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Injury patterns in cyclists attending an accident and emergency department: a comparison of helmet wearers and non-wearers

C Maimaris, C L Summers, C Browning, C R Palmer

Abstract

Objectives—To study circumstances of bicycle accidents and nature of injuries sustained and to determine effect of safety helmets on pattern of injuries.

Design—Prospective study of patients with cycle related injuries.

Setting—Accident and emergency department of teaching hospital.

Subjects—1040 patients with complete data presenting to the department in one year with cycle related injuries, of whom 114 had worn cycle helmets when accident occurred.

Main outcome measures—Type of accident and nature and distribution of injuries among patients with and without safety helmets.

Results—There were no significant differences between the two groups with respect to type of accident or nature and distribution of injuries other than those to the head. Head injury was sustained by 4/114 (4%) of helmet wearers compared with 100/928 (11%) of non-wearers ($P=0.023$). Significantly more children wore helmets (50/309 (16%)) than did adults (64/731 (9%)) ($P<0.001$). The incidence of head injuries sustained in accidents involving motor vehicles (52/288 (18%)) was significantly higher than in those not involving motor vehicles (52/754 (7%)) ($\chi^2=28.9$, $P<0.0001$). Multiple logistic regression analysis of probability of sustaining a head injury showed that only two variables were significant: helmet use and involvement of a motor vehicle. Mutually adjusted odds ratios showed a risk factor of 2.95 (95% confidence interval 1.95 to 4.47, $P<0.0001$) for accidents involving a motor vehicle and a protective factor of 3.25 (1.17 to 9.06, $P=0.024$) for wearing a helmet.

Conclusion—The findings suggest an increased risk of sustaining head injury in a bicycle accident when a motor vehicle is involved and confirm protective effect of helmet wearing for any bicycle accident.

Introduction

The incidence of bicycle related injury and the resulting morbidity and mortality have serious economic implications in terms of provision of health care and lost working time. Admissions to hospital and deaths from bicycle related trauma are usually due to head injury.¹ Several studies of the use of cycle safety helmets report that they reduce head injuries,²⁻⁹ and in a case control study the risk of head injury was significantly reduced if a helmet was worn.² The wearing of approved helmets by cyclists has been made compulsory in several states in Australia and the United States and recently in New Zealand. However, the prevalence of wearing cycle helmets remains low in Britain and in other countries,³⁻¹⁰ despite various

campaigns aimed at encouraging their use, especially among the vulnerable teenage population.⁴ Some authors have argued that cycle helmets are not effective in protection in collisions with motor vehicles,¹¹⁻¹³ while others have maintained that they are effective.¹⁴⁻¹⁶ It has also been suggested that evidence of a lower risk of head injury in cyclists wearing helmets is flawed because such cyclists may be more cautious.^{10,11} But, again, others have claimed that such cyclists feel less vulnerable and ride less cautiously, so that they are more likely to have an accident.¹³

The aims of this study were to assess all patients presenting in an accident and emergency department with bicycle related injuries and to compare the types of injuries sustained by those who wore helmets with the injuries of those who did not.

Patients and methods

From 1 January 1992 to 31 December 1992 we prospectively collected data on all patients who attended the accident and emergency department of Addenbrooke's Hospital as a result of a bicycle accident. The information collected included age and sex, date and place of accident, and the nature of the accident—whether the accident involved a moving motor vehicle (car, lorry, bus, or motorcycle) or cycle, a pedestrian, or a stationary object or whether it was the result of simply falling off the machine. We also recorded details of helmet use at the time of the accident and helmet ownership; details of the injuries sustained, including the presence of a head injury; and details on follow up of patients, including the length of stay for those admitted to hospital.

In this study we recorded head injury if there was evidence of skull fracture, brain injury shown by computed tomography, or if loss of consciousness or post-traumatic amnesia was associated with important postconcussion symptoms (defined as persistent headaches, dizziness, nausea, vomiting, tiredness, or lack of concentration that required time off school or work or did not allow immediate resumption of normal activities). We did not regard simple scalp abrasions, lacerations, or contusions not associated with loss of consciousness or postconcussion symptoms as head injuries.

