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Bicycle helmet legislation: Can we reach a consensus?

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Abstract

Debate continues over bicycle helmet laws. Proponents argue that case-control studies of voluntary wearing show helmets reduce head injuries. Opponents argue, even when legislation substantially increased percent helmet wearing, there was no obvious response in percentages of cyclist hospital admissions with head injury—trends for cyclists were virtually identical to those of other road users. Moreover, enforced laws discourage cycling, increasing the costs to society of obesity and lack of exercise and reducing overall safety of cycling through reduced safety in numbers. Countries with low helmet wearing have more cyclists and lower fatality rates per kilometre.

Cost-benefit analyses are a useful tool to determine if interventions are worthwhile. The two published cost-benefit analyses of helmet law data found that the cost of buying helmets to satisfy legislation probably exceeded any savings in reduced head injuries. Analyses of other road safety measures, e.g. reducing speeding and drink-driving or treating accident blackspots, often show that benefits are significantly greater than costs. Assuming all parties agree that helmet laws should not be implemented unless benefits exceed costs, agreement is needed on how to derive monetary values for the consequences of helmet laws, including changes in injury rates, cycle-use and enjoyment of cycling. Suggestions are made concerning the data and methodology needed to help clarify the issue, e.g. relating pre- and post-law surveys of cycle use to numbers with head and other injuries and ensuring that trends are not confused with effects of increased helmet wearing.

Keywords: Bicycle; Helmet; Legislation; Head injury; Case-control; Bias

1. Introduction

Hagel and Pless (2006) criticised evidence against bicycle helmet legislation (Curnow, 2005) arguing that large population studies of the effects of helmet laws provide weaker evidence than case-control studies. The two sources of data are compared and discussed, along with what information should ideally be collected to provide the best possible evaluation and understanding of helmet legislation, including effects related to risk compensation or reduced safety in numbers.

2. Case-control studies

Serious problems in the methodology of analysing self-selected samples came to light after publication of randomised control trials showing hormone replacement therapy (HRT) significantly increased the risk of heart disease. Yet a review of what were considered the best quality observational studies (11 case-control studies, 16 prospective studies, 3 cross-sectional studies) concluded that HRT decreased the risk by 50% (Lawlor et al., 2004a). The problem was attributed to the same sort of differences between users and non-users of HRT being present in nearly all studies, leading to difficulties in correctly adjusting for confounders. Similar misleading results were also reported for studies of other self-selected populations, e.g. users of vitamin supplements (Lawlor et al., 2004b).

Evidence suggests that cyclists who choose to wear helmets may differ substantially from those who do not. Helmet wearers are more likely to ride in parks, playgrounds or bicycle paths than city streets (DiGuisseppi et al., 1989), obey traffic laws (Farris et al., 1997), wear fluorescent clothing and use lights at night (McGuire and Smith, 2000). These factors affect both the risk of colliding with motor vehicles, and impact speed when collisions occur. The former was evident in the data of Thompson et al. (1996) in that non-helmeted cyclists collided with motor vehicles 41% more frequently than helmet wearers (OR = 1.50, $P < 0.0001$). The latter was demonstrated by a study of bike/motor vehicle collisions. The authors (Spaite et al., 1991) concluded: "*This implies that non-users of helmets tend to be in higher impact crashes than helmet users, since the*

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injuries suffered in body areas other than the head also tend to be much more severe".

Bike/motor vehicle collisions caused a majority (34 out of 62) brain injuries >AIS2 in the case-control study of Thompson et al. (1996). The authors attempted to adjust for age and whether a motor vehicle was involved (reporting no significant effect of other factors), but did not consider impact speed in collisions with motor vehicles, although this significantly affects the risk of head injury (Janssen and Wismans, 1985). Thus any differences in head injuries due to differences in impact speed between wearers and non-wearers, as observed by Spaite et al. (1991), would be incorrectly attributed to helmets.

