Bicycle Helmet Effectiveness – a broader perspective

A Critique of

Department for Transport Road Safety Research Report No 30, 2002
Bicycle Helmets – A review of their effectiveness
A critical review of the literature

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Executive Summary

Bicycle Helmets – A review of their effectiveness was commissioned by the UK Government to analyse the most up to date evidence for and against cycle helmets. This Critique examines the scope of the research, and the strength of the evidence put forward.

Although the Review concludes unequivocally that there is considerable scientific evidence that cycle helmets are effective in reducing injury, it examines only one type of evidence, that provided by non-randomised case control studies. Such studies have serious limitations for cycle helmet research and the Review identifies many shortcomings. These limitations are sufficient for at least 8 of the 16 papers reviewed to be ineligible as credible scientific evidence, whilst the remaining papers are unreliable evidence if other factors (identified in this Critique) are taken into account.

The Review makes no reference to traffic casualty trends where helmet use has become significant or to any other large population research, although most of this evidence shows no benefit through helmet use. There is no reference at all to evidence that helmet use has sometimes been associated with increased risk of injury or injury severity. Consideration of risk compensation, which could be one reason for such an increase, is deliberately excluded from the Review.

An examination of helmet promotion campaigns makes no reference to their effect on cycling, despite the far-reaching consequences for public health of further reducing levels of physical activity. 16 of the 19 studies reviewed yield no information about head injury trends, and the data from the 3 other studies lead to conclusions that are not credible. The effects of helmet legislation are examined, but the data presented misrepresents evidence on reductions in cycle use and there is no reference to increases in risk of head injury through helmet wearing.

Analysis of the epidemiology of cycle injuries portrays cycling as a much more hazardous activity than is actually the case. There is no recognition that cyclists, on average, live longer and with better health than people who do not cycle, or that head injuries are less likely to be a cause of death for cyclists than for pedestrians or car occupants. No reference at all is made to the principal causes of death and chronic intellectual disablement through brain injury, that cycle helmets do not mitigate. Similarly there is no mention that helmets may increase the likelihood of the most serious injuries.

The Review is neither a balanced nor an impartial evaluation of evidence on the efficacy of cycle helmets, omitting reference to so much that is crucially relevant. Fundamentally, the impact of helmet promotion on wider public health goals is not assessed, with no evaluation of the net benefit to society of less cycling with helmets against more cycling without helmets.

Public policy requires a broader assessment of all the evidence available, and one that takes account of wider public health and relative risk. On the basis of evidence presented in the Review, the case for the promotion of cycle helmets is at best unproven.

Introduction

Bicycle Helmets – A review of their effectiveness (RR30, Research Report No 30) was commissioned by the then Department of the Environment, Transport and the Regions acknowledging that *"there is a wealth of published evidence both for and against promotion and compulsory use of cycle helmets"*, requiring *"an independent objective critique of the most up to date evidence on the efficacy of cycle helmets"*[1].

Sections of the report cover the epidemiology of cycling injuries, cycle helmet standards, a review of observational and intervention studies, helmet legislation, and barriers and facilitators of helmet use. There is also a section on 'Opinion pieces'.

This critique deals principally with those parts of the report that examine the efficacy of cycle helmets. Matters regarding the promotion of helmet wearing are relevant only if a case is established that there is in the first place a need for cycle helmets at all, and in the second place that there are tangible benefits to be realised through more cyclists wearing helmets.

Helmet efficacy

At the end of RR30, the authors reach the unequivocal conclusion that *"There is now a considerable amount of scientific evidence that bicycle helmets have been found to be effective at reducing head, brain and upper facial injury in bicyclists. Such health gains are apparent for all ages, though particularly for child populations"*[2]. The only part of the report that examines evidence of the efficacy of cycle helmets is Section 3, Observational Studies.

Section 3 comprises a *"systematic review of the literature on observational studies"*[3]. For this purpose 16 papers were chosen for review, which was carried out using a common extraction form to summarise the scope of each study, its population and results.

For an *"independent critique"* it is remarkable that the 16 studies chosen coincide exactly with the 16 studies that were the subject of meta analysis by Attewell et al in 2000 for the Australian Transport Safety Bureau[4]. Critics of that analysis have cited methodological shortcomings and ideological bias in the studies, which, it has been suggested, are some of the most pro-helmet research to be found. The Department for Transport (DfT) report does not declare this criticism.

It is all the more remarkable that 7 of the observational studies coincide with the 7 papers that were the subject of the Cochrane Review 2001/2 by Thompson, Rivara & Thompson[5]. Two further observational studies were also referenced by the Cochrane Review, but excluded as unsuitable for incorporation. The Cochrane Review has also attracted much criticism[6], not the least because 4 of the 7 papers were the work of the reviewers themselves and dominate the analysis. Again the DfT report makes no reference to this criticism.

RR30 references both the Attewell and Cochrane reviews, stating that its own review builds on them. It should acknowledge that all three reviews are based on common source material, but does not.

Thompson et al are also dominant in the observational studies. Five of the 16 papers are their work, based on only 2 data sets, yet these data sets account for nearly one half of the total number of cyclists on whom the review as a whole is based. This team of researchers has a reputation as strong and uncompromising campaigners for helmet wearing. Their estimates of injuries that might be saved through helmets are far in excess of predictions by most other researchers.

Notwithstanding the choice of material, the DfT reviewers identify a considerable number of limitations of the papers reviewed. For example, the commonly cited prediction (by Thompson et al) that cycle helmets prevent 85% of head injuries and 88% of brain injuries is recognised by RR30 as an over-estimate. Similarly RR30 accepts that there is no evidential support for the prediction by Dorsch et al that helmets could prevent 90% of deaths due to head injuries, and clearly this has never been achieved in the real world. When such a key conclusion has been so discredited, it is astonishing that the paper was retained in a review of credible scientific evidence, let alone that it be rated as a 'good' study.

Most of the criticism is to be found only in the Technical Annexe to RR30, which is not supplied as a matter of course with the main document. The Appendix to this critique looks in detail at the 16 observational studies. It notes the shortcomings found by the DfT reviewers and also factors observed by others that RR30 does not identify. The DfT Review has taken the data content of observational studies at face value, with no apparent investigation into underlying or conflicting data, even when the subject of published criticism.