Patients admitted to hospital were followed up through hospital records, and any patient who had sustained a head injury but was not admitted was followed up by telephone inquiry for evidence of postconcussion symptoms. The assessors (CLS and CM) knew whether patients had worn helmets, but questions were standardised to minimise possible bias.

STATISTICAL METHODS

Differences in the incidence of injuries between helmet wearers and non-wearers at the time of the

Accident and Emergency Department, Addenbrooke's Hospital, Cambridge CB2 2QQ
C Maimaris, consultant
C L Summers, senior registrar
C Browning, senior house officer

Department of Community Medicine, Institute of Public Health, University of Cambridge, Cambridge CB2 1TN
C R Palmer, medical statistician

Correspondence to: Mr C Maimaris.

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accident were assessed with χ^2 tests with continuity correction and with a 95% confidence interval estimate of the odds ratio.¹⁷ In a sample of more than 1000 patients with an anticipated 10% wearing helmets there is at least 90% power to detect a (one-sided) difference in injury rates of 5% in helmet wearers against 10% in non-wearers at the 0.01 level of significance.

Hierarchical log linear modelling¹⁸ was used to describe significant interactions among those features of potential relevance to sustaining various injuries including those to the head. These included the patient's age and sex, if the accident occurred in Cambridge or in the peak summer months (May to August inclusive), if a motor vehicle was involved, and if a helmet was worn. Further analyses included the nature and anatomical distribution of all injuries received, length of hospital stay if admitted, and whether a cycle helmet was owned but not worn at the time of the accident. Logistic regression¹⁷ was used to model the probability of sustaining a head injury after adjustments for important concomitant variables. All analyses were carried out with SPSS software.¹⁹

Results

Of the 1107 people attending the accident and emergency department during 1992 because of a cycle accident, complete data were available for 1040, of whom 114 were wearing a cycle helmet at the time of their accident. Two deaths occurred within 8-16 hours of hospital attendance; one due to an extensive head injury associated with a chest injury and the other mainly due to a high cervical spine injury, also associated with a head injury. Both patients had collided with motor vehicles, but neither had been wearing a safety helmet.

Table I shows that there was no significant difference between the two populations of cyclists (helmet wearers and non-wearers), in the type of accidents that they were involved in ($\chi^2=3.23$, $P=0.36$). Table II shows the nature of the injuries sustained. Most were soft tissue injuries only (abrasions, contusions, and lacerations), mainly in the limbs. Table III shows the sites of the injuries. There were no significant differences between the two groups of cyclists with respect to the nature and site of injuries sustained except in the incidence of head injury: the difference between helmet wearers (4/114 (4%)) and non-wearers

TABLE I—Nature of accidents experienced by cyclists* attending accident and emergency department. Values are numbers (percentages)

Accident involving	Helmet worn		Total
	Yes (n=114)	No (n=928)	
Moving motor vehicle†	28 (25)	260 (28)	288
Other bicycle	5 (4)	67 (7)	72
Pedestrian	1 (1)	19 (2)	20
Fall	80 (70)	582 (63)	662

*Data available on 968 patients.

†Includes car, lorry, bus, and motorcycle.

TABLE II—Nature of injuries sustained by cyclists attending accident and emergency department. Values are numbers (percentages)*

	Helmet worn		
Injury sustained	Yes	No	Total
<i>Injuries other than head injury</i>			
Multiple fractures or dislocations	1 (1)	9 (1)	10
Single fracture or dislocation	31 (31)	228 (28)	259
Soft tissue only	69 (68)	587 (71)	656
Total	101	824	925
<i>Head injury</i>			
Yes	4 (4)	100 (11)	104
No	110 (96)	828 (89)	938

*13 patients had no injuries.