There may also have been difficulties in correctly adjusting for other confounders. Thompson et al. (1989) reported only 3 age categories: <15, 15–24 and >25. However, a subsequent analysis of a subset of the same data (Thompson et al., 1990) showed that 83% of children aged 0–4 suffered head injury, compared to 42% of 5–9 year olds and 23% of 10–14 year olds. Such large differences indicate that age adjustment in the original study may have been inadequate. Another indication of confounding in Thompson et al. (1989) was the vast discrepancy between helmet wearing of children in the control (CC) group (21.1%; $n = 478$) and an observational study (OS) of children riding round the same city in the same year (3.2%; $n = 4501$, DiGuisseppi et al., 1989). The larger OS study was intended to estimate population helmet wearing rates. If the sole difference between CC and OS cyclists was that the former fell off their bikes, it would imply that helmet wearing was associated with a seven-fold increase in the risk of falling off the bike, negating any benefit of helmets.

Curnow (2005) argued that fear of death or chronic disability (which he defined as brain injuries of severity AIS4-6) was the main motive for wearing helmets. However, the majority of head injuries treated in emergency departments (73% of the 757 head injuries in the study of 3390 injured cyclists by Thompson et al., 1996) did not involve brain injury. Brain injuries >AIS2 comprised only 8% of head injuries (Thompson et al., 1996). The Cochrane review (Thompson et al., 2003) calculated odds for brain injury >AIS2 from at most 90 such injuries in two studies (4.2% and 1.8% of injuries in Thompson et al., 1989, 1996, respectively). The small numbers and potential problems of confounding noted above suggest that the conclusions concerning brain injury >AIS2 should be treated with caution.

3. Helmet law studies

A published review examined data from enforced helmet laws in all jurisdictions where legislation increased percent helmet wearing (%HW) by at least 40 percentage points within a year. In contrast to the 90 brain injuries >AIS2 in the Cochrane review, the helmet-law review included 10,479 head injuries severe enough to appear in hospital admissions databases (Robinson, 2006). In five jurisdictions with hospital admissions data, %HW increased from a pre-law average of 35% to a post-law average of 84%. If, as claimed by the Cochrane review, helmets reduce serious head injuries by 63–88%, an increase from 35% to 84% helmet wearing would reduce percent head injury (%HI) by 39–62%. It would be impossible to miss such large, sudden changes in time series data. Yet there was little or no noticeable response in %HI to the changes in %HW, leading to serious doubts about the benefits of helmet legislation (Robinson, 2006).

Fig. 1a illustrates some of the factors involved, contrasting %HW in Victoria, Australia with (1) numbers of *non-head* injuries from bike/motor vehicle collisions to cyclists and pedestrians and (2) percentages of serious injuries in collisions with motor vehicles involving death or serious head injury (%DSHI). Police enforced the helmet law. Surveys in the first month (July 1990) showed 94%, 87% and 89% of primary and secondary school children and adults wore helmets, compared to 65%, 37% and 44% in March 1990 (Sullivan, 1990).

The obvious and sharp decline in numbers of *non-head* injuries (Fig. 1a) coinciding exactly with legislation can be explained by noting that numbers counted in identical pre- and post-law observational surveys declined by 36% (Robinson, 1996); non-head injuries declined because cycle-use declined. There was also a more gradual change in the ratio of adult to child cyclists. Helmet laws discouraged children (42% reduction in the first year) more than adults (29% reduction), resulting in an