Despite acknowledging that most of the observational studies have serious limitations, RR30 still concludes that there is now clear scientific evidence to support cycle helmet use. The Technical Annexe states that consultation took place with 'key informants'. There is no mention of who was consulted or of the input received. On the other hand, some researchers who submitted to the Review detailed data and in-press papers have stated that their contribution was not acknowledged, nor was there any response to offers to provide further evidence.

The most serious criticism of the 16 observational studies is their very limited scope. The research brief had acknowledged that there is a considerable amount of evidence both for and against helmets. However, only papers supportive of helmet promotion or compulsion were reviewed, as is admitted in stating the criteria for selection. Furthermore, the studies are limited to only one type of data collection, that derived from case-control studies.

Randomised controlled trials can be a good choice in medical research where the researchers are able to control most of the variables that are not under analysis. In cycle helmet research there are no randomised studies for practical and ethical reasons. Hence control of many of the variables has proved unattainable, for there have been so many auxiliary differences between populations wearing and not wearing helmets that the various effects are unable to be distinguished. For example, helmeted and unhelmeted cyclists often differ in injuries experienced to parts of the body other than the head. Case control studies are also based on small populations. In the observational studies examined for this Review the largest population is 3,390 and the smallest as little as 21.

By contrast, whole population statistics from traffic casualty records are much less subject to bias. The same applies to data for hospital treatment to cyclists before and after a helmet law, because the pre and post law populations comprise essentially the same people. The fact that these sources, across several countries, consistently contradict case-control studies, by showing little or no benefit from increased helmet wearing[7], is surely a strong argument for their inclusion in any review that strives to be impartial and concerned with the full picture.

RR30, however, makes no reference at all to trends in casualties of whole cyclist populations. There is no examination of injury trends, in the UK or elsewhere, where helmet use has become significant, although this information is readily available, including from within the Department for Transport.

For a project concerned with improving the safety of cyclists[8], it is a serious omission that there is no reference to, or evaluation of, recorded *increases* in the risk of injury (and injury severity) across several countries as helmet use has risen (e.g.[9 10 11]). Most noticeable in this context is the lack of any reference to the US Consumer Product Safety Commission announcement[12] that an increase in helmet wearing from 18% to 50% between 1991 and 2001 was associated with a 40% rise in risk of head injury. Such a dramatic contradiction of the predictions of case-control studies deserves acknowledgement and thorough investigation.

Also not investigated is the apparent greater propensity of helmet wearers to hitting their heads in crashes[13]. Many falls result in arm and shoulder impacts to the ground, with an unhelmeted head missing the ground by perhaps a couple of inches. This distance is comparable to the larger size of a helmeted head which means that in many crashes when a bare head will not touch the ground, a helmet will. Design 1 for case-control studies – identified by RR30 as the optimum – is a valid estimate of the efficacy of helmets only if wearers and non-wearers are equally likely to sustain head impacts.

RR30 includes no reference to comparative trends in head injury between cyclists and non-cyclists. Pedestrians in particular can be a useful control for cyclists, as both groups are vulnerable road users and experience similar casualty trends. In some places, however, the similarity in trends has changed as cycle helmet use has become more common, with cyclists experiencing proportionally more serious injuries than pedestrians[14].

Other relevant material noticeable by its absence includes studies into the cost-benefit of helmet promotion. Cost-benefit studies from Australia[15] and New Zealand[16] have concluded that helmet mandation in those countries has not been cost effective, and much of the analysis is equally valid for promotion outside the context of helmet laws. No cost-benefit analysis is known that has concluded unequivocally in favour of helmet promotion.

Epidemiology of cycle injuries

The first section of RR30 sets the scene for the 'problem' that cycle helmets are intended to address. It paints a picture of cycling as an exceptionally hazardous activity.

The actual likelihood of suffering serious head injury when cycling is not stated. This risk is in fact very low. In Britain the average cyclist may expect to suffer serious head injury only once in more than 3,000 years[17] [18]. Nor is there any reference to risk relative to other modes of transport[19]. There is no correlation with improved life expectancy and general health for cyclists compared with people who do not cycle[20]. There is no comparison with other, more common, causes of head injury, ill-health or premature death[21] [22].

Despite recognition by the authors that it is important to link mortality and morbidity patterns with exposure, the fatality rates cited and the 'key point' that *"males are four times as likely to be killed or injured as females"* mislead as they take no account of exposure. There is no reference to non-medical sources that could have provided additional information about exposure.

It is noted that head and face injuries make up a significant proportion of cycling injuries, but not that this proportion is no greater (indeed, less) than for pedestrians and car occupants[23]. The report repeats, presumably unchecked, a factor of 10 error in the proportion of emergency admissions due to cycling published in a report by Cook & Sheikh[24], although the error was quickly acknowledged by those authors and a correction published.

RR30 makes no distinction between head and face injuries that are superficial and those that are life-threatening. There is no reference at all to diffuse axonal injury (DAI) or subdural haematoma (SDB), although these are the brain injuries from which protection is most required. Cycle helmets do not prevent these types of injury. *(See further comment and references below)*

No mention is made of research demonstrating that the most effective way to reduce the likelihood of injury when cycling is to increase the number of people who cycle[25] [26] [27]. This has the potential for injury savings far in excess of anything yet reported for cycle helmets, but may not be unachievable side-by-side with helmet promotion.

Bicycle helmet standards

Section 2 of RR30 discusses how cycle helmets work, and the various international standards that prescribe their design and manufacture.

The description of head injury makes the assumption that the principal mechanism – even in cases of serious injury – is linear acceleration of the skull by impact with another object, and that helmets produce benefit by reducing and spreading this force.

There is no reference at all to injury due to angular (rotational) acceleration, which leads to diffuse axonal injury (DAI) and subdural haematoma (SDH). These are the most common brain injuries sustained by road crash victims that result in death or chronic intellectual disablement [28]. Cycle helmets are not designed to mitigate rotational injuries and research has not shown them to be effective in this.

To the contrary, concern has been expressed that helmets might make some injuries worse by converting direct forces to rotational ones[29] [30]. These injuries will normally form a very small proportion of the injuries entered into case-control studies, but they are likely to form a large proportion of the injuries with serious long-term consequences. In this way, helmets may be harmful in a crash, but this harm will not be detected by the studies available.

