Injuries Involving Off-road Cycling

Frederick P. Rivara, MD, MPH; Diane C. Thompson, MS; Robert S. Thompson, MD; and Viviana Rebolledo
Seattle, Washington

BACKGROUND. Data on injuries due to off-road bicycling are scarce, but do indicate that injuries in this sport are frequent. We examined the pattern of injuries to off-road riders as part of a larger study of bicycle injuries and helmet use.

METHODS. We undertook a prospective study of bicycle-related injuries identified at seven emergency departments in Seattle, Washington, between March 1992 and August 1994. Hospitalized patients and medical examiners' cases were included. Detailed questionnaires and abstraction of all medical records provided information on crash and rider characteristics and injury type and severity.

RESULTS. A total of 3390 injured riders participated, representing an 88% response rate. Of all injured cyclists, 127 (3.7%) were injured riding "off road." Seventy-three percent of off-road cyclists were 20 to 39 years of age, and 86.6% were male. Helmet use was 80.3% for off-road cyclists as compared with 49.5% for other cyclists. The number of head and face injuries for the off-road cyclists was only 40% of the number incurred by other cyclists. Four percent of off-road cyclists had severe injuries (Injury Severity Score >8), and 6.3% were hospitalized, compared with 6.8% and 9.4%, respectively, of other cyclists.

CONCLUSIONS. The majority of off-road bicycling injuries are minor. Off-road cyclists are less likely to have head and face injuries than other cyclists and are more likely to wear helmets.

KEY WORDS. Bicycling; head protective devices; facial injuries; head injuries. *(J Fam Pract 1997; 44:481-485)*

Off-road bicycles (known as mountain bikes) have become increasingly popular in the United States. These bikes are designed to ride on various types of unpaved surfaces, such as hiking trails, ski slopes, dirt roads, and other rough terrain. Sales of off-road bikes accounted for 62% of the US bicycle market in 1992.[1] In 1983, the National Off-Road Bicycle Association (NORBA) was organized to promote the sport and organize races. In 1996, off-road cycling will have a full Olympic medal competition.

Data on injuries due to off-road biking are scarce, but do indicate that injuries in the sport are frequent. Chow et al[2] found that 83% of competitive off-road cyclists and 51% of recreational off-road cyclists reported injuries during the preceding year. In another study, Kronisch and Rubin[3] found that 20% of those they surveyed sustained significant traumatic injuries requiring medical attention and limitations in activity during the preceding year.

Because of the tremendous growth of off-road biking and the potential importance of the injuries incurred, we examined the pattern of injuries to off-road cyclists as part of a larger study of bicycle injuries and helmet use.

METHODS

DESIGN

This study was part of a larger study of bicycle injuries and helmet effectiveness.[4] Data collected as part of this larger study gave us the opportunity to examine a relatively large series of injuries to off-road cyclists. Subjects were recruited from seven Seattle area hospitals: Central and Eastside Hospitals of Group Health Cooperative of Puget

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From the Harborview Injury Prevention and Research Center, Department of Pediatrics (F.P.R., D.C.T., V.R.), and Department of Epidemiology (F.P.R.), University of Washington; and the Department of Preventive Care, Group Health Cooperative of Puget Sound (R.S.T.), Seattle, Washington. Requests for reprints should be addressed to Frederick P. Rivara, MD, MPH, Harborview Injury Prevention and Research Center, 325 Ninth Ave, Box 359960, Seattle, WA 98104-2499.

Sound, a large staff-model HMO; Harborview Medical Center, a Level I Regional Trauma Center; University of Washington Medical Center, a tertiary university hospital; Overlake Medical Center, a community hospital serving the east side of Seattle; Children's Hospital and Medical Center, a tertiary children's hospital in Seattle; and Mary Bridge Children's Hospital, a community and secondary level children's hospital in Tacoma, Washington. The records of the King and Pierce counties medical examiners' offices were also examined during the study period to detect out-of-hospital deaths from bicycling.

Subject Identification

Injured cyclists were identified by regular surveillance of emergency department logs or treatment forms in each of the seven hospitals at least 1 to 2 times per week during the study period, March 1, 1992, through August 31, 1994. Any person who was injured while on a bicycle (whether moving or not) was eligible for the study. Pedestrians who were injured by a bicycle were not included. Only child passengers on bicycles were included. Also excluded were cyclists sustaining injuries from assault while riding a bicycle.