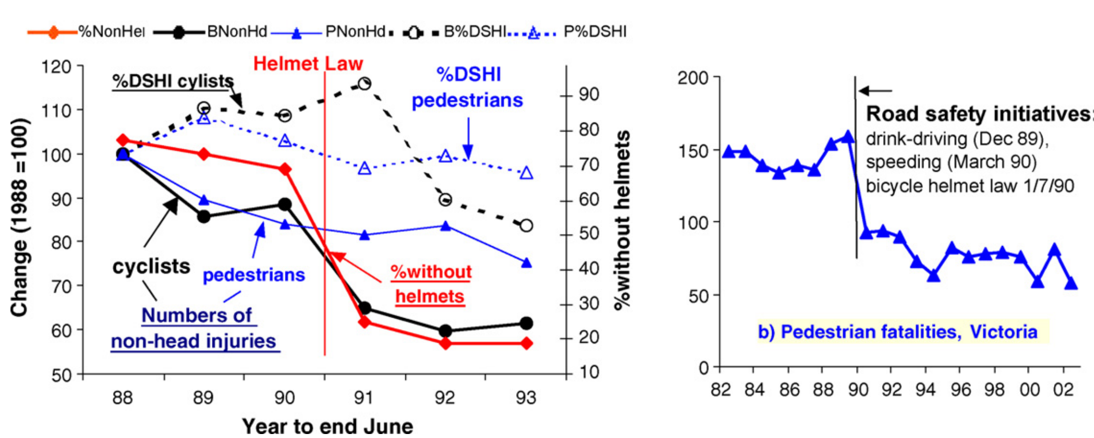

Fig. 1. Comparison of two road safety interventions in Victoria, Australia. (a, left) Percent without helmets (%NonHel) before and after helmet legislation, compared with numbers of *non-head* injuries to bicyclists (BNonHd) and pedestrians (PNonHd) and percentages of serious injuries involving death or serious head injury from collisions with motor vehicles for bicyclists (B%DSHI) and pedestrians (P%DSHI). (b, right) Numbers of pedestrian fatalities and timing of campaigns against speeding and drink-driving. Sources: ATSB (2002) and the Victorian Transport Accident Commission.

increasing proportion of adults (50%, 55% and 60%) counted in the 1990, 1991 and 1992 surveys respectively. This was reflected in an increasing proportion of injuries to adults (36% pre law, increasing to 42%, 46% and 50% in 1991, 1992 and 1993 respectively). Adults had lower %DSHI (19%) than children <18 years (29%). The gradual decline in %DSHI of cyclists relative to pedestrians is not consistent with the change in %HW, but might be explained by the increasing proportion of adult cyclists.

If legislation did not increase risk taking or discourage cycling, helmet law studies would compare identical populations of cyclists before and after legislation, the only change being increased helmet wearing. The absence of obvious benefit would imply that helmets are largely ineffective. However, all studies of enforced helmet legislation that measured cycle-use reported substantial declines. Thus it is possible to conclude only that helmet *laws* did not reduce the risk of injury per cyclist, but not whether this is due to risk compensation (Adams and Hillman, 2001), reduced safety in numbers (Jacobsen, 2003; Robinson, 2005), or over-optimistic predictions of the benefits of helmets in preventing serious head injuries.

4. Experimental evidence

Experimental evidence shows that the brain is particularly susceptible to damage from rotations, which can shear connections between neurones and even blood vessels. For example, Gennarelli et al. (1972) subjected 12 squirrel monkeys to linear accelerations with peak levels 665–1230 g, and 13 primarily to rotational accelerations in the range of 348–1025 g. Contact phenomena were minimised by the design of the apparatus. None of the monkeys receiving linear acceleration was concussed, but all 13 receiving rotational acceleration suffered concussion and the group had a high incidence of brain injuries such as subdural haematoma, subarachnoid haemorrhage and intracerebral petechial haemorrhage. Thus rotational accelerations can cause more severe brain injuries than linear accelerations.

Corner et al. (1987) measured rotational accelerations when dummies wearing bicycle helmets went over the handlebars at 45 km/h and hit a smooth surface. Compared with a tolerance of 1800 rad s^{-2} for concussion and 4500 rad s^{-2} for onset of vein rupture, measurements (averaging 58,000 rad s^{-2}) were described as "enormous". No comparable results were reported for non-helmeted dummies, but other experiments showed that wearing bike helmets increased rotational accelerations (Corner et al., 1987).