Given the consequences for a project concerned with minimising injury, this subject deserves thorough evaluation, but RR30 does not mention it at all.

The Review details the key features of cycle helmet standards, but does not comment on the validity of the testing mechanisms vis-à-vis typical cycling crash scenarios. Nor is there any reference to the compromise in standards that has been necessary to satisfy the requirements of manufacturers and to enable cycle helmets to be acceptable to consumers. For example, the move from hard shell to soft shell helmets, with more ventilation slots, may have reduced protection of the skull and increased focal injury to the brain[31 32].

More importantly, there is no reference to evidence that cycle helmets frequently do not meet the standards to which they are designed[33], although this has direct consequence for the protection afforded to helmet purchasers.

Helmet promotion

Section 4 of RR30 summarises 19 reports on the effects of intervention studies to promotion cycle helmet wearing.

Helmet promotion for its own sake is of no value. The only justification for encouraging helmet use is to reduce head injury rates without reducing the amount of cycling, as the health benefits of cycling far outweigh the risks of head injury[34]. Yet only 3 of the 19 summaries mention either of these critical issues. The other 16 studies are reported only as increasing helmet wearing rates and are therefore irrelevant to assessing the achievement of helmet promotion goals.

Ekman et al[35] found that in the helmet promotion areas, head injuries fell by 5% more than in other parts of Sweden. Changes in cycle use are not reported, but the fall in all kinds of injury to cyclists was 50% more than in Sweden generally. This suggests a fall in cycle use much greater than the reduction in head injuries, and thus a rise in risk of head injury for those who still cycle.

Mock et al[36] reported increased helmet wearing and fewer head injuries but no information about cycle use. No useful conclusions can therefore be drawn from these results. Furthermore an increase of 32% in helmet use is associated with a 66% fall in serious head injuries – something not possible even if helmets prevented 100% of such injuries. Other factors are clearly affecting injuries so the results cannot be taken at face value.

Lee et al[37] was the only other report claimed to mention head injury rates. The question again arises as to how an increase in helmet wearing from 11% to 31% of all cyclists can plausibly be responsible for a reduction from 22% to 12% of cyclists visiting A&E departments having injuries to the head. Correlation of this report with an earlier report by Lee[38], suggests that at least part of the decrease in head injuries occurred before the increase in helmet wearing. Other factors may therefore have had influence, without the knowledge of which no reasonable and balanced conclusions can be drawn.

The reviewed intervention studies raise more questions than are answered and give no basis for judging that helmet promotion campaigns are successful in achieving their principal goals.

Although the selected studies yield no direct evidence about the effect of helmet promotion on levels of cycling, other studies do. TRL has found promotion campaigns to be *"strongly linked to a decrease in the numbers of cyclists observed"*[39]. Other research has shown that prominent helmet promotion leads to significant falls in cycle use, particularly amongst young people[40].

Declining physical activity is now acknowledged as a principal cause of illnesses such as obesity and heart disease, which result in more than 500 times as many deaths per annum in the UK as cycling[41]. Since 1990, the fall in cycle use in Great Britain (in absolute numbers) has been almost twice the increase in helmet use[42].

In view of the far-reaching consequences for public health, it is a serious omission that Section 4 of RR30 makes no mention of the effect of helmet promotion on cycle use, and that no study recording a fall in cycle use was selected for review.

Helmet legislation

Section 5 of RR30 considers the effects of cycle helmet legislation through a number of evaluated studies, and two more detailed case studies from Victoria and British Columbia.

The evaluated studies are not assessed in detail for this critique as some of the papers are not readily available. Judging from those reports that are known, the evidence has been taken at face value. For example, whilst the report by Scuffham et al [43] did conclude, on the basis of the data published, that the New Zealand helmet law had a positive effect on head injury (albeit very small by comparison with the predictions of observational studies), re-analysis of the source data over a longer span of time pre and post law shows no such benefit[44].

In almost all known studies, helmet laws have increased the proportion of cyclists wearing helmets more through reducing cycling than by increasing the absolute numbers wearing helmets. The Review 'key point' [45] that helmet legislation has been associated with head injury reductions fails to acknowledge that the decline in cycling was at least as great.

The case studies reported in this section of RR30 also appear to have been taken at face value, without acknowledgement that conflicting evidence from reputable sources sometimes exists.

The Victoria case study is vague about reduced exposure and selective in the statistics presented. For example, the claim that adult cycling increased slightly post-law is on the basis of a comparison between post law and 3.5 years previously, through surveys carried out at different times of year and officially described as 'unreliable'. On the other hand, counts in Melbourne in the first year post-law showed 29% fewer adult cyclists than a year before[46] and cycle use by under 18s declined by 43% during the first post-law year.

The Review does recognise that at least some cycling activity declined as a result of the Victoria law, but does so reluctantly. It does not reflect upon the potential significance of other analysis that the decrease in cycling was 4 times greater than the increase in helmet wearing[47], or that the relative risk of head injury *increased* for those who continued to cycle following legislation[48].

It is not clear why the second case study, based on British Columbia, is included in RR30, as the paucity of data available makes it impossible to draw conclusions. With no information on trends in either head injury or exposure, the only valid outcome is that legislation resulted in increases in the proportion of cyclists wearing helmets. There is no evidence of benefit to individual cyclists or to societal health more generally.

Opinion Pieces

Section 7 of RR30 states its purpose as to summarise the range of arguments used in the debate about cycle helmets, and to consider the ways in which the debate has been conducted. What the Review does not do, is to consider the merits of the arguments in order to better inform the debate.

This is the only place in the Review that opinion contesting the efficacy of helmets finds a place. Many of these arguments are based on evidence no less substantial or authoritative than that supporting helmet use. This deserves to be evaluated fairly and scientifically, not the least because – as the Review acknowledges – helmet-sceptic opinion is supported by a much greater range of arguments than opinion that advocates helmet use.

It is unfortunate that the tone of the section suggests an attempt to discredit alternative views by polarising opinion as either 'for' or 'against'. In many cases correspondents have done no more than to question the soundness of the more commonly cited research and to seek a more factual basis for policy. The section is very superficial, limited in scope and omits key arguments such as DAI and actual risk when cycling. Wider consultation during the preparation of the Review might have led to a better analysis and a more informed outcome.

