A Case-Control Study of the Effectiveness of Bicycle Safety Helmets in Preventing Facial Injury

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Abstract: In a case-control study we sought to assess the potential effectiveness of helmets in preventing facial injuries. Our study included 212 bicyclists with facial injuries and 319 controls with injuries to other body areas, who were treated in emergency rooms of five Seattle area hospitals over a one-year period. Using regression analyses to control for age, sex, education and income, accident severity, and cycling experience we found no definite effect of helmets on the risk of serious facial injury (odds ratio 0.81; 95 percent confidence interval = 0.45, 1.5), but protection against serious injuries to the upper face (odds ratio 0.27; 95% CI = 0.1, 0.8). No protection was found against serious injuries to the lower face. The independent effect of helmet use on facial injury was difficult to isolate due to the association of head and facial injuries.

Our results suggest that bicycle helmets as presently designed may have some protective effect against serious upper facial injuries. (*Am J Public Health* 1990;80:1471–1474.)

Introduction

Recently we showed that bicycle helmets reduce the risk of head injury by 85 percent.[1] Facial injuries in the population we studied occur at nearly identical rates (43 per 100,000) as head injuries (45 per 100,000) in bicyclists and can be serious. Bicycle crashes were found to account for 7.1 percent of all facial fractures treated in a large Swedish University hospital over a three-year period.[2]

There are no reported studies on the effectiveness of bicycle helmets in altering the risk of facial injury. Several reports suggest facial injuries are decreased in helmeted motorcyclists and moped riders,[3–5] but motorcycle and moped helmets generally have face pieces whereas traditional bicycle helmets have no face pieces.

The present case control study describes facial injuries resulting from bicycle crashes and evaluates the effect of bicycle helmets on the risk of these injuries.

Methods

Data for the present study were collected as part of a case control study of head injuries resulting from bicycle crashes. The methods have been described in detail elsewhere.[1] In brief, the study was conducted by emergency room surveillance at five major Seattle area hospitals: the Central and Eastside Hospitals of Group Health Cooperative (GHC) of Puget Sound, a large staff model health maintenance organization; University Hospital of the University of Washington; Harborview Medical Center, a regional Level I trauma center; and Overlake Hospital, a community hospital caring for a large proportion of the trauma to the east of Seattle. The records of the medical examiner's office were examined for the study period to ascertain any cyclist deaths occurring at the scene of a crash.

Definitions

Cases were defined as bicyclists who had suffered a facial injury in a bicycle crash and who sought treatment at the emergency room of one of the five study hospitals during the one-year study period December 1, 1986 through November 30, 1987. Facial injury was defined as injury to the area of the face beginning with the eyebrows and extending to the chin, mouth, and teeth. Injuries to the forehead and skull were classified as head injuries and those without concurrent facial injuries were excluded from the facial injury case group.

To address possible overascertainment of minor facial injuries among those individuals who seek care for more serious concomitant injuries, such as head injuries, we used only cases with more serious facial injury, defined as lacerations, fractures of the facial bones, and fractures of the teeth.[6,7]

Patients with serious facial injury were divided into two groups: the upper facial region included the midface, nose and eye/orbit area, the region where helmets would be expected to have the greatest protective effects; the lower facial region included the mouth and chin.

The case groups formed by the above definitions contained bicyclists who had injuries to both the head and facial regions and those who had face injury without concomitant head injuries. It is difficult to separate the possible effect of an intervention (helmet) on different injuries particularly when there is close anatomical association (head and face). We felt the most appropriate definition of a facial injury case group would include all crashing cyclists who sustained a facial injury regardless of the presence of injuries to other areas of the body.

The main comparison group (N = 319) was composed of bicyclists who sought care at the same five emergency rooms for bicycle related injuries other than to the face or head. Head injuries were excluded from the control group, since a cause and effect relationship between bicycle safety helmet use and head injury exists.