The lack of evidence for significant reductions in serious head injury following helmet legislation, small numbers of serious brain injuries and problems of confounding in case-control studies, together with experiments such as the above, suggests that the effect of helmets on rotational injuries requires further study.

5. Odds ratios versus risk of head injury

Odds ratios (OR) for helmet efficacy are commonly described as reductions in risk. For example, Thompson et al. (1989) state that "*riders with helmets had an 85% reduction in their risk of head injury* (*odds ratio 0.15;...*)". Sacks et al. (1991) cited this as evidence that, over a 5-year period, 2500 out of 2985 head injury deaths to US cyclists could be prevented if all cyclists wore helmets. The American Academy of Pediatrics (2001) stated that "*The bicycle helmet is a very effective device that can prevent the occurrence of up to 88% of serious brain injuries*".

The above predictions ignore the fact that the risk of head injury (and risk reduction calculated from odds ratios) is highly dependent on the circumstances of the crash. In bike-only crashes when the rear wheel skids, common impact sites are legs, hips, arms or shoulders. Lacking the extra size and mass of the helmet, bareheaded cyclists rarely hit their heads in minor crashes, let alone sustain serious head injuries. In contrast, a head-on collision with a vehicle travelling at more than 80 km/h is likely to cause death or serious head injury, irrespective of helmet wearing.

Fitting odds ratios by logistic regression is equivalent to fitting a relationship between the risk of head injury for helmeted and non-helmeted cyclists that depends on the severity of the collision (see Table 1). So, for collisions so severe that 95% of non-helmeted cyclists would suffer serious brain injuries, an OR = 0.31 (the Cochrane review estimate for head injury, Thompson et al., 2003) means that 85.6% of helmeted cyclists would be similarly afflicted, i.e. only 10% of injuries would be prevented.

Table 1
Relationship between crash severity, represented by the percentage of non-helmet wearers with head injury (%HI_N), and risk reduction (RRD) or percent head injuries prevented, for a model with an odds ratio of 0.31

Crash severity (%HI_N)	Odds non-helmeted (O_N)	Odds helmeted (=0.31 × O_N)	%HI helmet wearers	Percent HI prevented (RRD)
20	0.25	0.08	7.2	64.0
40	0.67	0.21	17.1	57.2
60	1.50	0.47	31.7	47.1
80	4.00	1.24	55.4	30.8
90	9.00	2.79	73.6	18.2
95	19.00	5.89	85.5	10.0
99	99.00	30.69	96.8	2.2

Odds are calculated as percent with head injury (%HI) divided by percent without HI, i.e., O = %HI/(100 − %HI). The odds ratio, OR, is defined as O_H/O_N where O_H and O_N are odds for helmeted and non-helmeted cyclists respectively. An OR of 0.31 implies that $O_H = 0.31 \times O_N$. %HI_N can then be calculated from O_H, to give the risk ratio (RR) = %HI_H/%HI_N and the risk reduction (RRD) or percent HI prevented = 100(1 − RR). Because most serious head injuries are from serious bike/motor vehicle crashes, the overall percent head injury prevented will be much less than what people are led to believe when an OR of 0.31 is described as "preventing 69% of head injuries".

This explains why estimated reductions in head injuries based on data from emergency departments may not be appropriate for more serious crashes. For example, McDermott et al. (1993), analysing hospital admissions data, reported that 29% of helmeted adult cyclists (and 18% of helmeted child cyclists) had head injuries. If, as was claimed, helmets prevented 63–88% of all head injuries, expected injury rates in adult non-wearers would be 78–241%, a far cry from the 38% actually observed.

A detailed investigation of cyclists with severe or fatal head injuries (Corner et al., 1987) found that all fatalities were caused by bike/motor vehicle collisions. For 13 of the 14 non-helmeted cyclists who died, there was no indication that a helmet might have made any difference to the outcome. Despite head protection, helmeted cyclists frequently suffer head injuries. Nearly all deaths and debilitating head injuries are caused by bike/motor vehicle collisions (Kraus et al., 1987). The costs and benefits of helmets should therefore be compared to those for other road safety measures.

