, this is a large, nationally representative study.

CONCLUSION

There are approximately 15 000 mountain bike–related injuries each year. Girls and women may be more likely to sustain mountain bike–related injuries requiring hospitalization. Adolescents have a greater proportion of TBIs and injuries to the head. The sex and age differences in mountain bike–related injury may represent opportunities to further reduce injuries through focused injury prevention and increasing use of protective equipment. More research is necessary to identify the role that specific injury prevention interventions can play.

REFERENCES