Discussion

The Discussion section in RR30 attempts to draw together the threads of the Review. It acknowledges the considerable heterogeneity of the evidence and the difficulty of combining its results.

Very briefly, and only in this section, is there mention of risk compensation, with a statement that there was no review of evidence on this topic. Risk compensation is concerned with the way that risk-taking is influenced by a person's perception of safety and danger. There is clear evidence that cyclists sometimes take more risks if they perceive that cycle helmets make them less vulnerable [49] [50] [51]. Considering how important many people believe to be a link between helmet use, risk compensation, crash involvement and thus overall likelihood of injury, to dismiss this subject in less than a dozen lines without considering any of the readily available literature is bewildering.

It is true that the focus of the Review was on secondary prevention. However, if secondary prevention leads to heightened primary risk, as is the case with risk compensation, then that should be a matter for concern and assessment. As stated previously in this critique, there is no shortage of evidence that helmet use has been associated with increased likelihood of injury.

Absent from the Discussion is any comparison of the evidence for and against cycle helmets. The Discussion is more a summary of the topics that have been covered rather than an informed, scientifically-based and objective analysis of conflicting evidence.

Conclusions

On the basis of a review of 16 previous studies, RR30 concludes that *"There is now a considerable amount of scientific evidence that bicycle helmets have been found to be effective at reducing head, brain and upper facial injury in bicyclists"*. However, what matters is not the amount of evidence, but the quality of that evidence.

Even on its own terms, RR30 identifies so many shortcomings in the reviewed studies that it is hard to see any logical or scientific basis for the conclusion that the effectiveness of cycle helmets has been well established. On the basis of criticism by the DfT reviewers alone, at least 8 of the 16 papers are ineligible as credible scientific evidence. If other established data are taken into account (as identified in the Appendix to this critique), then the remaining papers are at best unreliable support for helmet wearing.

The Review acknowledges the heterogeneous nature of the studies and the difficulty in generalising results. Nonetheless, it does precisely that.

The project had the purpose of reviewing the evidence both for and against the promotion of cycle helmets. It is extraordinary, therefore, that there is so little reference to – and no evaluation of – any of the considerable literature that does not find in favour of helmet efficacy. The 16 observational studies at the centre of the Review all support helmet use because such support was inherent in the criteria for inclusion.

The choice of studies, and the fact that many are from sources widely recognised as predisposed to helmet wearing, suggest a lack of independence or impartiality in the literature review or selection criteria which informed the choice of material.

The greatest weakness of the observational studies lies in the generic shortcomings of non-randomised case control studies as an appropriate way to measure the effectiveness of cycle helmets. This is the principal failing of the DfT Review. By considering only one type of evidence, it fails to balance the strengths and weaknesses of all the data sources.

There is no reference to trends in traffic casualty statistics, no reference to hospital admission studies before and after helmet laws, no reference to other time-series or large population data, and no reference to cost-benefit analyses. Particularly disturbing is the lack of reference to the many sources of evidence that helmet wearing can result in increased likelihood or severity of injury.

Public concern about head injury is emotive and dominated by fear of death or chronic intellectual disablement, which is most likely to be associated with serious brain injury. However, most injuries to the head are superficial and recovery is quick. As such, these injuries are no more important than injuries of equivalent severity to other parts of the body. Neither RR30, nor the studies selected for review, make sufficient distinction between head injuries that are superficial and those that are life-threatening. There is no reference to scientific knowledge of the mechanisms of serious brain injury, and no evidence is presented that cycle helmets are effective at mitigating the rotational forces most likely to be involved.

The 'scientific proof' of helmet efficacy which the reviewers conclude has been met is by assertion. It is certainly not by a lack of evidence to the contrary, or through the analysis and disproof of such evidence. A key principle of sound scientific evaluation is to seek out and explain apparently confounding data, but nowhere has that been done.

Fundamentally, RR30 has made no attempt to establish a 'need' for helmets for cyclists, especially in isolation to other road users who suffer more head injuries and have a lower average life expectancy. The Review is unequivocally supportive of the perceived benefits of helmets. It is much more cautious that 'some evidence' indicates helmet promotion 'may have resulted' in less cycling, although this evidence is substantial and much less controversial.

The principal threats to public health at the beginning of the 21st century are illnesses such as obesity and heart disease, in large part caused by physical inactivity. Cycling has considerable potential to prevent these illnesses, but not if people are deterred from cycling through ill-founded fear of injury or helmet promotion. RR30 makes no attempt to evaluate the net benefit to society of less cycling with helmets against more cycling without helmets.

Public policy requires a broader evaluation of *all* the evidence available on cycle helmets, and one which puts into context the relative risk of injury when cycling and takes account of the wider consequences for public health. But if, as has been asserted, the material presented in the DfT Review is the best pro-helmet evidence that is available, then the case for the promotion of cycle helmets must at best be judged as unproven.