6. Cost-benefit analyses: helmet laws

Two groups of researchers used helmet law data to investigate costs and benefits. Neither considered the cost of the reduction in cycling because of helmet legislation, nor the consequences of reduced safety in numbers. Despite this, neither concluded that the benefits of legislation were likely to have exceeded the costs.

In New Zealand, the estimated cost of helmets in the first 5 years of the law was NZ$7.51 million, mainly for purchase of helmets, 27 times greater than the estimated reduction of NZ$0.28 million in hospital costs (Taylor and Scuffham, 2002). It was also noted that there was no significant effect of increased helmet wearing in models that fitted a time trend (Scuffham et al., 2000), so even this modest reduction in hospital costs may have been over-estimated.

For Western Australia, initial modelling was unable to detect any change in %HI of cyclists compared to other road users. Different models were tried; some indicated possible reductions in %HI compared to pedestrians, the benefits ranging from about 30%–109% of the cost of the helmet law (A$21.6 million over the 7-years 1992–1998). The authors (Hendrie et al., 1999) concluded: "*In monetary terms, it is unlikely that the helmet wearing legislation would have achieved net savings of any sizeable magnitude*".

Even though cycling to work was estimated to reduce mortality by 40% (Andersen et al., 2000), the two cost-benefit analyses discussed above ignored the loss of health benefits from reduced cycling. Some effects are hard to value, such as the inconvenience or discomfort of wearing a helmet, or pain from a wound to the head. The fact that some cyclists choose to wear helmets, but others do not, plus the 36% decline in counts of cyclists in Victoria with helmet laws, suggests that these intangibles have different values to different cyclists.

For a more intuitive understanding of risks vs intangibles, note that the annual total of 8502 fatalities or hospital admissions for non-cycling road injuries in Victoria in 1989 (the year before the helmet law) equates to one death or hospital admission every 517 person-years. At that time, Victoria had about 2 million cyclists (Cameron et al., 1994) and 430 cyclist hospital admissions with some form of head injury (not necessarily the reason for admission). Even if universal helmet wearing prevented half these head injuries, it would represent only one head injury per 9302 cyclist-years. In reality, even these modest benefits were not achieved (Fig. 1a), perhaps because of risk compensation, reduced safety in numbers, poor fitting or incorrectly worn helmets.

Curnow (2005) compared 1988 (before any helmet law) with 1994 (when all states had enforced laws); cyclist, pedestrian and all road user deaths fell by 35%, 36% and 38% respectively; head-injury deaths fell by 30%, 38% and 42%. Thus, despite helmet legislation, the reductions for cyclists were no greater than for other road users. Factoring in the reduction in cycling (Fig. 1), cyclists may even have been worse off with helmet laws than without them.

Cost-benefit analyses are a common feature of many road safety decisions, e.g. whether to treat accident blackspots. Usually, predicted savings in injury costs (amortised over a period of several years) must be several times greater than the cost of implementation. Some measures are reasonably effective. A review of area-wide traffic calming schemes estimated that they reduce the number of injury accidents on residential streets by an average of 25% and 10% on main roads (Elvik, 2001). However, individual schemes vary, so continuous evaluation and assessment is needed to ensure resources are used in the most effective manner and predicted benefits are realised. Some traffic calming measures have also been shown to generate other benefits such as increased pedestrian activity leading to increased physical health (Morrison et al., 2004).

