The effectiveness of cycle helmets

An investigative paper by John Franklin

Introduction

Helmets for cyclists began to be produced towards the end of the 1970s. Few were seen in Britain, however, until the mid 1980s. Early helmet promotion was largely by the helmet manufacturers, making claims and counter-claims about the merits of their particular helmet design.

All this changed at the end of the 1980s following the publication of reports suggesting that if cyclists wore helmets, their likelihood of head injury would be reduced considerably. From that time, the promotion of helmet wearing for cyclists has been a main thrust of road safety practitioners and legislators in many western countries.

Research world-wide

In 1987 Dorsch[1] predicted that there would be a 90% saving in fatalities if all cyclists wore hard-shell helmets. However the report that did most to encourage the promotion of helmet wearing came from Thompson RS, Rivara and Thompson DC[2] in 1989. It has been quoted extensively to the present day.

The researchers undertook a study at five hospitals in Seattle between December 1986 and December 1987 of cyclists admitted to an emergency room. Of 776 cyclists admitted, 269 had head injuries. 235 of these, and 433 of the 507 cyclists who were admitted without head injuries, completed a questionnaire. The study concluded that cycle helmets reduce the risk of head injury by 85% and of brain injury by 88%.

However, as well as being quoted extensively in favour of helmet wearing, this report has also received much criticism, although this appears to have reached a much smaller audience. Principal criticisms are:

- The study is non-randomised.
- Cyclists wearing helmets were mostly white and riding in parks or on cycle paths accompanied by adults. Cyclists without helmets were more often black or other races, riding alone on city streets.
- The control population had a helmet wearing rate nearly 7 times greater than that confirmed by a concurrent study for children in the Seattle area as a whole.
- Most of the injuries were minor, and there were no instances of helmeted cyclists in collision with motor vehicles, but the results were extrapolated to apply to all types of injury.
- The same methodology can be used on other data in the study to show that helmet use also reduces the risk of injury to other parts of the body by 72%.
- The study does not distinguish facial injuries from other head injuries, although helmets would not prevent the former.

The authors themselves acknowledged two sources of uncertainty: statistical error due to the fairly small sample, and bias in the sample: *"We cannot completely rule out the possibility that more cautious cyclists may have chosen to wear helmets and also had less severe accidents"*.

In 1993 McDermott[3] re-worked Thompson's data to eliminate forehead lacerations and re-calculated the benefit of wearing helmets as a 61% reduction in head injuries (instead of 85%). After further re-working of the data, McDermott found that only 40% of head injuries would be reduced using approved helmets, though injury rates increased for the neck, extremities and pelvic region. He also noted the small sample size in the Thompson data and considered this statistically unreliable. Using his own data, McDermott suggested that helmets give a 25% reduction in risk of head injury for adults, but no reduction in serious injuries.

In 1996 the researchers involved in the 1989 Seattle study published a new paper[4], based on 7 Seattle hospitals and involving 3,390 cyclists who were injured or killed during 1992-4. The individuals with head or brain injuries were compared to those involved in crashes but who did not suffer such injuries. 50.6% had worn helmets at the time of their crash. The paper concludes that helmets decrease the risk of head injury by 69%, brain injury by 65% and severe brain injury by 74%. Helmets are said to work equally well for all age groups, and in crashes with and without motor vehicles. Substantial protection is provided against lacerations and fractures to the upper and mid face, but not to the lower face. Hard shell helmets may offer the greatest protection against severe brain injury.

Other studies have predicted large reductions in head injuries through the wearing of helmets. Wasserman[5] predicted that helmets would reduce concussions by 29% and skull fractures by 82%. Spence[6] that 80% of child fatalities would be prevented. Sacks[7] predicted a 70% fall in fatalities and a 84% reduction in head injuries generally. Spence (and probably Sacks) used the Seattle study as the basis for the predictions, and seem to have assumed that all impacts are within the design limits of cycle helmets, in particular a collision speed of less than 20km/h.

A comprehensive compilation of the arguments in favour of cyclists wearing helmets was produced by Henderson[8] in 1995. The author did not himself carry out any original research, but summarised the findings of others, as well as dealing with the biomechanics of head injury. The author states that helmets *"substantially"* reduce the risk of head injury.

