The pattern of injury in fatal pedal cycle accidents and the possible benefits of cycle helmets

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Abstract

Objective—To establish the number of fatal pedal cycle accidents occurring in the Sheffield and Barnsley area, UK, and to investigate the possible benefits of helmet wearing by cyclists.

Design—All medicolegal investigations into fatal road traffic accidents in the areas of Sheffield and Barnsley (total population 757 300) were reviewed to identify cases in which pedal cyclists had died. The necropsy reports of the cases were compared with those of an equal number of controls (pedestrians and motor vehicle occupants) which were matched by sex, age and year of death.

Results—28 deaths occurred in the last 15 years giving a mortality of 0.25/100 000 per annum, which is lower than the rate for the UK as a whole (0.43/100 000), but in five cases the accidents which eventually led to death occurred outside the area under study. These deaths represented 3.3% of road traffic deaths between 1979 and 1993. Over 80% of both cases and controls had severe head injuries, but the controls had suffered more fatal injuries to other parts of the body. None of the cyclists had worn helmets and, in order to assess the maximum possible benefit of helmet wearing, it was assumed that a helmet would have saved all those who only had head injuries. It was found that helmets might have saved 14 lives in 15 years. A similar calculation based on the controls suggests that if all pedestrians and vehicle occupants had worn helmets, 175 lives might have been saved in the same period.

Conclusions—There is no justification for compelling cyclists to wear helmets without taking steps to improve the safety of all road users.

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Key terms: cyclists; fatal accidents; safety helmet

Although there are many non-fatal cycle accidents, many of which are never reported, deaths are quite uncommon and there are few pathological studies of the injuries involved. Surveys in Florida,¹ Italy,² Brisbane,³ Sweden,^{4 5} and New Zealand⁶ all reported a high incidence of head injuries. None of these studies is from the United Kingdom, where the incidence of head injuries in fatal cycle accidents is estimated to be 70%.⁷ Furthermore none of the studies quoted allowed for the analysis of the effects of multiple injuries,

and without such information it is not possible to make an assessment of the possible value of cycle helmets in preventing death. In view of these gaps in our knowledge it was decided to examine the fatal cycle accidents in the Sheffield area in order to establish their frequency, the presence of any secular trend, and the possible benefits of helmet wearing as deduced from the pattern of injury.

Methods

The lists of all medicolegal investigations into deaths occurring in the area of Sheffield and Barnsley during the years 1979-1993 were screened to identify deaths arising as a result of road traffic accidents and the pedal cycle accidents were identified. For each death of a pedal cyclist a control was selected matched by sex and, as closely as possible, by age and year of death from among the pedestrians and motor vehicle occupants.

After the cases and controls had been identified, the necropsy reports were studied to establish the pathologists' conclusions as to the cause of death, the individual major injuries involving the skull, brain, spinal cord, thoracic cage, lungs, great vessels, and abdominal viscera. From the sites and nature of the injuries found in each case it was possible to identify deaths which might or which could not have been prevented had a helmet been worn.

Population figures estimated for mid 1993 were obtained from the Sheffield Health Authority. Figures for volumes of cycle traffic were provided by the Road Safety Unit of Sheffield City Council.

Results

A total of 28 necropsy reports relating to cycling deaths was found (table 1); these amounted to 3.3% of all traffic fatalities during the 15 year period studied. The annual number of road traffic deaths fell over this period of

Table 1 Numbers of road traffic deaths in Sheffield and Barnsley 1979-1993 in three-year periods (percentages in brackets).

Years	Pedestrians	Cyclists	Motor cyclists	Motor vehicle occupants	Totals
1979/81	96 (47)	4 (2)	44 (22)	60 (29)	204
1982/84	87 (50)	4 (2.3)	27 (15)	57 (33)	175
1985/87	74 (48)	6 (3.9)	24 (15)	51 (33)	155
1988/90	78 (50)	8 (5.1)	19 (12)	52 (33)	157
1991/93	63 (41)	6 (3.9)	17 (11)	68 (44)	154
Totals	398 (47)	28 (3.3)	131 (16)	288 (34)	845

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Table 2 Adults and juvenile (less than 18) cyclists killed in Sheffield and Barnsley 1979-93 (percentages in brackets)

Years	Juveniles	Adults	Total
1979-81	3 (75)	1 (25)	4
1982-84	2 (50)	2 (50)	4
1985-87	4 (66.6)	2 (33.3)	6
1988-90	4 (50)	4 (50)	8
1991-93	0 (0)	6 (100)	6
Totals	13 (46.4)	15 (53.6)	28 (100)

time and the most notable falls were amongst the pedestrians and motorcyclists, but the number and proportion of cyclists killed rose.