Both cyclists and pedestrians should benefit from measures directed at improving overall road safety. A 42% fall in pedestrian fatalities in Victoria was attributed to campaigns against speeding and drink-driving that coincided almost exactly with the bicycle helmet law (Fig. 1b, Powles and Gifford, 1993). Road deaths also fell substantially in other Australian states (including New South Wales and South Australia) that adopted similar road safety campaigns. One estimate, from UK literature, was that accident costs in Victoria were reduced by an estimated £100 million for an outlay of £2.3 million (A$5 million, see Powles and Gifford, 1993). This compares with at least $39 million for purchase of cycle helmets to satisfy Victoria's helmet law. The above suggests that measures to improve overall road safety can be more cost effective than helmet legislation.

Recent research highlighted the importance of 'Safety in Numbers'. Injury and fatality rates per kilometre cycled are substantially higher – more than five times for higher for fatalities – in countries where fewer people cycle (Jacobsen, 2003). Countries with the low helmet wearing have more cyclists and lower fatality rates per cycle-km. (BHRF, 2006). Thus helmet legislation may be counter-productive and actually increase injuries per cyclist if, as in Australia, cycling is discouraged (Robinson, 2005).

It has been argued that cyclists would need to increase their risk-taking four-fold to overcome the protection of helmets (Thompson et al., 2003). Table 1 demonstrates the fallacy of this argument. For crashes severe enough to cause injury to 95% of non-wearers, even if helmet wearing increased risk-taking by only 10%, there would be the same number of head injuries as without helmets, but 10% more non-head injuries.

Less-serious crashes have a lower percentage of head injuries (e.g. 11% of non-wearers, Maimaris et al., 1994). A 10% increase in crashes per km cycled (due to reduced safety in numbers or risk compensation) would result in the same or more (in the case of reduced safety in numbers) injuries per km, even if helmets prevented 80% of head injuries.

Costs and benefits have been calculated for helmets for motor vehicle users (already required by law to wear seatbelts). Based on real-life crash-data suggesting they could prevent 28%, 40% and 26% of minor, moderate and severe brain injuries, McLean et al. (1997) estimated that helmets for Australian motor vehicle occupants would reduce injury costs by $1.9 billion (over 5 years, all vehicles equipped with airbags) or $2.2 billion (only half the fleet with airbags). This compares with $0.78 billion to equip the entire population with helmets (20 million at $39 each, the cost used by Hendrie et al., 1999). Yet helmets are not widely accepted by motorists (except racing car drivers), presumably because intangible costs (e.g. comfort or convenience) are deemed to outweigh the benefits.

7. General principles

The following general principles should have widespread support:

(1) Any legislation (including helmet laws) should not be enacted unless the benefits can be shown to exceed the costs. Ideally, the benefits should be greater than from equivalent ways of spending similar amounts of money on other road safety initiatives.
(2) Helmet legislation should be evaluated in terms of the effect on cycle-use, injury rates per km cycled, and changes in percentages of hospitalised cyclists with head and brain injuries (%HI). Because public health and loss of liberty are involved, it should be the responsibility of governments who pass such legislation to ensure adequate funds are set aside for evaluation.
(3) Trends are a common feature of %HI data for all road users, not just cyclists. %HI data for cyclists should therefore be compared with the same statistics for other road users. Models should also be able to differentiate between gradual changes over time that do not correspond with the changes in helmet wearing and consequences of increased %HW.
(4) Odds ratios should not be described as "percentage reductions in head injury". Instead, the fitted models should be used to predict and report head injury rates and risk ratios for crashes of different severities, e.g. bike only crashes requiring emergency treatment, bike/motor vehicle crashes requiring admission to hospital for short or long periods. Given the discrepancy in %HW of cyclists reporting falls from bikes and observational surveys of people cycling, case-control studies should also survey and report data on observed %HW of the cycling population.
(5) Surveys of cycle-use should use the same sites and observation periods and be conducted at the same time of year, ideally the year before and year after legislation, to avoid confounding with long-term trends. Labour costs could be reduced by use of automatic counters on cycleways and road camera footage.
(6) Risk of injury for different groups (e.g., helmet wearers versus non-wearers) should be evaluated by comparing numbers of injuries with estimated cycle-use. Changes in risks per km cycled should be compared with similar data for other road users.
(7) If the benefits of helmet laws cannot be shown to exceed the costs by similar ratios to other road safety initiatives, the legislation should be repealed.

