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Bicycle-Related Injuries Among Children and Adolescents in the United States

Tracy J. Mehan, MA, Ricky Gardner, BS, Gary A. Smith, MD, DrPH, and Lara B. McKenzie, PhD, MA

The objective of this study is to describe the epidemiology of bicycle-related injuries among children and adolescents 18 years and younger on a national level. This is a retrospective analysis of data from the National Electronic Injury Surveillance System of the US Consumer Product Safety Commission for patients 18 years and younger who were seen in emergency departments (EDs) between January 1, 1990, and December 31, 2005, for injuries received while operating a bicycle. During the 16-year study period, there were an estimated 6 228 700 individuals 18 years and younger treated in US EDs for bicycle-related injuries. Children with head injuries were more than 3 (relative risk, 3.63) times as likely to require hospitalization and were almost 6 (relative risk, 5.77) times more likely to have their injuries result in death. The large number of annual bicycle related–injuries is evidence that prevention of these injuries should remain an important area of bicycle safety research and practice.

Keywords: bicycles; injury; prevention; emergency department; NEISS; children/adolescents

Bicycles are sources of exercise, transportation, and recreation for many people in the United States. Bicycle industry reports indicate that there are more bicycles being sold per year in the United States than new cars[1,2] (18.2 million bicycles vs 16.5 million new cars in 2006). An estimated 44 million individuals 21 years and younger ride bicycles,[3] and more than 70% of all children between the ages of 5 and 14 years ride bicycles.[4]

Unfortunately, in 2003 alone unintentional bicycle injuries were among the top 5 causes of nonfatal injuries among children aged 5 through 14 years in the United States.[5] The only consumer product associated with more childhood injuries than bicycles is automobiles. Although many education programs aimed at preventing bicycle-related injuries have been implemented and evaluated, large numbers of injuries continue to occur.

The majority of bicycle-related injury research has been restricted to local or state-level analyses,[6-9] has concentrated on only 1 type of injury (such as head injuries or handlebar-related injuries),[10,11] or has focused on 1 injury prevention strategy, mainly helmets (such as effectiveness of helmets or evaluations of the impact of helmet laws).[12-23] The few national studies were based on data that did not allow for population-based estimates[24] or were outdated and based on a short period ($\leq$5 years).[25]

To our knowledge, no study has performed a recent, nationally representative, detailed analysis of the epidemiology and trends of bicycle-related injuries. The objective of this study was to comprehensively examine bicycle-related injuries among children and adolescents 18 years and younger on a national level.

Methods

Data

Data were obtained through the National Electronic Injury Surveillance System (NEISS), which is

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operated by the US Consumer Product Safety Commission (CPSC). The CPSC provides data on consumer product–related and sports activity–related injuries treated in US emergency departments (EDs). The NEISS receives data from a network of approximately 100 hospitals that represent a stratified probability sample of 6100 hospitals with at least 6 beds and a 24-hour ED.[26] The database provides information regarding injury events presenting to participating hospitals, including the patient's age, sex, race/ethnicity, injury diagnosis, body part injured, products involved, disposition from the ED, and a brief narrative of the incident. Each year, the NEISS provides data on approximately 500 000 injury-related ED visits. The probability sample method of the NEISS allows the use of statistical weights to make nationally representative estimates of the number of injurious events.

Data from 166 403 cases of bicycle-related injury among children and adolescents 18 years and younger for the 16 years from January 1, 1990 to December 31, 2005, were identified using the NEISS consumer product codes for bicycles (code 5040) and mountain bikes (code 5033). A bicycle-related injury was defined as an injury event that occurred to an individual while participating in bicycle-related activities as an operator or as a passenger. Cases were excluded on the basis of the narrative description if a bicycle was not being ridden or worked on (eg, a stored bike falling on an individual), if the injury was to a pedestrian or a bystander, or if the injury was the result of a motorized bicycle or a 3-wheeled product such as a tricycle.

Information about race/ethnicity and helmet use was missing in more than 60% of the cases. Therefore, these variables were not included in the analysis.

Statistical Analysis

Data were analyzed using SPSS version 14.01 (SPSS Inc, Chicago, Illinois) statistical software and the complex sample module, with adjustment for sample weights and the stratified survey design, as recommended by the CPSC. Statistical analyses included χ^2 analysis and relative risk (RR) with 95% confidence intervals (CIs). The level of significance for all statistical tests was $P < .05$. All data reported in this article are national estimates unless otherwise specified. Estimated numbers of injuries were rounded to the nearest 100 in the text. Injury rates were calculated using the US Census Bureau intercensal data for each study year.[27] The institutional review board of The Research Institute at Nationwide Children's Hospital approved this study.