The mid-year estimated populations for 1993 was 757 300 for Sheffield and Barnsley. Therefore the fatality rate was 0.25 per 100 000 per annum. This compares with a total of 242 cycling deaths in the UK as a whole in 1991, which is a rate of 0.43/100 000.⁸ All but four of the victims were male and 46.4% were under the age of 18 years (table 2) but all those killed in the past three years were adults.

THE INJURIES

The anatomical distribution of the sites of serious injury is summarised in table 3. Similar numbers of cyclists and controls suffered serious head injuries, which included skull fractures, subdural and subarachnoid haemorrhage, cerebral contusions, lacerations, oedema, and in some cases uncal or cerebellar herniation. Five cyclists were killed without suffering significant head injuries; the causes of death in these five cases were transection of the spinal cord in four and a crush injury of the chest which ruptured the aorta in the fifth. The injuries in this last case were a result of crushing by the wheel of a heavy goods vehicle (HGV).

Eight cyclists suffered spinal injuries, six of which involved the cervical spine and among these there were two cases of atlanto-occipital dislocation. In the other two cases the dorsal spine was damaged and, in one of these, death occurred nine years after the accident as a result of the urinary complications of the injury to the dorsal cord.

These findings are in agreement with those of Fife *et al*¹ who found that, in cycling accidents, spinal injuries decrease in frequency further down the vertebral column.

Over one third of cyclists had major thoracic injuries. Seven had large haemothoraces; 11 had multiple fractures of the ribs and sternum, five had lacerations of the lung, and two had lacerations of the heart or disruption of the aorta. These severe injuries were not confined

Table 3 Number of fatal injuries found at necropsy in cyclists and controls (percentages in brackets)

	Cyclists	Controls (Pedestrians and vehicle occupants)
Cranial	23 (82)	24 (86)
Spinal	8 (29)	8 (29)
Thoracic	11 (39)	20 (71)
Abdominal	4 (14)	8 (29)

Table 4 The relation between the lethal injuries and the type of accident in 27 cases (percentages in brackets)

	Solo accidents	Impact with cars and motorcycles	Impact with HGVs and PSVs
No of cases	5	17	5
Cranial	4 (80)	15 (88)	3 (60)
Spinal	2 (40)	6 (35)	0
Thoracic	2 (40)	5 (29)	4 (80)
Abdominal	0	2 (12)	2 (40)

HGV, heavy goods vehicle; PSV, public service vehicle.

to cyclists who had collided with motor vehicles.

The only fatal abdominal injuries were four cases of laceration of the liver and all of these had been hit by motor vehicles.

THE RELATION BETWEEN THE INJURIES AND THE TYPE OF ACCIDENT

For one of the cases who died nine years after the original accident the details of the accident were not available; the findings in the remaining 27 cases are summarised in table 4.

In solo accidents, in which no other moving vehicle had been involved, the cyclists had fallen off and hit the road, street furniture, or a stationary vehicle. There were five accidents of this type and four of them had severe head injuries, two had fatal fractures of the cervical spine, and two had multiple fractures of the ribs with haemothoraces.

The group of 17 cases who had been hit by motor vehicles had the highest incidence of severe head injuries but they also had more widespread damage to the spine, chest, and abdomen.

Four cyclists had collided with HGVs and one with a public service vehicle (PSV). There were only three injuries in this group but there were massive injuries of the chest, abdomen, and limbs caused by crushing.

Discussion

During the period under study, the number of fatal cycle accidents was well below the national average for the United Kingdom, less than the rate of 0.5 in the USA,⁹ and well below the figure of 1.6 which may be calculated for northern Sweden.¹⁰ The true fatality rate is below the figure of 0.25 given above as, in some cases, the accident leading to death took place outside South Yorkshire, although the deaths occurred within the county. In one case, mentioned above, the accident had taken place before the beginning of the 15 year period studied. The obvious reason for this low fatality rate is that the area is hilly and this dissuades many people from cycling at all so that there are fewer cyclists at risk.

The total number of road deaths in the area studied fell throughout the 15 years (table 2) but the annual numbers and proportions of cyclists rose from 2% of the total to a peak of 5.1% in 1988/90, followed by a fall to 3.9% in the last three years. The changes in the number of cycle journeys made are shown in table 5. Using 1984, the earliest year for which counts

Table 5 The changes in the number of cyclists entering the centre of Sheffield, counted each autumn (1984 = 1.00).