These principles could provide a framework for future research to evaluate and compare results, and so facilitate agreement. For example, excluding Australia and New Zealand, a Medline search revealed 23 papers reporting consequences of helmet laws; 65% considered only the effect on helmet wearing. Despite the fact helmet laws are intended to reduce head injury rates, only two reported significant declines in %HI, but neither compared head injury and helmet wearing rates.

One (Macpherson et al., 2002) reported declining trends in %HI for child cyclists in Canadian provinces that passed helmet laws, compared with those that did not. However, the trends started before helmet legislation and continued after helmet wearing should have stabilised. It therefore seemed unlikely that the trends were a consequence of legislation (Robinson, 2003). Subsequent data confirm this. Ontario's law was not enforced (Burdett, 2002) and %HW returned to pre-law levels by 1999 (Macpherson, 2006). The dominant feature (Fig. 2) is a relatively smooth downward trend, unrelated to published %HW rates. If helmets were an important factor, the trend should have reversed when helmet wearing returned to pre-law levels. More realistic estimates might have been obtained if the initial research had considered point 3.

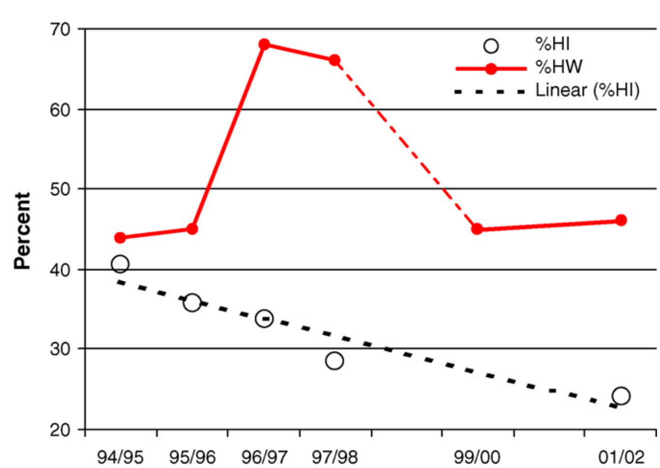

Fig. 2. Percent helmet wearing (%HW) from surveys of children in Ontario, Canada and percentage of child cyclist hospital admissions with head injuries (%HI). Sources: Macpherson et al., 2002; CIHI, 2003; Parkin et al., 2003; Macpherson, 2006.

Similar difficulties were noted for a study of voluntary wearing (Cook and Sheikh, 2003). A subsequent analysis of the same and later data found identical trends in %HI for boy and girl cyclists, despite increasing %HW for girls and falling %HW for boys (Hewson, 2005). Although trends for cyclists and pedestrians were not identical, the author considered the evidence strongly suggestive that the difference could not be due simply to helmet wearing. Greater recognition of point 3 might have encouraged Cook and Sheikh (2003) to make use of the divergent %HW trends in boys and girls to test whether helmets were responsible, instead of assuming this was the case.

The only other paper (out of the 23 noted above) reporting a significant reduction in %HI following legislation (Lee et al., 2005) did not even consider trends and provided no information on %HI by year. Instead, average %HI for various categories of cyclists for 1991–1993 were compared with averages for 1994–2000. There was a reduction for children in California but not adults. However, there is no evidence of a divergence in %HW of adult and child cyclists. %HW of adults attending a trauma centre in California increased by a similar number of percentage points as %HW of children (Ji et al., 2006), suggesting both may have followed similar trends. Point 2, that legislation should be evaluated, would encourage governments to collect the required data, making it unnecessary to speculate on helmet wearing and how this might have affected %HI rates.