A population-based control group (N = 558) consisting of GHC member bicyclists who had experienced a crash in the last year was employed in ancillary analyses. Those under 15 years of age in this control group had significantly higher helmet usage rates at the time of the cycle crash (21.1 percent)

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as compared to the same age group from the emergency room controls (5.9 percent).[1]

Data Collection

As described elsewhere[1] emergency room cases and controls were identified by weekly surveillance of emergency room logs. All cases and controls were mailed an introductory letter and study consent form explaining the purpose of the study. Detailed questionnaires described earlier[1] were sent to each person with telephone follow-up of nonrespondents. Medical data on injuries was obtained by abstracting the emergency room records.

Statistical Analysis

The statistical package SASPC was used to evaluate descriptive information and prepare crude risk estimates. Unconditional logistic regression techniques were used to estimate the relative risk of facial injury associated with helmet use and to control for multiple confounding factors.[8] The Egret software package was used to carry out logistic regression. The Mantel Haenszel procedure was used to compute age stratified odds ratios in instances where cell sizes were small or included zero.[9]

Results

Seven hundred seventy-six people were treated in the five hospital emergency rooms for bicycling injuries during the study period. Two hundred fifty-six individuals had facial injuries and were potential cases; 368 had injuries involving other parts of the body and were potential emergency room controls. An additional 151 emergency room controls with head injuries were excluded from the analyses. Overall response rate to our questionnaire was 85.0 percent (82.8 percent of cases and 86.7 percent of controls) resulting in 212 cases and 319 emergency room controls available for analysis.

The type and location of the injuries are presented in Table 1. Of the 212 individuals with facial injuries, 136 (64.2 percent) had injuries to one area of the face, 53 (25 percent) had injuries to two areas of the face, 18 (8.5 percent) had injuries to three areas, and 2.3 percent had injuries to four or five areas of the face.

There were three deaths in the study, all of whom were adults with severe head injuries in addition to facial injuries. No bicyclists died at the crash scene.

Demographic Characteristics and Helmet Use of Cases and Controls

As shown in Table 2, cases were younger than controls. There were no important differences between case and control groups by sex, education of head of household, or household income. The distribution of helmet use at time of crash differed between cases and controls. Individuals with any type of facial injury were less likely to have been using helmets at the time of the crash than the control group. There was substantially lower helmet usage among the youngest cyclists. Helmet ownership rates followed a pattern similar to usage rates. Approximately 90 percent of the helmets were of the hardshell variety.

TABLE 1—Type and Location of Facial Injuries Experienced (N = 212 individuals)

	Number and Type of Injury		
Location	Abrasion/ Contusion	Laceration	Fracture
Eye/Orbit	23	8	4 (orbit)
Nose	20	12	4
Midface	72	18	7 (zygoma)
Mouth	12	20	33 (teeth & maxilla)
Chin	29	52	4 (mandible)

Notes: Injuries to one area/location of the face are not mutually exclusive of injuries to other areas.
Types of injuries at each location are mutually exclusive.

Crash Characteristics of Cases and Control

Table 3 portrays various aspects of crash severity. Cases were more likely to have hit a stationary obstacle than were controls. Damage to the bicycle was somewhat more frequent for cases. Collisions with motor vehicles, self-reported bicycle speed at the time of crash, and the type of surface impacted was similar for both cases and controls. Cycling experience (kilometers ridden per week, data not shown) was significantly greater in control group.

Risk of Facial Injury Adjusted for Covariates

The focus of our study was to examine the association between bicycle safety helmet use and a set of successively more restrictive and biologically plausible outcomes: all facial injuries, serious facial injuries, and serious upper facial injuries.

The following variables were evaluated using logistic regression analyses: age, sex, cycling experience (kilometers per week cycled), severity (cause of crash, damage to cycle), education, income, and hospital. Only age, as a covariate, accounted for marked changes in computed odds ratios; therefore, we chose to use the simplest model adjusting only for the effects of age. There appeared to be no definite association between safety helmet use and all facial injuries (odds ratio 0.69; 95% CI = 0.41, 1.1) or serious facial injuries (odds ratio 0.81; 95% CI = 0.45, 1.5). When cases with only serious upper facial injuries were examined, a protective effect emerged (odds ratio 0.27; 95% CI = 0.1, 0.8).

Independent Effect of Helmet Use

The analysis of the association between bicycle safety helmet use and facial injury is difficult because some of the association demonstrated between helmet use and facial injury risk is due to the additional association of facial injury and head injury.