Year	Factor based on 1984
1985	1.11
1986	1.45
1987	1.74
1988	1.51
1989	1.94
1990	1.88
1991	1.93
1992	1.93
1993	1.62

are available as a baseline, the number of cyclists nearly doubled by 1989 but since then there has been a fall back to 1.62 times the baseline figure of 1455 cyclists. This suggests that the trends in fatal cycle accidents follow the trends in cycle usage and, that if cycling is to be encouraged, then additional safety measures will have to be taken to prevent a rise in the number of casualties.

The second notable feature is that nearly half the fatalities were juveniles. Spence and colleagues reported a mortality of 1.44 deaths per 100 000 children on Ontario and in 89% of these head injuries were considered to be responsible.¹¹ In 96% of deaths the cause was a collision with a motor vehicle. Similarly Sacks *et al* studied a five year period in the USA and found that 62% of all cycling deaths were due to head injuries and that 76% of head injury deaths were children under the age of 15.¹²

Even in the solo accidents which involved no other moving vehicle the injuries were quite severe (table 4), although they were limited to the head, neck, and thorax. There were four massive skull fractures, two fractures of the cervical spine at C4/5 and C6/7, and one case of multiple rib fractures. The severity of some of these injuries may be explained by the hilly nature of the terrain for in three of these cases, including one in which the accident occurred outside Yorkshire, the cyclists were descending hills. High speeds are easily obtainable in some of the long descents out of the Pennine hills so that impacts may occur at speeds which are similar to those in accidents involving motorised vehicles and the injuries are accordingly severe.

Collisions with cars or heavy vehicles produced severe injuries to the trunk by blunt impact or by crushing. It was in these groups that there were lacerations of the lungs, heart, aorta, and liver so that survival was unlikely even if helmets had been worn. In all, half of the cyclists had lethal injuries to the trunk or spinal cord. None of the cyclists had worn helmets but if it is assumed that helmets would have been 100% effective in preventing head injury, the maximum number of lives which might have been saved would have been 14, which is the number in which the major injuries were limited to the head. This is the best possible estimate of the life saving potential of helmets but even those who are strong advocates of helmet wearing found that approved helmets reduced the proportion of head injuries by only 45%.¹³ Bjornstig *et al* concluded that helmets would have had an injury reducing effect in two of every five fatal

cases.¹⁴ Wood and Milne found that 80% of bicycle fatalities were caused by head injuries and that head injury rates in Victoria had fallen following legislation but these findings made no allowance for any changes in cycle usage which may have been caused by the compulsory wearing of helmets.¹⁵

The controls had a similar number of head injuries but in addition they suffered more widespread damage than the cyclists (table 3). In only eight of the controls (28%) were the injuries limited to the head, but if the same reasoning is applied as in the case of the cyclists then eight lives might have been saved had helmets been worn. The difference is that while fatal cycle accidents are uncommon, deaths of pedestrians and vehicle occupants are very common, so that if the figure of 28% is applied to columns 2 and 5 of table 1 then it may be argued that the lives of over 170 pedestrians and vehicle occupants might have been saved. This conclusion is in good agreement with the findings of Hillman, who concluded that cyclists account for only one in 12 of all road fatalities which result from head injury.¹⁶ Deaths of cyclists are only a minor part of the road traffic accident problem but it seems unreasonable to propose that all road users should be compelled to wear helmets. A more sensible approach would be to reduce vehicle speeds and traffic volumes as well as providing safer routes for cyclists and pedestrians; it may be necessary to apply special restrictions to HGVs in urban areas.¹⁷

As none of the cyclists in this series wore helmets it is not possible to say whether there are any disadvantages to helmet wearing, but the bulk of the published evidence – based upon non-fatal accidents – indicates the helmets provide some protection against injury to the head and, in the series reported by Spaite *et al*, helmet users seemed to have fewer injuries to other parts of the body.⁹ The wearing of a helmet makes a cyclist much more conspicuous and so it may act as a primary preventive measure. The adverse effects of risk compensation are fully discussed by Hillman¹⁶ and the only other way in which helmets might be disadvantageous is by increasing the amount of energy transferred to the cervical spine in the event of a crash, so increasing the risk of spinal injury.

The results of the present series indicate that, at best, helmets could only have saved 50% of the deaths and that other measures, directed at making roads safer, are required to improve on this figure. Particular attention needs to be given to the training and supervision of juvenile cyclists. Helmets may have a part to play but we need to put more effort into the primary prevention of accidents as recommended by McCarthy.¹⁷

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