At first sight this paper appears to offer convincing evidence in favour of helmet wearing, not the least because of its authoritative size and detail (29 pages of small print). However, the paper has received much criticism from others on account of a perceived bias towards including only material favourable to its conclusions. Some of the criticisms are:

- Henderson makes no reference to the decline in cycling brought about by helmet legislation in Australia. The reduction in head injuries that he cites as having been achieved is in absolute numbers, not relative to cycle use.
- He makes no reference to other research that casts doubt on the efficacy of cycle helmets in reducing injury.
- There is little concession to the location of real-life head injuries and the fact that over half occur to parts of the head for which a cycle helmet offers no protection.
- Some of his principal references have themselves come in for much criticism, of which he makes no mention (*e.g.* the 1989 Seattle study).
- Henderson is dismissive of the possibility that helmeted cyclists might differ in their behaviour to non-helmeted cyclists.
- He makes no attempt to put the risk of head injury into perspective (relative to distance cycled or the risk faced by other road users), thereby exaggerating the impact on society of such injuries.

Despite these criticisms, the paper by Henderson does include references to the limitations of helmets and helmet testing procedures. For example, he cites research by Mclntosh and Dowdell[9] of helmeted cyclists involved in crashes, which suggests that effective head protection is afforded by a helmet only if the impact speed is less than 20 km/h. Henderson is himself critical of the tests required by the various standards for helmets, saying that they are too simplistic.

Other research has also cast doubt on the limitations of cycle helmets. As early as 1988 Rodgers[10] studied over 8 million cases of injury and death to cyclists in the USA over 15 years. He concluded that there was no evidence that hard shell helmets had reduced the head injury and fatality rates. Furthermore, he found that there was a significant positive correlation between fatalities and helmet use *(i.e.* helmeted riders are more likely to be killed).

In New Zealand, reports of the Land Safety Transport Authority[11] referred to 42 unhelmeted cyclists over 3 years who had been killed. It was stated that at most 6 may have survived with a helmet. For 21 others with head injuries, a helmet would probably have made no difference.

A study by Spaite[12] found that not wearing a helmet is strongly associated with severe injuries. However, this is true even when cyclists without major head injuries were analysed as a group. The implication is that people who do not use helmets tend to be in higher impact collisions than helmet users, since the injuries suffered in body areas other than the head also tend to be more severe.

British research

There has been no original research into the effectiveness of cycle helmets commissioned by the British Government.

The Transport Research Laboratory (TRL) undertook a literature review[13] into research carried out internationally, finding that most of this was supportive of encouraging cyclists to wear helmets.

A hospital-based accident study[14] suggested that £80m in injury costs might be saved each year if cyclists wore helmets, but for no apparent reason other than that this proportion of cyclist casualties involved head injury. It was made clear that the two deaths included in the research would not have been avoided by the use of helmets.

Other TRL research has been confined to monitoring trends in helmet use and means by which cyclists might be encouraged to wear helmets.

A number of papers about helmets have appeared in the British medical press. Thomas[15] suggested a potential 63% reduction in all head injuries to children under 14 years of age. Worrell[16] predicted a fall of more than 50% in slight head injuries, with serious injuries much reduced.

A one-year study was undertaken at Addenbrooke's hospital[17] based on 1,040 cyclist casualties, 114 of whom had worn helmets. No difference was found between helmet wearers and non-wearers with respect to type of accident and the nature of non-head injuries. However, only 4% of helmet wearers sustained head injury against 11% of non-wearers. The researchers deduced a protection factor of 3.25 for cyclists who had worn a helmet.

Kennedy[18] examined 28 cyclist deaths over 15 years in Sheffield and Barnsley. Over 80% of both cases and controls had severe head injuries, but controls (an equal number of pedestrians and motor vehicle occupant fatalities) suffered more fatal injuries to other parts of the body. If helmets had saved all those who only had head injuries, at best 14 (50%) of cyclist deaths would have been prevented. On the other hand, if the pedestrians and motor vehicle occupants had worn helmets, some 175 lives may have been saved in the same period.

In 1992 the British Medical Journal published complementary articles[19] putting the case for and against helmets, but they made no reference to new research.