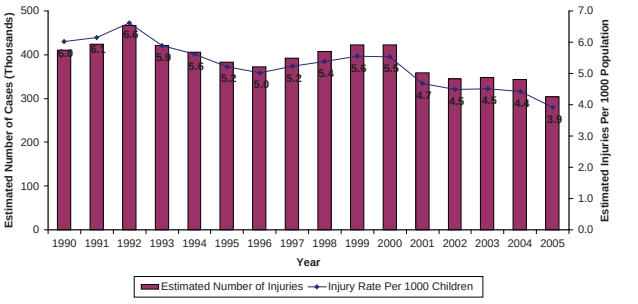

Figure 1. Estimated number and rate of bicycle-related injuries among children 18 years and younger in the United States per year (1990-2005).

Results

There were an estimated 6 228 700 (95% CI, 5 439 376-7 018 002) children and adolescents 18 years and younger treated in EDs for bicycle-related injuries during the 16-year study period. This represents a mean of 389 300 patients annually, ranging from a high of 466 300 (95% CI, 382 407-550 141) in 1992 to a low of 304 400 (95% CI, 237 080-371 799) in 2005. The mean annual rate of injury was 5.24 injuries per 1000 children and ranged from 6.63 injuries per 1000 children in 1992 to 3.92 injuries per 1000 children in 2005 (Figure 1). Most injuries (75%) occurred during the warm-weather months of April through September.

The mean (SD) age of injured children was 9.7 (3.9) years (age range, 1 month to 18 years). Children between the ages of 5 and 14 years accounted for 78.6% of the injuries (Figure 2). This age group also had the highest injury rates (7.54 injuries per 1000 children aged 5-9 years and 7.98 injuries per 1000 children aged 10-14 years). Overall, boys (7.24 injuries per 1000 children) had higher rates of injury than girls (3.23 injuries per 1000 children), with boys accounting for 70.2% of all injuries (Table 1). Boys aged 10 through 14 years (11.67 injuries per 1000 children) had the highest injury rate, while girls aged 15 through 18 years (1.02 injuries per 1000 children) had the lowest injury rate.

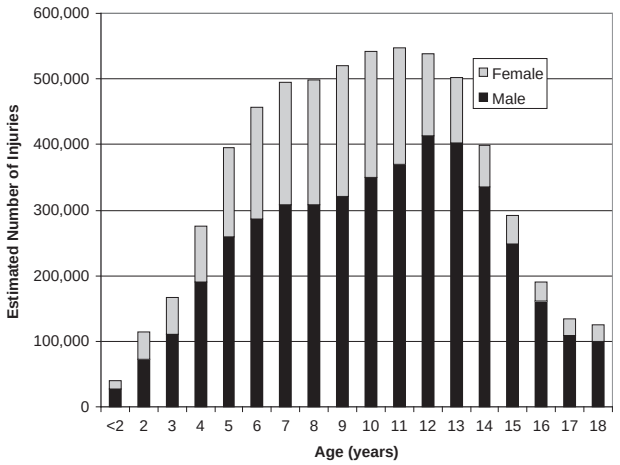

Figure 2. Age and sex distributions of estimated number of bicycle-related injuries among US children.

Type of Injury

The most common types of injuries overall were contusions and abrasions (30.4%), lacerations (29.9%), and fractures (18.8%) (Table 1). Contusions and abrasions were the most common injury diagnoses for children 9 years and older, while lacerations were the most common injury diagnosis for children younger than 9 years. Lacerations accounted for 42.7% of injuries among children younger than 5 years and 20.6% of injuries among adolescents aged 15 to 18 years. While the percentage of lacerations decreased with age, the reverse was true for fractures. Fractures accounted for 11.0% of injuries to children younger than 5 years, doubling to 23.8% by age 13 years. More than three-quarters (77.8%) of fractures were to the upper extremities. An examination of the injury trends showed that the estimated number of contusions and lacerations decreased significantly ($P < .001$) during the 16-year study period, while internal organ injuries and concussions remained consistent (Figure 3).