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Notes and references

[1] Advertisement in professional press, March 2001.
[2] RR30, page 80, §4.
[3] RR30, page 22, §2.
[4] *Bicycle helmets and injury prevention: a formal review*, Australian Transport Safety Bureau: Report CR195, 2000; also published as *Bicycle helmet efficacy: a meta-analysis*, Accident Analysis & Prevention 2001 v33 n3 p345-52
[5] *Helmets for preventing head and facial injuries in bicyclists*, Cochrane Database Sys Review, issue 4 2002.
[6] Summaries of criticism from a number of respondents is embodied within the Cochrane review.
[7] National traffic casualty statistics from Great Britain, USA, Canada and New Zealand show no detectable improvement in trends for fatalities, serious injuries (not available for Canada) or severity ratio as helmet use increased from zero to 22% (UK), 50% (USA) and 50% (Canada). Statistics from Australia are more ambiguous, but analysis taking account of the fall in cycling shows no improvement. Local studies (e.g. London, Cambridge, Nova Scotia) also record no improvement despite high helmet use (50%, 35% and 86% respectively).
[8] Project brief.
[9] In Greater London, cyclist injuries became more serious as helmet use increased in the mid 1990s. In 2001, although about half of cyclists wore helmets, the severity of injuries was significantly higher than in 1981, and fatalities were at their highest since 1989.
Traffic casualty statistics from Transport for London (previously London Research Centre Accident Analysis Unit).
[10] In New Zealand, the proportion of head injuries to cyclists rose with helmet use in the 2 years leading up to the helmet law. Re-analysis by Perry of original data collected for *Head injuries to bicyclists and the New Zealand bicycle helmet law*, Scuffham et al, Accident Analysis & Prevention 2000, 32,p565-573.
[11] In Australia, helmet laws caused head injuries to fall by between 11% and 21%. But cycle use fell by 30% to 60%. The risk of head injury to those who continue to cycle has risen.
An Economic Evaluation of the Mandatory Bicycle Helmet Legislation in Western Australia, Hendrie et al, Road Accident Prevention Research Unit, University of Western Australia, 1999.
Head injuries and bicycle helmet laws, Robinson. Accident Analysis & Prevention 1996, 28:463-475.
[12] Consumer Product Safety Commission, July 2001. Reported in New York Times, 29th July 2001.
[13] A study in Vermont observed only 7.8% of cyclists wearing helmets. Yet when it came to reporting hitting their heads in the past 18 months, this had happened to 8 cyclists wearing a helmet and only 13 without. Helmeted cyclists hit their heads in 20% of crashes, unhelmeted cyclists in only 2.7% of crashes.
Bicyclists, helmets and head injuries: a rider-based study of helmet use and effectiveness, Wasserman et al, American Journal of Public Health, 1988 Sep;78(9):1220-1
[14] Since 1985, and in particular the early 1990s, the average seriousness of pedestrian casualties in Greater London has decreased more than that for cyclists, over a period when helmet use has risen from close to zero to around 50%.
Transport for London road casualty statistics.
[15] Net benefit of helmet wearing in Australia in range $2 million to minus $10 million. *An Economic Evaluation of the Mandatory Bicycle Helmet Legislation in Western Australia*, Hendrie et al, Road Accident Prevention Research Unit, University of Western Australia, 1999.
This study is referenced in Section 5 of RR30 but the cost-benefit outcomes are not mentioned and the data presented is selective and at the extreme end of the sensitivity analyses.
[16] Large cost disbenefit in New Zealand for adult helmet wearers. Some benefit for children under 12, but even this is contradicted by subsequent analysis of data by Perry (unpublished).
New Zealand bicycle helmet law-do the costs outweigh the benefits?, Taylor & Scuffham, Injury Prevention 2002 8:317-320.
[17] It takes over 3,000 years of average cycling to suffer a serious head injury. Correlation of Transport Statistics Great Britain, National Travel Survey and next reference.
[18] Head injuries to cyclists account for only around 1 in 1,000 emergency admissions to hospital.
Trends in serious head injuries among cyclists in England, Cook & Sheikh, BMJ 2000 v321 p1055.
[19] 6 times more pedestrians and 18 times more motor vehicle occupants suffer lethal head injuries than cyclists.
The pattern of injury in fatal cycle accidents and the possible benefit of cycle helmets, Kennedy, British Journal of Sports Medicine 1996. Vol 30 p130-133.
[20] People who cycle regularly live longer than non-cyclists, with better health throughout their lives. Cycling to work is the most effective way of increasing longevity.
All-cause mortality associated with physical activity during leisure time, work, sports and cycling to work, Andersen et al, Arch Intern Med: 2000 Jun 12;160(11):1621-8.
[21] Road cyclists account for less than 1% of serious head injuries seen by hospitals.
Disability in young people and adults one year after head injury, Thornhill et al, BMJ 2000 Vol 320 p1631-5. Cross-tablulated with data from the Office of Population Censuses and Surveys.
[22] In 2001 there were 138 cyclist deaths through RTAs in Great Britain and 29 other cycling deaths compared with 58,090 caused by heart disease due to inactivity and around 30,000 (in England alone) due to obesity. Most of the deaths due to heart disease and obesity could have been prevented if more people cycled.
Office of National Statistics and Department for Transport.

[23] 82% of cyclists, but 86% of pedestrians and motor vehicle occupants, who die in crashes suffer lethal head injuries. Cyclists are much less likely than others to suffer lethal injuries to the abdomen and thorax (14% v 29% and 39% v 71% of fatalities respectively).
The pattern of injury in fatal cycle accidents and the possible benefit of cycle helmets, Kennedy, British Journal of Sports Medicine 1996. Vol 30 p130-133.

[24] *Trends in serious head injuries among cyclists in England: analysis of routinely collected data*, Cook & Sheikh, BMJ 2000, v321 p1055.

[25] When cycle use doubles, the risk of injury per cyclist falls by 35% to 40%.
Assessing the actual risk faced by cyclists, Wardlaw, Traffic Engineering & Control, 2002.

[26] *An expert judgement model applied to estimating the safety effect of a bicycle facility*, Leden et al, Accident Analysis & Prevention 2000. 32:589-599.

[27] *On the treatment of flow in traffic safety analysis: a non-parametric approach applied to vulnerable road users*, Ekman, University of Lund, 1996.

[28] *The efficacy of bicycle helmets against brain injury*, Curnow, Accident Analysis & Prevention 2003.
Article in press made available to DfT researchers early in 2002.

[29] *Motorcycle and bicycle protective helmets: requirements resulting from a post crash study and experimental research*, Corner, J.P., Whitney, C.W., O'Rourke, N. and Morgan, D.E., Federal Office of Road Safety report no. CR 55, Canberra 1987, p. 5.

[30] *Football injuries of the head and neck,* National Health and Medical Research Council, AGPS, Canberra, 1994.

[31] *The efficacy of bicycle helmets against brain injury*, Curnow, Accident Analysis & Prevention 2003. Article in press made available to DfT researchers early in 2002.

[32] *Pedal cycle helmet effectiveness: a field study of pedal cycle accidents*, McIntosh et al. Accident Analysis & Prevention, 1998, 30:161-168.

[33] Tests for the Consumers Association found that 14 out of 24 helmet types failed tests for shock absorption, only 2 met the more demanding Snell standard, and one of these caused some impairment of a cyclist's vision. *Get a head start,* Which?, 1998.
Subsequent tests by Head Protection Evaluations Ltd (unpublished) have shown similar results.

[34] Rutter has estimated that the health benefits of cycling outweigh the risk of injury by at least 15:1 and probably much higher. Cycling and Health conference, Nottingham University, March 2003. Previously Hillman had suggested 20:1.
Earlier references under Epidemiology of cycle injuries also apply.