Large sample research

In 1990/1 Australia became the first country to require cyclists to wear helmets through legislation. Arguably this provided the best possible sample for research, based upon the whole cycling population. A principal effect of the laws was to increase substantially over a short period of time the number of cyclists wearing helmets. This enabled a comparison of a very large number of the same individuals wearing and not wearing helmets, eliminating most of the other variables that are present when comparing different people or dissimilar riding conditions.

Pre-legislation, predictions were made of substantial savings in head injuries and lives through increased helmet use, in line with much of the research that had taken place up until that time. The reality post-legislation would appear to be much less successful.

Dorothy Robinson[20] suggests that the greatest effect of the laws has been to discourage cycling. Despite an increase to at least 75% in the number of those still cycling who wear helmets, head injuries declined by only 13%. The risk per cyclist would appear to have increased. Furthermore, Robinson suggests that the reduction in head injuries for cyclists has been very similar to that for pedestrians over the same period, indicating that what reduction has been achieved may be more associated with concurrent speed and drink-driving initiatives than helmets.

Bruce Robinson[21] (no relation to Dorothy) also questions the effectiveness of helmets in the light of the Australian experience. A self-confessed long-time advocate of helmets, he says that the initial belief in the effectiveness of helmets and legislation may have been ill-founded, for there is no convincing evidence that increased helmet use has reduced the risk of head injury in real-life crashes.

Monash University has monitored head injuries to cyclists in Victoria since the introduction of legislation, and annual reports[22] have related the trend. The first reports suggested that legislation had achieved its aim of reducing head injuries. Although hospital data did not show a relationship between helmet wearing and head injury in the immediate pre-law years for crashes not involving a motor vehicle, head injury rates for cyclists in these crashes were significantly lower post law. A significant inverse relationship between helmet use and head injury was found for cyclists involved in crashes with motor vehicles.

At first, accident insurance claims showed head injury rates significantly below pre-law predictions, but by the third year the researchers admitted that the benefits had been lost. The hospital records failed to show any additional benefit of the law over pre-law trends in the 3 post-law years.

The Monash research has been criticised, in part because it makes no reference to trends in the number of people cycling or relative risk. Other shortcomings were acknowledged by the researchers themselves in their 1995 report, suggesting that there had been bias in the injury data used previously. These errors were held responsible for the less positive nature of their more recent research, and it was stated that in fact hospital admissions in the first 4 years were 40% below pre-law trends and that the severity of injuries had declined. Again no mention was made of relative risk.

Subsequently, in 1999, the Australian Road Accident Prevention Research Unit reported[23] that head injuries since helmet use became compulsory may only have fallen by 11 per cent – less than the decrease in cycle use. The report also concluded that from a financial viewpoint helmet legislation had not been cost-effective.

In 1994 New Zealand followed Australia in the introduction of a mandatory helmet law. Research into the effects of the law is limited, but that which is known also casts doubt on the efficacy of helmets to reduce head injuries.

Hansen and Scuffham[24] calculated the cost of helmets per life saved as varying from $88,379 for schoolchildren to $1,014,850 for adults. By comparison, avoided hospital costs ranged from $3,304 to $56,035.

In 1996 Scuffham published a further paper[25] looking at the trends in cycle injury in New Zealand under voluntary helmet use, pre-law. In the period 1989 to 1992, helmet wearing rates increased from 46% to 84% for primary schoolchildren, 23% to 62% for secondary schoolchildren, and 21% to 39% for adults. During the same period serious injuries to cyclists (all causes) decreased substantially for children, but not for adults. However, serious head injuries as a percentage of all serious injuries remained constant for all groups, with no apparent difference between bicycle-only and motor vehicle related crashes. The percentages of mild concussions and lacerations to the scalp did decrease more than other cyclist head injuries. Failure to achieve the predicted decline in serious head injury was thought to be attributable to a number of factors, including the incorrect fitting and wearing of helmets.

Scuffham noted that benefits from helmet wearing did not appear to have been achieved post-legislation either, and there was an increase in neck injuries. A separate paper was said to be in preparation.