Body Region

The upper extremities (32.7%) and lower extremities (24.1%) were the most frequently injured body regions, followed closely by injuries to the face (21.4%) and head (12.4%) (Table 1). Fractures (44.7%) and contusions (26.3%) were the most common diagnoses for upper extremity injuries, while contusions (33.8%) and lacerations (33.7%) were the most frequent diagnoses for lower extremity injuries. Lacerations (64.9%) were the most common type of facial injury, while concussions, contusions, and internal organ injuries accounted for 68.4% of injuries to the head. For children 8 years and younger, the face was the most frequently injured body part. Upper extremity and lower extremity injuries were most frequent for children aged 9 to 18 years. When analyzed across the 16-year study period, the estimated number of injuries to the head, face, and lower extremities decreased significantly ($P < .01$) (Figure 4).

Disposition

The majority (96.2%) of patients with bicycle-related injuries were treated and released from the ED (Table 1). Only 3.8% of the injuries required admission to the hospital, which represented an estimated 235 900 children, or a mean of 14 700 children annually. Those requiring hospitalization most frequently had sustained injuries to the head (34.0%), upper extremity (23.4%), or lower extremity (18.8%). Children with head injuries were more than 3 (RR, 3.63; 95% CI, 3.22-4.10) times as likely to require hospitalization and almost 6 (RR, 5.77; 95% CI, 2.56-12.98) times more likely to have their injuries result in death than patients with injuries to other parts of the body. A total of 44.9% of patients admitted to the hospital had fractures, and another 20.3% had sustained internal organ injuries. In this data set, 96.1% of internal organ injuries occurred to the head. Patients with internal organ injuries were 5.84 (95% CI, 4.90-6.97) times more likely than patients with other types of injuries to require hospitalization.

During the 16-year study period, there were an estimated 1965 (95% CI, 1189-2739) fatalities. Of those, the largest percentage, 45.0%, had injuries to the head, with another 28.4% classified as having injuries to "all parts." While adolescents aged 15 through 18 years accounted for 11.9% of the total number of injuries, 34.6% of the fatalities were among this age group. Adolescents aged 15 through 18 years were approximately 4 (RR, 3.93; 95% CI, 1.63-9.46) times more likely than children younger than 15 years to sustain fatal injuries.

Location of Injury

When location of injury was recorded (57.9% of the cases), 47.5% of the injuries occurred at home,

Table 1. Bicycle-Related Injuries to Children and Adolescents Treated in US Emergency Departments, 1990 to 2005

Characteristic	Actual Cases	National Estimate (95% Confidence Interval)[a]	%[b]
Age, y	(n = 166 403)		(n = 6 228 689)
<5	17 186	595 496 (529 034-690 585)	9.6
5-9	64 759	2 364 084 (2 133 634-2 701 342)	38.0
10-14	66 043	2 528 639 (2 239 440-2 924 785)	40.6
15-18	18 415	740 470 (621 700-887 858)	11.9
Sex	(n = 166 359)		(n = 6 226 693)
Male	117 311	4 372 380 (3 887 520-5 043 001)	70.2
Female	49 048	1 854 313 (1 665 782-2 128 008)	29.8
Body region injured	(n = 165 597)		(n = 6 206 647)
Head	23 299	770 929 (683 272-891 953)	12.4
Face[c]	35 583	1 328 469 (1 191 540-1 526 568)	21.4
Upper extremity[d]	52 104	2 031 921 (1 798 417-2 348 479)	32.7
Lower extremity[e]	38 842	1 498 312 (1 330 068-1 733 404)	24.1
Trunk[f]	13 542	475 382 (420 915-549 751)	7.7
Other[g]	2227	101 634	1.6
Injury diagnosis	(n = 166 056)		(n = 6 219 417)
Contusion and abrasion	47 900	1 888 324 (1 672 702-2 190 289)	30.4
Laceration	47 286	1 860 092 (1 669 358-2 136 875)	29.9
Fracture	32 006	1 166 409 (1 034 363-1 346 077)	18.8
Strain and sprain	13 236	549 565 (478 656-643 346)	8.8
Concussion	3404	126 873 (104 988-153 687)	2.0
Other	22 224	628 154 (534 935-744 371)	10.1
Hematoma	1612	55 265 (47 020-65 846)	0.9
Dental injury	2356	52 946 (43 831-64 020)	0.9
Internal organ injury	10 413	258 353 (205 954-320 610)	4.2
Avulsion and amputation	1332	53 405 (46 107-63 124)	0.9
Other	6511	208 185 (165 069-257 727)	3.3
Location of injury	(n = 89 545)		(n = 3 604 073)
Home	38 830	1 711 963 (1 374 433-2 123 623)	47.5
Street	40 298	1 418 507 (1 133 311-1 759 771)	39.4
School	902	33 547 (23 683-44 718)	0.9
Sports and recreation place	5432	258 600 (127 288-399 200)	7.2
Other public place	4009	177 878 (132 627-230 592)	4.9
Other	74	3578 (2335-4977)	<1
Outcome of emergency department visit	(n = 166 183)		(n = 6 222 249)
Treated and released	158 010	5 984 340 (5 334 362-6 894 877)	96.2
Treated and admitted	7493	235 944 (205 767-276 277)	3.8
Fatality	680	1965 (1211-2799)	<1