Data Collection

Detailed questionnaires were sent to all study subjects. Those who did not respond were telephoned approximately 14 days after the initial mailing. The questionnaires included inquiries about the demographic characteristics of the subjects, cycling experience, circumstances of the crash, self-reported speed, severity of damage to the bike, ownership and use of helmets, and self-reported helmet fit. Helmets were classified as hard shell if they were manufactured with a thick plastic shell over a polystyrene liner; thin shell if the shell was very thin, flexible plastic over the liner; and no shell if there was no or only a cloth outer shell over the liner.

Since the majority of bicycles sold currently in the United States are off-road bikes, the type of bicycle could not be used to identify subjects injured while riding off-road. Instead, we used the reported location of the crash to identify these subjects. This included any cyclist reporting injury while riding off-road, off-road trails, forest or logging roads, and forested or dirt areas of city parks.

Information on the injuries was gathered from the emergency department, hospital, and medical examiner's records. These records were abstracted by trained abstractors, using a standardized form. The Abbreviated Injury Scale (AIS)[5] was used to assess the severity of injuries, and an Injury Severity Score (ISS)[6] was calculated. This was done using a commercial computer program, TRI-CODE,[7] which converts textual injury descriptions into *International Classification of Diseases, 9th Revision* (ICD-9) codes and AIS codes and calculates AIS scores for each injury and an overall ISS score. We used the TRI-CODE program to provide consistent and accurate injury coding and injury severity scoring, given that the data were abstracted from seven different hospitals. Injuries with ISS scores ≥ 8 were defined as severe, and those with ISS scores ≤ 8 were nonsevere.

Data Analysis

Data were double key-entered, cleaned, and analyzed using SAS software.[8] Univariate analyses were conducted to examine associations between type of cycling and injury severity, crash characteristics, and demographic characteristics. Odds ratios (OR) were used to express the likelihood of these findings in off-road cyclists, compared with other riders unless otherwise indicated. Odds ratios and 95% confidence limits were calculated using the maximum likelihood method and the Cornfield method, respectively. Unconditional logistic regression was used to calculate odds ratios adjusted for a number of covariates.

RESULTS

During the study period, there were 3849 eligible subjects treated in the emergency departments of the seven study hospitals. In addition, 5 subjects died from bicycle-related injuries before arriving at the emergency department and were identified from the medical examiner's records. We obtained completed questionnaires and injury data on 3390 subjects for an overall response rate of 88.0%.

There were 127 cyclists who reported that they were injured while riding off-road, accounting for 3.7% of injured cyclists. Nearly three fourths of the off-road injured cyclists were 20 to 39 years old. The characteristics of the off-road cyclists were compared with the 3263 bicyclists who were injured on

TABLE 1

Characteristics of Persons Involved in Off-road Biking Injuries Compared with Persons Injured in Other Biking Crashes (N=3390)

Characteristic	Off-road Cyclists (n=127) No. (%)	Other Cyclists (n=3263) No. (%)	*P* Value*
Sex			.001
Male	110 (86.6)	2328 (71.3)	
Female	17 (13.4)	935 (28.7)	
Age, y			.001
<6	0 —	253 (7.8)	
6-12	4 (3.1)	1212 (37.1)	
13-19	20 (15.7)	524 (16.1)	
20-39	93 (73.2)	936 (28.7)	
≥40	10 (7.9)	338 (10.4)	
Frequency of riding†			.024
Daily	63 (50.5)	2039 (62.7)	
Weekly	48 (38.1)	836 (25.7)	
Monthly	8 (6.3)	149 (4.6)	
<Monthly	2 (1.6)	72 (2.2)	
Seldom	6 (4.7)	157 (4.8)	
Miles cycled per week‡			.4
<10	26 (22.0)	307 (21.3)	
10-20	31 (26.1)	298 (20.6)	
21-50	28 (22.5)	410 (28.4)	
>50	33 (28.6)	429 (29.7)	

*P values indicate the significance of differences in distribution between cases and controls, by chi-square analysis.
†For all bicycling, adults and children.

pavement or other similar surfaces; the results are shown in Table 1. The off-road cyclists were more likely to be male, nearly three times as likely to be aged 20 to 39 years, and were somewhat less likely to report that they rode daily. They did not differ from the other adult riders, however, in the number of miles ridden per week.