Ninety-eight (46.2 percent) of the 212 facial injury cases had a concurrent head injury; 48 (37.8 percent) of the 127 cases with serious facial injury (lacerations, fractured bones or teeth) had a concurrent head injury. The serious facial injury group included a total of 44 individuals with injuries to the upper facial region and 99 individuals with injuries to the lower face; 16 of those individuals had injuries to both regions of the face. Concurrent head injury was present in 27 (61.4 percent) individuals with serious upper facial injury, and in 31 (31.3 percent) of those with serious lower facial injuries.

A series of ancillary analyses were undertaken to attempt to isolate the effect of helmets on facial injuries. The age-adjusted odds ratio for all cases with concurrent head and face injuries (N = 98) was 0.4 (95% CI = 0.18, 0.83). However, when only serious lower facial injuries were examined, the age-adjusted odds ratio was 1.0 (95% CI = 0.6, 2.0) for cases with facial injury only (N = 114) 1.1, (95% CI = 0.57, 1.97).

Finally, we performed analyses utilizing the population control group of GHC cyclists experiencing a crash in the prior year to address the question of protective effect in crashing cyclists in general. Protective effects were found for

TABLE 2—Demographic Characteristics and Helmet Use of Cases and Controls

Characteristics	All Facial Injury Cases (N = 212)		Serious Facial Injuries (N = 127)		Serious Upper Facial Injuries (N = 44)		Emergency Room Controls (N = 319)	
	N	%	N	%	N	%	N	%
Sex								
Male	155	(73.1)	89	(70.1)	30	(68.2)	224	(70.2)
Female	57	(26.9)	38	(29.9)	14	(31.8)	95	(29.8)
Age (years)								
2–14	138	(65.1)	81	(63.8)	23	(52.3)	126	(39.5)
15–24	24	(11.3)	14	(11.0)	6	(13.6)	86	(27.0)
≥25	50	(23.6)	32	(25.2)	15	(34.1)	107	(33.5)
Education of Head of Household								
High School or less	36	(17.0)	17	(13.4)	5	(11.4)	39	(12.3)
College	116	(54.7)	72	(56.7)	25	(56.8)	168	(53.0)
Graduate school	50	(23.4)	31	(24.4)	13	(29.6)	91	(28.5)
Refusals & unknown	10	(4.7)	7	(5.5)	1	(2.3)	21	(6.6)
Household Income								
<$15,000	32	(15.1)	15	(11.8)	9	(20.5)	56	(17.6)
$15–$35,000	65	(30.7)	33	(26.0)	10	(22.7)	79	(24.8)
≥$35,000	89	(42.0)	62	(48.8)	20	(45.5)	138	(43.3)
Refusals & unknown	26	(12.3)	17	(13.4)	5	(11.4)	46	(14.4)
Wearing Helmet at Time of Crash	30	(14.2)	21	(16.5)	4	(9.1)	83	(26.0)

TABLE 3—Characteristics Contributing to Crash Severity

	Cases (N = 212)		Serious Facial Injuries (N = 127)		Upper Serious Facial Injuries (N = 44)		ER Controls (N = 319)	
	N	%	N	%	N	%	N	%
Cause of Crash								
Contact with moving motor vehicle	30	(14.2)	15	(11.8)	7	(15.9)	51	(16.0)
Contact with other moving objects[a]	16	(7.6)	9	(7.1)	2	(4.6)	40	(12.5)
Contact with stationary obstacle[b]	70	(33.0)	45	(35.4)	16	(36.4)	74	(23.2)
Bicycle malfunction[c]								
Riding unsafe bicycle	21	(9.9)	12	(9.4)	2	(4.6)	27	(8.5)
Falls and other	75	(35.3)	46	(36.3)	4	(9.1)	127	(39.8)
Nature of Surface Involved								
Paved (concrete, asphalt)	188	(88.7)	111	(87.4)	37	(84.1)	268	(84.0)
Gravel	14	(6.0)	10	(7.9)	3	(6.8)	21	(6.6)
Dirt/grass	10	(4.7)	6	(4.7)	4	(9.1)	30	(9.4)
Self-Reported Speed at Time of Crash								
Slow (<5 MPH)	70	(33.0)	42	(33.1)	16	(36.4)	96	(30.1)
Moderate (5–15 MPH)	73	(34.4)	46	(36.2)	18	(40.9)	123	(38.6)
Fast (>15 MPH)	48	(22.6)	28	(22.1)	10	(22.7)	87	(27.3)
Unknown	21	(9.9)	11	(8.7)	0	(0)		
Damage to Bicycle								
No	99	(46.7)	63	(49.6)	24	(54.6)	176	(55.2)
Yes	113	(53.3)	64	(50.4)	20	(45.6)	143	(44.8)