TABLE III—Sites of injuries sustained by 1042 cyclists attending accident and emergency department. Values are numbers (percentages)* unless stated otherwise

Injury site	Helmet worn		Odds ratio (95% confidence interval)	P value†
	Yes (n=114)	No (n=928)		
Head	4 (4)	100 (11)	3.25 (1.16 to 9.06)	0.024
Face or neck	22 (19)	212 (23)	1.32 (0.77 to 2.26)	0.32
Trunk	11 (10)	48 (5)	0.54 (0.26 to 1.11)	0.092
Arm	56 (49)	418 (45)	0.90 (0.61 to 1.33)	0.59
Leg	31 (27)	231 (25)	0.90 (0.57 to 1.42)	0.65

*Percentages do not sum to 100 because of multiple injuries: helmet wearers had a mean of 1.088 injuries each, non-wearers had a mean of 1.087.

†Adjusted for accident involving a motor vehicle.

TABLE IV—Cross classification of helmet use and head injury according to age and if accident involved a motor vehicle

	Helmet worn				Total
	Yes		No		
	Head injury	No head injury	Head injury	No head injury*	
<i>Children (aged <16)</i>					
Motor vehicle involved:					
Yes	0	9	8	36	53
No	0	41	20	195	256
Total	0	50	28	231	309
<i>Adults (aged ≥16)</i>					
Motor vehicle involved:					
Yes	2	17	42	174	235
No	2	43	30	421	496
Total	4	60	72	595	731

*Age unknown for two cases not involving a motor vehicle.

(100/928 (11%)) was significant, with an odds ratio of head injury in unhelmeted cyclists of 3.32 (95% confidence interval 1.20 to 9.20).

Table IV gives further details of head injury according to the cyclists' age group and whether a motor vehicle was involved in the accident. A significantly higher proportion of children wore helmets (50/309 (16%)) than did adults (64/731 (9%)) ($\chi^2=10.7$, $P<0.001$). A greater proportion of accidents involving motor vehicles resulted in head injuries (52/288 (18%)) than did other accidents (52/754 (7%)), with an odds ratio of 2.97 (95% confidence interval 1.97 to 4.48). No child who wore a helmet at the time of the accident sustained a head injury.

FOLLOW UP

Of the 102 patients with head injuries who survived, 68 were discharged from hospital but reported important postconcussion symptoms at telephone follow up; only two of these were wearing helmets. Of the remaining 34 patients, 32 were admitted predominantly for head injuries. Thirteen patients were detained for overnight observation only, and 14 stayed less than five days. Of the five patients who stayed more than five days as a result of a head injury (range of stay 7-29 days), four patients had skull fractures—two associated with cerebral contusions and one with an acute subdural haematoma. The fifth patient had a large chronic subdural haematoma that required evacuation. The two patients kept in hospital for treatment of other injuries (chest and orthopaedic injuries) had worn cycle helmets and had sustained only concussive head injuries. Another 73 patients were kept in hospital for treatment for musculoskeletal injuries (mainly fractures) other than to the head: 10 (14%) had been wearing a helmet and 63 (86%) had not. The average stay in hospital was 4.6 days (range 1-37).

MODELLING OF INTERACTIONS

The figure shows the model derived from hierarchical log linear analysis of the results, with backwards

elimination of the variables listed in table IV together with yes or no variables (for sex and whether the accident occurred in Cambridge and in summer).

Graphical representation of best log linear model (see text for details). P values associated with dropping each term from model

Direct lines between variables indicate significant interactions. As noted above, there was a strong relation between head injury and helmet wearing and between head injury and involvement of a motor vehicle. Most children's accidents occurred during the summer holidays (173/320 (54%)) whereas only 302/780 (39%) of adult accidents occurred during the same period (using all available data). Only 93/477 (19%) of summer accidents involved motor vehicles whereas the proportion for the rest of the year was 198/624 (32%). Adults were significantly more likely than children to be involved in accidents taking place in Cambridge (672/776 (87%) *v* 198/318 (62%)) or with a motor vehicle (236/780 (30%) *v* 55/319 (17%)). There were 686 male and 356 female patients, but sex, being unconnected, was important only as a main effect in the model and did not interact significantly with any variable.