[35] *Can a combination of local, regional and national information substantially increase bicycle-helmet wearing and reduce injuries? Experiences from Sweden*, Ekman et al. Accident Analysis & Prevention 1997, 29:321-328.

[36] *Injury prevention strategies to promote helmet use to decrease severe head injuries at a Level 1 trauma centre*, Mock et al. Journal of Trauma 1995, 39:39-33.

[37] *A hospital led promotion campaign aimed to increase bicycle helmet wearing among children aged 11-15 living in West Berkshire 1992-98*, Lee et al. Injury Prevention 2000, 6:151-153.

[38] *A bicycle helmet promotion campaign for the under 16 year olds in West Berkshire, England 1992-1995*, Lee & Smyth. Pro Velo Australis International Bicycle Conference, Freemantle, Western Australia, 1996.

[39] *Cycle helmet wearing in 1996*, Bryan-Brown & Taylor. TRL Report 286.

[40] In Arizona, an increase in helmet wearing was accompanied by "a considerable decrease" in children cycling.
Trends in bicycle helmet use by children: 1985 to 1990, Weiss. Pediatrics 1992, 89:78-80.

[41] Correlation of data from Office of National Statistics and Department for Transport.

[42] Calculation based on Department for Transport traffic census data and TRL helmet wearing surveys. Cycle use 1990-9 fell by approx 0.8 million regular cyclists; the number of people who started to wear a helmet was no more than 0.5 million.

[43] *Head injuries to bicyclists and the New Zealand bicycle helmet law*, Scuffham et al. Accident Analysis & Prevention, 2000, 32:565-573.

[44] The apparent post-law benefit only corrected the *increase* in head injury in the immediate pre-law years as helmet use rose in anticipation of the law. Over the period 1988 - 1996 (law in 1994), head injuries increased slightly relative to cycle use.
Analysis by Perry (unpublished) of *Head injuries to bicyclists and the New Zealand bicycle helmet law*, Scuffham et al, Accident Analysis & Prevention, 2000, 32,p565-573.

[45] RR30 page 47.

[46] *Bicycle use and helmet wearing rates in Melbourne, 1987 to 1992: the influence of the helmet wearing law*, Finch, C.F., Heiman, L. and Neiger, D., Monash University Accident Research Centre report no. 45, February 1993, pp. 35, 36.

[47] *Bicycle use and helmet wearing rates in Melbourne, 1987 to 1992: the influence of the helmet wearing law*, Finch, C.F., Heiman, L. and Neiger, D., Monash University Accident Research Centre report no. 45, February 1993, pp. 35, 36.

[48] *Head injuries and bicycle helmet laws*, Robinson D, Accident Analysis & Prevention 1996. 28(4):463-75.

[49] 16% of cyclists claim that their riding behaviour is affected by wearing a helmet, and 10% admit to taking more risks.
Cycle helmet wearing in Great Britain, Taylor & Halliday. TRL Report 156, 1996.

[50] A significant minority of cyclists (believed to be 19%) admit to riding faster or on busier roads when wearing a helmet, teenage boys and young men especially. *"I always feel safe wearing it, because when I'm not wearing it I don't feel like I can really go top speed because if I do have an accident I'll be killed, but if I'm wearing it I'll be all right"* (young man 15-17).
Attitudes to cycle helmets – a qualitative study, Halliday, Finch & Ward. TRL Report 154, 1996.

[51] 1n 1999 21.8% of cyclists wore helmets on built-up major roads, but only 8.2% on built-up minor roads.
Cycle helmet wearing in 1999, Bryan-Brown & Christie, TRL Report 487, 2001.

Appendix: The Observational Studies

Paper 1: Do bicycle safety helmets reduce severity of head injury in real crashes?
Dorsch et al. 1987

Population size

Case: 69 + 37 + 16, Control: 75.

Limitations noted by reviewers

1. Self report of helmet use and type of injury
2. Restricted to cycling enthusiasts.
3. Unable to evaluate unpublished method used to predict preventable deaths.
4. High rate of (voluntary) helmet use: 62%.
5. 85% males.
6. Unclear about deaths (paper suggests 90% would be prevented).

Reviewers' assessment

Good study

Other factors not mentioned

1. Sage et al in NZ Med Journal 85 stated with regard to the study that: "Injuries of fatal severity to multiple organ systems were seen in sixteen of the twenty riders, including six with no significant head injury. Only four riders died of fatal injury to the head alone and one of these was the only rider know to be wearing a safety helmet. His death resulted from a fall from a bike at moderate speed rather than collision with a motor vehicle".
2. In 1985 Dr Dorsch told an Australian parliamentary committee that the conclusions of the study should be treated with care. "That was a hypothetical procedure based largely on an adult group of cyclists".
3. Small population.

Overall assessment

1. Small-size study with reporting bias.
2. Prediction of savings in fatalities wholly discredited by real-life experience.
3. Evidence unsound and out of context.

Paper 2: A case control study of the effectiveness of bicycle safety helmets
Thompson, Rivara & Thompson. 1989

Population size

Case: 235, Control: 433 + 558.

Limitations noted by reviewers

1. Cases less likely to be male, were older and had lower incomes than controls.
2. Those with head injuries twice as likely to have been in collision with a car.
3. Those with head injuries more likely to have been cycling on hard surfaces and to have damaged their bikes.
4. Crash situations of cases and controls different and not clear that those in worst crashes were more or less likely to be helmeted. Not clear if injuries to other parts of body similar.
5. Lack of conditional logistic regression could have serious effect on result.
6. Incorrect assumption about reduction in risk. Over-estimated reduction in risk due to helmets.

Reviewers' assessment

Good/reasonable study

Other factors not mentioned

1. Main control group (2) had 7 times helmet wearing rate of street cyclists at time of survey.
2. Hospital-based control group had too few helmet wearers to be meaningful. There were only 3 helmeted children under 15 in the case group, but they dominate the second control group.
3. Study did not include a single helmeted cyclist in collision with a motor vehicle.
4. Definition of head injuries includes facial injuries. 46% of head injuries were to forehead only.
5. Study not randomised. Too many variables are not within the control of the researchers.
6. Data not collected or treated to measure effects of helmets on serious brain injuries (e.g. DAI, SDH).