a) Bicycles, cars, pedestrians, animals
b) Parked cars, bumps, curbs
c) Chain fell off, flat tire, handlebars came off, no seat

serious upper facial injury; the age-adjusted odds ratio was 0.14 (95% CI = 0.04, 0.47). When facial injuries only were used as the case group, the odds ratio was 0.5, (95% CI = 0.3, 0.9).

Discussion

The results of this study are consistent in suggesting a protective effect of bicycle safety helmets on serious injuries of the upper facial region (lacerations and fractures of the midface, nose, eye/orbit). This conclusion has biological plausibility. The precise magnitude of the protective effect cannot be estimated, since it was not possible to completely disentangle protective effects against facial injury from the effects of head injury occurring concurrently in the same individual.

The significant association of head trauma and facial injury requires careful case and control definition. Head-injured patients were excluded from the emergency room control group because the head injury is directly related to the exposure (helmet use).[1] Their inclusion would have resulted in an underestimation of the protective effect of helmets on facial injuries by selecting for unhelmeted controls. This would be analogous to excluding individuals with lung cancer from the control group in a study of the association of smoking with heart disease.

The most representative facial injury case group is composed of all cyclists with facial injuries including those with injuries to the head or other portions of the body. Equal ascertainment of facial injuries among injured cyclists is important. The presence of a concurrent head injury increases the likelihood that an injured individual seeks medical attention and thus becomes a case. Since head injury is so strongly associated with the lack of helmet use, such a bias can result in an overestimation of the protective effect of helmets by potentially increasing the number of unhelmeted cases. Ascertainment bias was minimized by defining a case group with serious facial injury, i.e. injury serious enough to necessitate medical attention independently of the presence of a head injury. This analysis suggests no association between helmet use and the risk of facial injuries.

We attempted in the analysis to determine the independent effect of bicycle safety helmets on facial injuries. Although there was no effect of helmets on facial injury alone (cases with concurrent head injury excluded) when the emergency room controls were used as comparison, use of the same case group with the population-based control group suggested some protective effect of helmet use (odds ratio 0.5; 95% CI = 0.3, 0.9). This is a more conservative analysis since individuals with head injury and thus low chance of helmet use were excluded. If a helmet effect is present, one would expect to show this effect using the population controls as the comparison group. This is a less seriously injured group of cyclists and has a higher rate of helmet use than the emergency room controls. The demonstration of some protective effect with facial injuries only is important, since it indicates effect on facial injury separate from head injury effects.

Current bike helmets do not have a face bar; consequently one would expect little or no protection against injuries to the lower face. The negative results for serious lower facial injury lend credence to the positive protective effect found for serious upper facial injury.

The strong association between helmet use and decreased risk for serious upper facial injuries is likely explained by a combination of factors: the association of upper facial injuries with head injuries, (61.4 percent of those with serious upper facial injuries) and an actual protective effect of helmets for upper facial injury.

A potential limitation of this study is that unmeasured factors not taken into account in our analysis may have placed controls at lesser risk for striking their faces at the time of the crash.

In conclusion, our study suggests that bicycle helmets as presently designed have little or no effect on the overall risk of facial injury, but appear to provide some protection for serious upper facial injuries. The magnitude of this effect is not precisely quantifiable. This study also illustrates the methodologic problems of isolating exposure or intervention effects on one injury type when multiple simultaneous injuries result from a single event. This problem is inherent to injury research, but much less likely in cancer or cardiovascular investigations.

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