Multiple logistic regression of the probability of sustaining head injury, with adjustments for the same variables as in the analysis above (except for substituting a four category variable for age group), showed that only two variables were significant in a stepwise analysis: a motor vehicle being involved and wearing a helmet. The mutually adjusted odds ratios were a risk factor of 2.95 (95% confidence interval 1.95 to 4.64, $P < 0.0001$) for motor vehicle involvement and a protective factor of 3.25 (1.17 to 9.06, $P = 0.024$) for wearing a helmet.

RISK TAKING BEHAVIOUR

Table I shows that helmet wearers were just as likely to be in accidents involving a motor vehicle as non-wearers (28/114 (25%) *v* 260/928 (28%), $\chi^2 = 0.45$, $P = 0.50$). Other than head injury, there were no significant differences between helmet wearers and non-wearers in the nature of the injuries sustained, the anatomical regions injured, and type of follow up (discharge or appointment at a fracture clinic). Table V lists the numbers of head injuries according to a possible surrogate for risk taking behaviour, namely ownership of helmet. Neither Pearson's χ^2 test nor the Mantel-Haenszel test for linear association was quite significant (P values of 0.13 and 0.054 respectively). Indeed both 95% confidence intervals for differences involving the group who owned but did not wear a

helmet included zero, but the difference in head injury rate between those who owned a helmet (8.1% for non-wearers *v* 3.5% for helmet wearers) was probably not significant largely because of the small sample size.

Discussion

Over 30 000 cycle accidents were reported to the police in 1990 in Britain, but since there is considerable underreporting of cycle injuries²⁰ the total number of cycle injuries is much higher. Cambridgeshire has the highest casualty rate for cyclists in England (over 2.5 times that for Britain),²¹ with Cambridge itself having the highest rate (34.5 per 10 000 people).²² In 1992, 307 cycle accidents were reported to the police that occurred in Cambridge,²² whereas our study included 872 patients who had had a cycling accident in Cambridge. If the same proportion of underreporting occurs throughout the country we estimate that there are about 90 000 cycle related injuries annually in Britain. There are an estimated 40 000 regular cyclists in Cambridge out of 100 000 residents. We estimate that one in 40 cyclists will be involved in a cycle accident and seek help in our accident and emergency department each year.

HEAD INJURY

Considerable mortality and morbidity is caused by head injury in cycle accidents. In 1985, 296 pedal cyclists were killed,²³ and deaths after cycle accidents are nearly always caused by head trauma.²⁴ Two studies have shown that more than two thirds of admissions after bicycle accidents were because of head injury.^{24,25} Head injuries that are initially thought to be minor may later prove more serious. In this study we excluded from the definition of head injury all facial and other injuries that cannot be prevented by a cycle helmet. We also excluded simple head lacerations (which can be prevented by helmets) not associated with altered consciousness, or important postconcussion symptoms. Thus, head injuries in this study were moderate, severe, or fatal. The 10% incidence of head injuries in patients with bicycle related injuries in our study is lower than the 32% reported in another study,²⁶ probably because of our definition of head injury. Our study showed that the odds of head injury were significantly reduced, by a factor of three, by wearing a cycle helmet, and the protective effect of wearing a helmet was present in all ages and all types of accidents, including motor vehicle accidents. We also found that helmet wearers sustained less severe head injuries. All the patients with skull fractures and severe brain injury, including the two deaths, had not been wearing helmets.

SAFETY IN TOWNS AND CITIES

Most cycle accidents occur in urban areas, where speed of traffic is under 40 mph, with fewer (10%) accidents occurring in rural areas, where a speed limit of 60 mph applies. In our study 80% of the patients (including the two deaths) had accidents in Cambridge. Most cycle accidents involving motor vehicles also occur in urban areas where lower speed limits apply and are therefore not expected to result in high speed collisions. Our study, like previous studies, showed a significantly increased incidence of head injuries sustained in accidents involving motor vehicles (half of all head injuries). This suggests that motor vehicle accidents involving cyclists are more serious than might be expected from urban speed limits and that the head is more vulnerable when cyclists collide with motor vehicles than when they fall off their machine. There is therefore a need for improved road engineering methods, traffic calming devices, more cycling facilities separating bicycles from other vehicles,