Most commonly, riders hit an obstacle in the trail, causing the crash. As shown in Table 2, helmets were used by 80.3% of off-road cyclists and 49.5% of the other cyclists at the time of the crash (OR, 4.16, 95% CI, 2.62 to 6.64). Off-road cyclists were nearly two and one half times as likely to be wearing thinshell helmets and only one third as likely to be wearing hardshell helmets; there were no differences in the proportion of cyclists in the two groups using helmets without shells. Approximately two of five helmets in both groups of cyclists were visibly damaged in the crash.

Overall, the body parts injured (Table 3) and the types of injuries sustained (Table 4) were similar in the two groups of riders. There were, however, some notable exceptions. Off-road cyclists were about half as likely to sustain head and face injuries (Table 3). They were less likely to sustain abrasions and be treated for dental injuries than were other riders (Table 4). The majority of injuries were not severe, with only 4% of off-road cyclists having ISS scores > 8 and only 6.3% requiring hospital admission. This is comparable to 6.8% of the other riders with ISS scores >8 and 9.4% requiring hospitalization.

One cyclist, who was unhelmeted and riding off-road, died of a brain injury. Only 14 off-road cyclists had head injuries, thereby limiting our ability to analyze helmet effectiveness in

TABLE 2

Helmet Characteristics of Off-road Cyclists and Other Cyclists (N=3390)

Characteristic	Off-road Cyclists (n=127) No. (%)	Other Cyclists (n=3263) No. (%)	OR*	(95% CI)
Helmet use				
Yes	102 (80.3)	1615 (49.5)	4.16	(2.62-6.64)
Type of helmet				
Hardshell	28 (27.5)	815 (51.3)	0.37	(0.23-0.6)
Thinshell	48 (47.1)	447 (28.2)	2.40	(1.65-3.69)
No shell	22 (21.6)	310 (19.5)	1.18	(0.70-1.97)
Other/unknown	4 (2.9)	16 (1.0)	—	—
Visible damage to helmet	43 (42.2)	590 (37.1)	1.23	(0.81-1.89)

*OR denotes odds of these characteristics in off-road cyclists compared with other riders.

TABLE 3

Injuries to Off-road Cyclists and Other Cyclists (N=3390)

Injury Location	Off-road Cyclists (n=127) No.	(%)	Other Cyclists (n=3263) No.	(%)	OR*	(95% CI)
Head injury†	14	(11.0)	742	(22.7)	0.42	(0.23-0.76)
Face	16	(12.6)	684	(21.0)	0.43	(0.25-0.74)
Neck	4	(3.2)	93	(3.0)	1.10	(0.9-2.98)
Upper extremity	72	(56.7)	1949	(59.7)	0.87	(0.60-1.26)
Lower extremity	54	(42.5)	1537	(47.1)	0.81	(0.56-1.17)
Thorax, abdomen or pelvis	17	(13.4)	561	(17.2)	0.75	(0.43-1.28)
No injury	0	—	27	(0.8)	—	—

*OR denotes odds of these injuries in off-road cyclists compared with other riders.
†Head injury includes superficial lacerations, abrasions, and bruises on the scalp, forehead, and ears as well as skull fractures, concussions, cerebral contusions, and lacerations and all intracranial hemorrhages.

off-road crashes. Given these small numbers, helmets appear to be quite effective in decreasing the risk of head injury in off-road cycling crashes (OR for head injury in helmeted vs unhelmeted cyclists = 0.39, 95% CI, 0.10 to 0.65).

DISCUSSION

The majority of injuries to off-road cyclists were minor, with only 4% of patients having ISS scores greater than 8. In the four prior studies of off-road cyclist injuries in the literature, it was reported that 65% of the injuries were minor.[2,3,9,10] The results of our study indicate that extremity injuries accounted for only one half of the total, while other authors have found that 80% to 90% of the injuries are to extremities.

Only 11% of our subjects had head injuries, and only 3% brain injuries, probably because helmets are effective and because 80% of riders were helmeted at the time of their crash. From our data, it appears that off-road cyclists are more than four times as likely to be helmeted than are other riders, contributing to their relatively low rate of head injuries. Similar rates of helmet use have been reported by prior authors with similar proportions of injuries involving the head.[2,3] More off-road cyclists than other riders wore thinshell helmets, perhaps because these helmets are newer, more attractive, and may be more appealing to the serious, young male adult cyclists who ride off-trail. In addition, almost all adult helmets currently sold are thinshell,

TABLE 4

Type of Injuries Sustained by Off-road Cyclists and Other Cyclists (N=3390)