a. Calculated by applying statistical weights provided by the US Consumer Product Safety Commission National Electronic Injury Surveillance System to the actual cases.
b. Percentages do not always sum to 100.0% because of rounding.
c. Includes ear, eyeball, face, and mouth.
d. Includes shoulder, upper arm, elbow, lower arm, wrist, hand, and finger.
e. Includes upper leg, knee, lower leg, ankle, foot, and toe.
f. Includes upper trunk, lower trunk, neck, and pubic region.
g. Includes 25% to 50% of body and all parts of body.

39.4% took place on the street, and 7.2% happened at a sports recreation facility (Table 1). Injuries occurring at home took place in the yard, in the garage, on driveways, on the porch, and on sidewalks, as well as inside the house. Analysis by year indicated a shift in the location of injury during the years studied. In 1990, 54.8% of injuries occurred at home, and 38.2% took place on the street. In 2005, 42.2% of injuries occurred at home, and 47.0% took place on the street. When disposition was

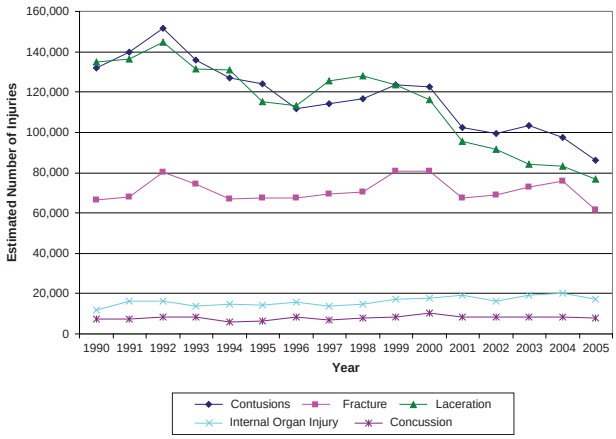

Figure 3. Bicycle-related injuries. Estimated number of selected injury types per year.

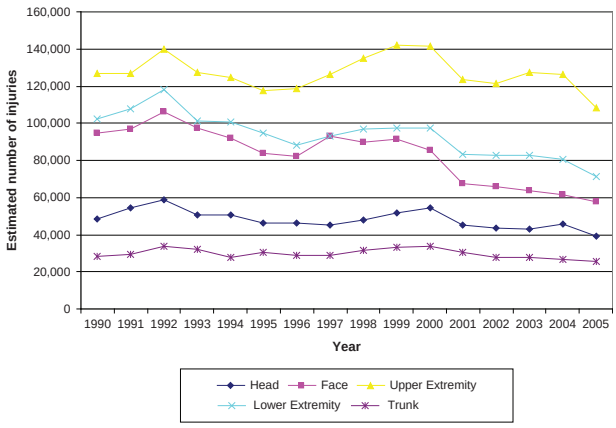

Figure 4. Bicycle-related injuries. Estimated number of selected injuries by body region per year.

analyzed by location of injury, 88.1% of fatalities with a recorded location took place on the street. Compared with children who were injured in other locations, children whose injury occurred on the street were more than 2 (RR, 2.36; 95% CI, 1.92-2.90) times as likely to require hospitalization and were more than 11 (RR, 11.42; 95% CI, 3.76-34.66) times as likely to sustain an injury that resulted in death.

Discussion

The objective of this study was to describe the epidemiology of bicycle-related injuries among children and adolescents 18 years and younger on a national level. The number of injuries decreased slightly during the 16 years studied; however, even in the year with the fewest injuries, there was a mean of more than 850 bicycle-related injury events per day.