Overall assessment

1. Discrepancy in helmet wearing rate between case and control 2 invalidates any net benefit from helmets. If the street cyclists are considered more representative of the cyclists in Seattle, then the data shows no significant benefit from helmets.
2. The many shortcomings of this paper and the extensive criticism that it has received mean that it is no longer safe for serious review.

Paper 3: A case control study of the effectiveness of bicycle safety helmets in preventing facial injury Thompson, Rivara & Thompson 1990

Same data set as Paper 2.

Population size

Case: 212, Control: 319 + 558.

Limitations noted by reviewers

1. Weak study
2. Results not valid.

Reviewers' assessment

Weak study

Other factors not mentioned

1. Cases and controls dissimilar in many respects.
2. Cases more likely to have hit a stationary vehicle or suffered cycle damage.
3. Cycling experience greater in control group.
4. No protective effect found for serious facial injuries; perhaps some for minor upper face.

Overall assessment

1. Paper considered weak and invalid by DfT reviewers.

Paper 4: Bicyclists, helmets and head injuries: A rider based study of helmet use and effectiveness Wasserman et al. 1988

Population size

Case: 7, Control: 14

Limitations noted by reviewers

1. Riders wearing helmets were more highly educated and reported higher car seat belt use.
2. Entirely self-report data.
3. Small numbers reporting injury and using helmets.
4. Due to very small numbers involved (7), little weight can be put on this study.

Reviewers' assessment

Reasonable study

Overall assessment

1. Very small sample, all self-reporting with no independent verification do not make for a sound study.
2. DfT reviewers acknowledge that little weight can be put on this study.

Paper 5: Helmet protection from head injuries among recreational bicyclists
Wasserman & Buccini 1990

Population size

Case: 109, Control: 82

Limitations noted by reviewers

1. Self-report of injury and helmet use (only 50% of riders sought medical attention)
2. Controls included those wearing non-ANSI helmets.
3. Neck injuries more frequent in helmeted riders.
4. Not clear how helmets protect against lower face injuries.
5. Cyclists killed or seriously injured excluded.
6. Cycling enthusiasts; how did helmet wearing compare with population norms?
7. Some cyclists counted more than once in injury tables.
8. Difficult to interpret injuries: inconsistent self report data.
9. Insufficient detail.

Reviewers' assessment

Reasonable study

Other factors not mentioned

1. Helmet wearers significantly older.
2. No information about place or purpose of cycling.

Overall assessment

1. Weak study, with too much reliance on self-reporting and limited crash detail.
2. Poor quality of paper, as noted by reviewers, makes it unsuitable for serious review.

Paper 6: A prospective analysis of injury severity among helmeted and non-helmeted bicyclists involved in collisions with motor vehicles
Spaite et al 1991

Population size

Case: 38, Control: 246.

Limitations noted by reviewers

1. Cases more likely to be female and adult.
2. Graph suggests those wearing helmets had more severe injuries generally.
3. Less severe injuries may be under-represented due to restriction to motor vehicle crashes.
4. Some figures small and hard to interpret.
5. Suggests helmet use/non-use is marker for other rider behaviours.

Reviewers' assessment

Good/reasonable study

Other factors not mentioned

1. The differences in injury severity by helmet use is not just presented in a graph, but highlighted in the text as a *"striking finding"* and the subject of much discussion. If head injuries are excluded, helmet wearers have much lower mean injury levels (ISS 3.6 v 12.9), are more than 7 times less likely to have sustained serious injury (4.4% v 32.1%) and are 6 times less likely to have sustained at least one major anatomical injury (3.5% v 21.4%).
2. Sample size is very small.
3. Head injury compared with other activities is not assessed in context with cycle use.

Overall assessment

1. The considerable differences in risk for all types of injury between helmeted and unhelmeted cyclists make it impossible to draw any conclusions about the protection capability of cycle helmets.
2. This and the other limitations make this paper ineligible as support for helmet efficacy.

Paper 7: The effectiveness of bicycle helmets; a study of 1710 casualties
McDermott et al 1993

Population size

Case: 261 + 105, Control: 1341.

Limitations noted by reviewers

1. Difficult to interpret some of the comparisons.
2. Half of sample had no impact.
3. Helmets increase neck injury (though reviewers are critical of this finding).
4. Critical of claim that design of research under-estimates protective effect of helmets.

Reviewers' assessment

Reasonable study

Other factors not mentioned

1. Helmet wearers more likely to suffer serious extremity and pelvis injury.
2. Effect on fatalities not significant. 2 non-wearers died of non-head injuries, but no helmet wearers. Does this indicate different riding styles?
3. Less clear evidence of protection against serious injury AIS > 4. Injuries classified only by severity score not by types of injury. For the more severe injuries (AIS 4 - 6) numbers are much too small to draw conclusions on effects of helmets on serious brain injuries.
4. Exclusion of 22 cases whose helmets were dislodged is questionable.

Overall assessment

1. Differences between wearers and non-wearers make comparison of two groups difficult.
2. Criticism by DfT researchers fundamental.

Paper 8: Injury patterns in cyclists attending an A&E department
Maimaris et al 1994 (Cambridge study)

Population size

Case: 114, Control: 928.

Limitations noted by reviewers

1. Cases and controls drawn from same population.
2. Higher proportion of children wore helmets.
3. Low rates of head injury. Not clear how many accidents included head impact.
4. Possible helmet users more likely to seek help at hospital.

Reviewers' assessment

Reasonable study

Other factors not mentioned

1. Helmeted cyclists much less likely to suffer face and neck injuries. They are also less likely to suffer trunk, arm and leg injuries.
2. No information about types of crash, nor where they took place.
3. Little information about severity of head injuries.
4. No impact on injury severity for road cyclists in Cambridge during or after survey period, as recorded by County road accident statistics.

Overall assessment

1. Difficult to draw conclusions if number of accidents involving head impact not known.
2. Overall lower likelihood of injury to helmeted cyclists suggests cases and controls have different cycling characteristics.
3. Findings inconsistent with independent injury monitoring through road casualty data.