Type of Injury	Off-road Cyclists) (n=127) No.	(%)	Other Cyclists) (n=3263) No.	(%)	OR*	(95% CI)
Abrasions	60	(45.7)	1998	(61.2)	0.56	(0.39-0.79)
Contusions	35	(26.8)	1202	(36.8)	0.79	(0.53-1.18)
Lacerations	51	(40.2)	1228	(37.6)	1.09	(0.75-1.59)
Fractures/dislocation	32	(25.2)	859	(26.3)	0.94	(0.61-1.44)
Sprains	19	(14.7)	401	(12.4)	1.24	(0.73-2.09)
Dental	2	(1.6)	204	(6.3)	0.24	(0.03-.89)
Internal organ/ vessel/nerve	4	(3.2)	67	(2.1)	1.41	(0.37-3.86)
Brain†	4	(3.2)	199	(6.1)	0.50	(0.13-1.35)
Other	12	(9.4)	111	(3.4)	2.96	(01.51-5.71)
No injury	—	—	27	(0.8)	—	—

*OR denotes odds of these injuries in off-road cyclists compared with other riders.
†Brain injury includes a diagnosis of concussion or more serious intracranial injury or hemorrhage (cerebral lacerations/contusions, and subarachnoid, subdural, and extradural).

and most off-road cyclists are adults. Regardless of the type, helmets appear to be quite effective in preventing head injuries in the off-road setting, despite the unevenness of the terrain and the risk for injuries from objects such as sticks that can penetrate the helmet liner. Other factors may account for the lower rate of head and neck injuries in off-road cyclists as well. Off-road cycling generally involves somewhat lower speeds than other cycling. In addition, off-road cyclists are very unlikely to encounter a moving motor vehicle.

Surprisingly, only 12.6% of off-road cyclists had facial injuries, significantly lower than the proportion for other riders. Given the type of terrain commonly ridden and the potential to encounter branches, trees, and other objects capable of producing facial trauma, the proportion of facial injuries appears low. Full-face helmets for off-road cycling are now available, although none were worn by subjects in our study. The low rate of facial injuries in this group, however, may be due to the high rate of helmet use. Another study conducted by the authors[11] indicates that regular bike helmets do offer substantial protection to the face, particularly to the upper and mid-face, where helmet use is associated with a 65% reduction in injuries.

CONCLUSIONS

While rates of injuries appear to be high in off-road cycling, the majority of these injuries appear to be relatively minor. Off-road cyclists are less likely to have head injuries than other cyclists, and this may be accounted for at least in part by the higher rate of helmet use in this group.

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REFERENCES

1. Pfeiffer RP, Kronisch RL. Off-road cycling injuries. An overview. Sports Med 1995; 19:311-25.
2. Chow TK, Bracker MD, Patrick K. Acute injuries from mountain biking. West J Med 1993; 159:145-8.
3. Kronisch RL, Rubin AL. Traumatic injuries in off-road bicycling. Clin J Sports Med 1994; 4:240-4.
4. Thompson RS, Rivara FP, Thompson DC. Effectiveness of bicycle helmets: a case-control study of 3390 injured cyclists. JAMA 1996; 276:1968-73.
5. Association for the Advancement of Automotive Medicine. The Abbreviated Injury Scale, 1990 Revision. Des Plaines, Ill: Association for the Advancement of Automotive Medicine, 1990.
6. Baker SP, O'Neill B, Haddon W, Long WB. The Injury Severity Score: a method for describing patients with multiple injuries and evaluating emergency care. J Trauma 1974; 14:187-96.
7. TRI-CODE 5.0 personal computer injury coding software. Tri-Analytics, Inc, Bel Air, Md. Des Plaines, Ill: Association for the Advancement of Automotive Medicine, 1989.
8. SAS Institute, Inc. SAS language and procedures: usage. 1st ed. Version 6. Cary, NC: SAS Institute, Inc, 1989.
9. Pfeiffer RP. Injuries in NORBA Pro/Elite category off-road bicycle competitors. Cycling Sci 1993; (5):21-4.
10. Pfeiffer RP. Off-road bicycle racing injuries—the NORBA Pro/Elite category: care and prevention. Clin Sports Med 1994; 13:207-18.
11. Thompson DC, Nunn ME, Thompson RS, Rivara FP. A case-control study of the effectiveness of bicycle safety helmets in preventing serious facial injury. JAMA 1996;.276:1974-5.