TABLE V—No (%) of head injuries sustained in cycling accidents according to ownership and use of cycle helmets

	Cycle helmet		
	Not owned	Owned but unworn	Worn
Head injury	50 (9)	7 (8)	4 (4)
No head injury	496	79	110
Total	546	86	114

Public health implications

- Each year about one in 40 of Britain's cyclists requires hospital treatment for injuries sustained in cycling accidents
- In this study 10% of such patients had serious head injuries
- Accidents that involved a moving motor vehicle were three times more likely to result in head injury
- Cyclists who wore safety helmets were just as likely to be involved in accidents but were three times less likely to have received head injury, and the head injuries sustained were much less severe
- The wearing of cycle helmets should be compulsory

and better education of all road users, particularly motorists, as well as helmet wearing to improve overall cycle safety.

ASSOCIATION BETWEEN VARIABLES

The model developed by using further analysis of our data demonstrated some other associations. Children were more likely to wear helmets than adults, had a higher incidence of accidents in summer months, and were less likely to be involved in motor vehicle accidents. Summer cycling accidents were less likely to involve motor vehicles, presumably because of improved weather conditions and longer day length as well as proportionately more children on bicycles. Our model was unable to show direct links between some factors. For example, helmet use and motor vehicle involvement were conditionally independent for each given age group and for whether a head injury was sustained. This absence of a difference in the rate of motor vehicle involvement for helmet wearers and non-wearers sheds some light on the vexed issue of risk taking behaviour since it means within each age group and head injury category helmet wearers and non-wearers were just as likely to be involved in the more serious type of accident. It has been argued that cyclists who own a safety helmet are more aware of the risks of cycling than those who do not. If helmet owners are safer riders than non-owners we would expect to see fewer injuries among cyclists who owned a helmet but were not wearing it. The 8.1% rate of head injury we observed in non-wearing helmet owners was near the rate for non-owners (9.2%) and much higher than the one for helmet wearers (3.5%). We also found no difference between helmet wearers and non-wearers in the types of injury other than head injury that were sustained and in the areas of the body injured. All these findings do not support claims made that helmeted cyclists are either more cautious²⁹ or take more risks.⁴

CONCLUSION

Our study has shown that wearing a helmet significantly decreases the risks of sustaining a head injury in all types of cycling accidents. However, the incidence of helmet wearing is low in Britain—10.9% in our study. Educational programmes have been effective in increasing helmet use to over 50% in some American cities, and this has been accompanied by a 75% reduction in the number of bicycle related head injuries requiring hospital care (F Rivara, personal communication). The early results of our educational programmes in Cambridge are encouraging: there has been an overall increase in helmet use for the past two

years, from 10% at the start of 1992 to over 16% in 1994. The introduction of legislation in Australia making cycle helmet wearing compulsory led to a fall in cycle use but resulted in a high level of compliance;²⁶ and we believe that such legislation should be introduced in Britain.

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Appendix

Generating class for best hierarchical log linear model

Simple effect	df	Change in likelihood ratio (χ^2)	P value
Head injury* Helmet	1	7.0	0.008
Helmet* Child	1	10.5	0.001
Motor vehicle involved* Summer	1	12.1	<0.001
Motor vehicle involved* Child	1	17.2	<0.0001
Child* Summer	1	27.1	<0.0001
Head injury* Motor vehicle involved	1	107.2	<0.0001

*Overall baseline $\chi^2=98.4$ 113 df, $P=0.835$.

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Correction

Collaborative overview of randomised trials of Antiplatelet therapy—1. Prevention of death, myocardial infarction, and stroke by prolonged antiplatelet therapy in various categories of patients

An authors' error occurred in this paper by the Antiplatelet Trialists Collaboration (8 January, pp 81-106). In Appendix 1 (p 98) the numbers of patients lost to follow up in the Danish low dose trial should have been two in the antiplatelet therapy group and one in the control group [not 46 and 44 respectively]. This change does not affect any of the analyses.