Paper 9: Effectiveness of bicycle helmets in preventing head injury in children
Thomas et al 1994

Population size

Case: 102 + 41, Control 278 + 65

Limitations noted by reviewers

1. Young children over-represented among controls.
2. Circumstances of crash different: head injured more likely to have been in collision with car or riding on hard surface and bicycle more likely to need repair.
3. Not clear whether unhelmeted children over-represented in more severe crashes.
4. Did not examine injury to other parts of body.
5. Response rates not specified.
6. Data not differentiated pre and post legislation.
7. Missing data could potentially cause serious bias in reported results.

Reviewers' assessment

Reasonable study

Other factors not mentioned

1. Study period straddled introduction of helmet law with no adjustment for circumstances before and after.

Overall assessment

1. Poor data for reasons noted by DfT reviewers.

Paper 10: The effects of bicycling helmets in preventing significant bicycle-related injuries in children
Finvers et al 1996

Population size

Case: 96, Control: 603

Limitations noted by reviewers

1. Most seriously injured may be excluded.
2. Parents may falsely report helmet use in injured children.
3. Not clear if helmets protect against non-severe injuries.
4. No numerical data presented on serious injuries to other parts of body.
5. Average age but no standard deviation.
6. No cycling exposure data presented and no clear information on population wearing rates in this age group.
7. Failure to adjust for possible confounding factors.
8. Insufficient data to draw clear conclusions from this study.
9. Children only.

Reviewers' assessment

Reasonable study

Overall assessment

1. Reviewers' assessment that data insufficient to draw clear conclusions makes this paper ineligible for serious study.

Paper 11: Effectiveness of bicycle helmets in preventing head injuries
Thompson, Rivara & Thompson. 1996

Population size

Case: 757, Control 2633.

Limitations noted by reviewers

1. Controls hospital based, none in community
2. Not clear whether injuries to other parts of body more severe.

Reviewers' assessment

Excellent study

Other factors not mentioned

1. Cases more likely to be younger, male, less educated and with lower income.
2. Cases more likely to be hit by motor vehicle, crash on a hard surface or sustain cycle damage.
3. Adjustment for above factors not proven and probably crude.
4. 3 deaths to non-helmeted cyclists attributed to chest injuries. No such deaths to helmeted cyclists.
5. No reference to DAI or SDH or assessment of capacity for cycle helmets to address these types of injury.
6. Dismisses, without evidence, the possibility that wearing a helmet may affect the likelihood of a crash. Study design requires cases and controls to have equal probability of striking their heads, but there is no evidence that this is so.

Overall assessment

1. Cycling characteristics of cases and controls different, making comparison unreliable.
2. Invalid with respect to serious brain injuries due to lack of appropriate methodology.
3. Conclusions by this team of researchers are considerably more optimistic than those produced by any other research world-wide.

Paper 12: Effectiveness of bicycle safety helmets in preventing serious facial injury
Thompson, Nunn, Rivara, Thompson. 1996

Same data set as Papers 11 and 13.

Population size

Case: 908, Control: 1979 + 2209.

Limitations noted by reviewers

1. Little information on cyclists in source population.
2. Unclear which is appropriate control group.
3. No population based control (both hospital based).
4. Low on detail.
5. Text and tables contain some discrepancies in the figures reported.

Reviewers' assessment

Good/reasonable study

Overall assessment

1. Above limitations do not yield reliable evidence of helmet efficacy.

Paper 13: Epidemiology of bicycle injuries and risk factors for serious injury
Rivara, Thompson & Rivara. 1997

Same data set as Papers 11 and 12.

Population size

Case: 1717, Control: 1668

Limitations noted by reviewers

1. Case more likely to be male, child or teen.
2. Small numbers in fatality study (14).
3. Some lack of clarity.
4. Large fatality result based on small numbers.

Reviewers' assessment

Good study

Other factors not mentioned

1. Study not concerned with head injuries and helmet use but other factors leading to serious injury.
2. However, states that helmets have no apparent effect on overall risk of severe injury.
3. Neck injuries (which other studies claim to be a result of helmet wearing) increase risk of death by 15 times compared with other serious injuries.
4. Cases more likely to cycle frequently than controls.

Overall assessment

1. Study not generally relevant to assessment of helmet efficacy.
2. Nonetheless indicates that helmet wearing does not reduce severe injury.

Paper 14: Bicycle injuries: Road trauma is not the only concern
Jacobson et al. 1998

Population size

Case: 115, Control 114.

Limitations noted by reviewers

1. Self-reported helmet use.
2. Small numbers of adults made some comparisons difficult to interpret.
3. Only 2 years' data on reported helmet use.
4. No breakdown by injury severity.
5. Not clear if head injuries include face.
6. No sense of severity of injuries.
7. Some groups small.

Reviewers' assessment

Good/reasonable study

Other factors not mentioned

1. For two groups of cyclists, age 10-14 off road and age 15+ on road, there was no difference in the likelihood of head injury between helmeted and unhelmeted riders (4/20 and 3/20 respectively for age 10-14 off road, and 5/25 and 5/24 for age 15+ on road).
2. No distinction between 'transport' and 'play' injuries.

Overall assessment

1. Given the limitations, number of variables and contradictory results, the study provides no clear evidence of the efficacy of cycle helmets.

Paper 15: Epidemiology of bicycle injury, head injury, and helmet use from British Columbia
Linn et al. 1998

Population size

Case: 327, Control 1135.

Limitations noted by reviewers

1. Characteristics of case and controls unclear.
2. No exposure data. Only injured children included.
3. Not enough breakdown of figures.
4. Difficult to know when unhelmeted children had more severe injuries to other parts of body.

Reviewers' assessment

Reasonable study

Other factors not mentioned

1. Distinction between head and face, and superficial and life-threatening injuries, unclear.

Overall assessment

1. Too many limitations as noted by DfT reviewers.

Paper 16: Impact of bicycle helmet safety legislation on children admitted to a regional pediatric trauma center
Shafi et al. 1998.

Population size

Case: 31, Control: 177

Limitations noted by reviewers

1. Only included children admitted to hospital, who were more likely to have head injuries than ER attenders.
2. Numbers very small for some calculations.
3. Difficult to interpret as suggests that helmets only protect from more severe injuries.

Reviewers' assessment

Reasonable study

Other factors not mentioned

1. No information about type of cycling, riding environment, social background or other relevant factors.

Overall assessment

1. Insufficient data to make meaningful assessment.