Whole population samples have also been created in certain parts of the USA where cycle helmets have been made compulsory, in most cases just for children. Krygowski[26] collected statistics for cyclist fatalities from the National Highway Transportation and Safety Administration for all states that had mandatory helmet laws, covering the period 1990 to 1995, as appropriate for when individual laws were introduced. The data was disaggregated by age group. Krygowski found a slight downward trend in fatalities, but no startling improvement as helmet use rose upon the introduction of a law. In most cases gains made in the first years of a law were eroded a year or two later. In Califomia, with its bigger population, better weather and much more cycling (thus yielding more robust data), there was no detectable effect at all. A general result of the laws was to reduce participation in cycling and it is possible that it is this that led to the reduction in fatalities.

Kunich[27] analysed cyclist and pedestrian fatalities for the whole of the USA from 1986 to 1996. During this period helmet use by cyclists rose from close to zero to 30% or more. Although cyclist fatalities fell during the period, the decline was proportionately less than for pedestrians, and the continuation of a long-term trend most probably associated with decreased exposure. Kunich concluded that there is no evidence that cycle helmets are effective in reducing deaths, and quoted research into football helmets[28] that suggested that helmets can even cause new injuries by increasing the effective size of the head.

Burdett[29] carried out a similar analysis for Canada from 1975 to 1997. Fatality trends were similar for cyclists and pedestrians throughout the period, and both fell. Although cycle helmet use grew from virtually zero in 1988 to over 30% in 1995 and up to 50% in 1997, there is no detectable impact on the fatalities recorded.

In Britain a paper from the London Research Centre[30] shows cyclist casualties in Greater London from 1981 to 1996. Despite an increase in cycle helmet wearing from nearly zero to almost 40% over the decade 1986 to 1996, this has had no noticeable effect on trends for any severity of cyclist casualty. Furthermore the 'severity ratio' (the proportion of casualties that are serious or fatal) was higher in the most recent years than in the earliest years of the comparison. Detailed data on cycle use is needed to refine the analysis, but the variation in cycle use is likely to be small compared with the increase in helmet use.

Accident statistics[31] from Great Britain as a whole and from Cambridge (with its large cycling population) also show no evidence of a 'helmet effect' – the severity of cyclist injuries continuing to follow well established trends despite large increases in helmet use.

Cycle use

Significant reductions in the number of people cycling have been experienced wherever a mandatory helmet law has been introduced.

In Western Australia there were still 10% - 20% fewer cyclists in 1999 than in 1991. In Perth the number was down 15% over the same period, despite a population increase of over 140,000. At the same time cyclist injuries are at their highest level in history[32].

Even where laws have not been introduced, it has been suggested that the promotion of cycle helmets discourages people from cycling by strongly associating cycling with danger. TRL[33] has found that helmet campaigns are linked strongly to a decrease in the number of cyclists observed.

Helmet standards

Helmet standards require helmets to be designed only to survive a simple drop test onto an anvil. The maximum permitted deceleration of the dropped head form is typically 300*g*, which is equivalent to an impact velocity of 20 km/h (12.5 mph).

The performance of a helmet above an impact velocity of 20 km/h is neither tested nor defined. Cycle helmets usually fail catastrophically rather than gradually, through total compression or disintegration. It is therefore not simply the case that the proportion of the force absorbed will decrease with increasing velocity. It is a matter of conjecture as to whether significant protection to the head would be afforded at higher speeds, and this is likely to vary from helmet to helmet. Mclntosh and Dowdell[34] appear to have found no cases of helmeted cyclists surviving crashes where the equivalent impact velocity was greater than 20 km/h.

Whilst it is possible that some helmets may provide useful protection above the impact velocity for which they are tested, a report by the Consumers Association[35] suggests that most helmets do not meet even the stipulated standard, and are therefore likely to provide reduced protection below 20 km/h. 14 helmets out of the 24 tested failed the test criteria for shock absorption, and two of the remainder failed tests related to retention and strap strength. Only two of the 24 helmets met the more demanding Snell absorption test, and one of these caused some impairment of a cyclist's vision.

Helmet testing standards are simplistic. Simple drop tests subject a helmet to linear acceleration impact only. No tests are carried out using angular acceleration impact (which leads to rotation of the head). However, it is understood that linear acceleration impact leads to focal injuries, but that angular acceleration results in the more serious diffuse injuries to the head. Henderson[36] cites (unspecified) research material showing rotation of the head to be the mechanism causing the most damage. There does not appear to be research evidence that cycle helmets are effective in mitigating angular impacts. Henderson is himself critical of vertical drop tests, noting that the solid head form used for standards approval does not mimic the deformable characteristics of the human head.