Studies[28-30] have highlighted the serious injury problem that head injuries present for cyclists. In the present study, children with head injuries were significantly more likely to require hospitalization and to have their injuries result in death. More than 40% of fatalities resulted from a head injury, and an additional 28% were the result of multisystem trauma, which undoubtedly included many with head injury. In 2005 alone, there were approximately 39 400 bicycle-related head injuries treated in EDs in the United States, which is a mean of approximately 100 per day. Bicycle helmet use has been recommended as a key strategy to prevent traumatic brain injury among bicyclists.[31] Previous research has examined rates of helmet use,[15,19,32] barriers to helmet use,[33-37] the effectiveness of helmets,[20,23] and the effectiveness of helmet laws.[38-41]

Also consistent with previous studies,[25,29] the distribution of types of bicycle-related injuries varied by age in our study. Children younger than 5 years had more facial injuries and lacerations, while children 5 years and older were more likely to have fractures and injuries to the upper and lower extremities. These associations have also been reported for other consumer products and childhood activities.[29,4,2-45] Ortega et al[29] hypothesized that the rise in upper extremity injuries with increasing children's age could be explained by older children's having a greater tendency to use their arms to protect their head and face when they fall.

A significant amount of research on bicycle-related injuries has focused on behaviors and situations that can lead to injury.[4,4,6-50] However, a few studies have examined how the bicycle itself can be part of the problem. For example, handlebars can cause severe abdominal injuries to children.[10,51,52] Because bicycle-related injuries continue to be a major public health concern in the United States, it is important to consider all opportunities for injury prevention. Success in the prevention of injury through design improvement for other child-related products (such as baby walkers[53]) indicates that it is important to consider passive prevention strategies that do not require constant vigilance or frequent action by the user of the product. Wheels with spoke covers that could prevent injuries caused by extremities'

getting caught in the spokes[54] and energy-absorbing handlebars that are less likely to cause abdominal injuries[11] are 2 examples of available modifications that would likely reduce the number of bicycle-related injuries if their use was more widespread. Continued analysis of the types of bicycle-related injuries sustained by children and adolescents may lead to further opportunities for design modifications.

This study has several limitations. Concerns have been raised regarding the ability of the NEISS to estimate children's injuries because the NEISS strata were initially based on geographic location and hospital size and not by hospital type.[55,56] In 1997, the NEISS sampling frame was revised to include a separate stratum for children's hospitals to address these critiques. Data used in this study were adjusted to account for this sampling frame modification. Another limitation to the study is that the NEISS data only include injuries treated in an ED. Injuries treated in other health care settings, by the parents, or not treated at all are not included. Therefore, bicycle-related injuries reported by the NEISS may not be representative of all bicycle-related injuries. Because only ED-treated injuries are included, our study is an underestimate of the total number of bicycle-related injuries. Fatalities are also likely underestimated for the same reason. Additional research examining other data sources is needed to better understand the causes and trends associated with bicycle-related fatalities. United States census data were used to calculate injury rates; however, the lack of bicycle exposure data precluded the calculation of true rates, which was also a limitation of this study.

Recommendations

Following some simple guidelines can help children be safer while riding their bicycles. Continued efforts need to be made to increase bicycle helmet use among individuals 18 years and younger, especially among adolescents aged 15 to 18 years. All children, even passengers on parents' bicycles, need to wear a helmet every time they are on a bicycle. For maximum protection, the helmet should fit properly and meet CPSC standards. In addition, the straps should always be snugly fastened.

Continued education efforts regarding general safety guidelines for the operation of bicycles are also recommended. This study found that injuries that occur on the street are significantly more likely to result in hospitalization and death. Many children are not able to consistently follow the traffic rules necessary to safely ride in the street until they are at least 10 years old. These traffic rules include using hand signals for turns, riding on the right side of the street (with traffic not against it), stopping at stop signs and lights, knowing the appropriate way to cross intersections (ie, walk the bicycle across), and being aware of the other vehicles around them (including vehicles backing out of driveways). Community efforts to create bicycle paths and to separate bicycle and motor vehicle traffic are also important strategies to reduce bicycle-related injuries. For more detailed information on bicycle safety recommendations, see policy statements from the American Academy of Pediatrics[57] or fact sheets from Safe Kids,[4] the CPSC,[58] or the National Highway Traffic Safety Administration.[59]

Conclusion

This research provides an important nationally representative analysis of bicycle-related injuries occurring to children and adolescents in the United States. These injuries continue to be a major problem for US children. According to *Healthy People 2010*,[31] increasing bicycle safety is a national priority. A multiprong approach to reducing the number of bicycle-related injuries among children is vital and includes increasing bicycle helmet use, improvements in passive protection (ie, spoke covers and energy-absorbing handlebars), and primary prevention measures to reduce bicycle crashes through construction of bicycle paths, educational campaigns, and other efforts.

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