Helmets are designed to suffer only one impact before replacement. Many cycle/car crashes involve a double impact: first of the cyclist's head against (for example) the car windscreen, then of the cyclist's head against the road. The first impact will weaken the helmet so that it is much less able to absorb the second blow.

Effect on behaviour

It has been suggested that the use of cycle helmets might cause both cyclists and motorists to take less care, in the perception that the cyclist is less vulnerable. Hillman[37] cites evidence that this might be the case, suggesting that it would be consistent with the normal behaviour of human beings.

TRL[38] reported that a significant minority of children (believed to be 19%) cycle less carefully when wearing a helmet.

Other research has suggested that those who wear helmets voluntarily may ride more cautiously than non-wearers, which makes any comparison of the accident risk of the two groups attributable to helmets difficult. For example, Farris[39] found that helmeted cyclists are 2.6 times more likely to obey stop signs and 7.1 times more likely to give hand signals.

Cycle helmets themselves sometimes lead to new dangers. In Sweden six children were hanged when their helmet straps became entangled on play structures. Children in Saskatchewan, Canada and Pennsylvania, USA have suffered similar fatalities. The Swedish authorities reacted by redesigning helmets to incorporate a buckle which releases under load, but this virtually ensures that the helmet will fly off in a cycling collision.

Relative risk of head injury

Cyclists are not alone in suffering head injury as a result of road crashes. From 1987 to 1991 fatalities in Britain due to head injuries were proportioned:

Car occupants	40.5%	
Pedestrians	39.1%	
Motorcyclists	11.9%	despite use of helmets and a lower total distance travelled than by pedal cycle
Cyclists	8.5%	

Even greater numbers of head injuries are believed to be suffered by people in the home and at work.

Analysis suggests that cyclists live at least 2 years, and possibly as much as 10 years, longer than non-cyclists, and cycling regularly is 20 times more likely to increase someone's life span than to shorten it[40]. This puts the risk of serious injury to cyclists in perspective.

Data from the DETR[41] suggests that one serious injury occurs for every 300,000 km of cycling, and one fatality for every 17 million km. Not all serious crashes involve head injury, many that do involve parts of the head or a severity of impact that a helmet cannot protect, whilst most fatal crashes result in multiple injuries and protecting the head alone may be insufficient.

Nonetheless, the average distance cycled per person in the UK each year is only 62 km[42] (and in the Netherlands only 850 km[43]), so the average cyclist would expect a serious injury only once in more than 80 lifetimes.

In Australia the promotion of helmets for car occupants is being considered. Research by the University of Adelaide and Monash University[44] has shown that bicycle-style helmets would afford motorists more protection than interior padding, air bags or seat belts. Helmets could lessen the severity of 50% to 60% of motorist brain injuries and avoid 1 in 5 fatal crashes.

A subsequent report from New Zealand[45] notes that helmets for car occupants have been proved to be more effective in preventing serious injury than helmets for cyclists.

Conclusions

The wearing of helmets by cyclists is a controversial and very emotive subject. It is not always easy to disentangle fact from conjecture and views can be strongly polarised. Also, people often find it difficult to make a logical assessment of relative risk.

Although there has been much research into cycle helmets, too much of this is suspect with regard to assumptons made and control groups used. It does not relate well to real-world circumstances. Most research has been predictive in nature and based on small samples. Little has looked at the results that have actually been achieved in large population samples when helmet use has increased significantly. No research has put the risk of head injury when cycling into perspective with the risk from other common activities and the overall effect on life expectancy and health.

It seems reasonable to expect that reductions in injuries brought about through the wearing of cycle helmets would be reflected in the general accident statistics in places where helmet use has become significant. This should particularly be the case if the more optimistic predictions for injury reduction are correct. However, whole population statistics from Australia, New Zealand, the United States and Canada show no distinguishable change in fatalities, and statistics for London show no such change for any severity of injury, as helmet use has increased substantially.

This suggests that the real-world performance of cycle helmets may be falling well short of the predictions that have been made.

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