To be convincing, there should be a clear response to the change in %HW (point 3), as apparent for *non-head* injuries in Victoria (Fig. 1a), presumably because enforced legislation discourages cycling. Hagel and Pless (2006) criticised Curnow (2005) for not citing Macpherson et al. (2003), Cook and Sheikh (2003) or Scuffham et al. (2000). However, as noted above, the first two failed to correctly account for trends. The third (Scuffham et al., 2000) reported that the addition of a time-trend caused the helmet wearing proportion to become insignificant, implying that the reduction in %HI might be due either to helmets or time trends. The continued declines in %HI in Ontario, despite a return to pre-law %HW, illustrates the potential confusion created by not correctly accounting for trends, or uncritically citing such work.

Point 4 advocates reporting risk ratios, not odds ratios. Helmets and helmet laws continue to be promoted by claims in the popular press that "*Cyclists who wear helmets are 85% less at risk of serious head injury*" (McKee, 2006). However, non-helmeted cyclists rarely have injuries only to the head (McDermott et al., 1993), so helmeted cyclists who crash will still need medical treatment for non-head injuries. Consequently, risk reductions (RRD, see Table 1) provide a more accurate estimate of the benefit of helmets. The crude RRD for voluntary wearing (25% for head injuries of adult cyclists admitted to hospital, McDermott et al., 1993; 56% for concussion or other brain injury of cyclists in non-motor vehicle crashes treated in emergency rooms, Thompson et al., 1996) convey a different message to the well-known 85% claim. Realised benefits from helmet laws will be even less, because of poor fit, risk compensation and reduced safety in numbers.

Point 5 above notes the important requirement that surveys should use the same sites and observation periods and be conducted at the same time of year, ideally the year before and after helmet laws. Hagel and Pless (2006) cite a detailed report (Finch et al., 1993) listing pre- and post-law counts in Melbourne from identical surveys in May 1990 and 1991. Teenage cycle-use fell by 44% and numbers of adults counted fell by 29%.

Rather than report the 29% fall in adults counted, Hagel and Pless (2006) draw conclusions from a tenuous comparison of the May 1991 survey with a much earlier survey (December/January 1987/1988). Other data, including cycling injuries in Victoria, show a marked annual cycle (Carr et al., 1995) so it is not possible to reliably estimate changes in cycle-use by comparing surveys at different times of year. For teenagers, the same comparison (1987/1988 versus 1991) yields an estimated 8% fall in cycle-use, nothing like the accepted value of 44%. Hagel and Pless (2006) criticised Curnow (2005) for failing to present all relevant evidence, then omit data from the 1990 survey (counts of adults) that refute their argument. Instead of easy to understand counts, Hagel and Pless (2006) cite only estimated cycle use, with an unbelievable value of 60 million hours per week in a city of 3 million – 20 hours per week for every man, woman and child (Cameron et al., 1994)!

General acceptance of points 1–7 could provide a framework to help reduce confusion. Non-compliance (e.g. claims based on counts of cyclists at different times of year, or long-term data series with no allowance for trends) would be noted as such and so identified as less reliable data.

8. Conclusions

Neither helmet law evaluations nor case-control studies should be considered in isolation. To view helmets in the correct perspective, we need to understand and explain both sets of results, and experimental data. The strongest helmet law studies are those with large increases in %HW in a short period of time. They show trends in %HI for hospital admissions data, but no obvious response to the large increases in %HW with legislation. The lack of response might be due to an inability of helmets to prevent the more serious head injuries associated with hospital admissions, reduced safety in numbers due to reduced cycle use, risk compensation, or other changes in the cycling population.

In the largest case-control study, 92% of head injuries from were of severity AIS1 or AIS2, suggesting they involved wounds to the head or concussions. Helmets presumably prevent wounds to the head. Although case-control data show wearers also have lower rates of concussions and other brain injuries, evidence suggests that helmet wearers were less likely to have collided with motor vehicles and tend to be in lower impact bike/motor vehicle crashes than non-wearers. As demonstrated by the contradictory results from randomized control trials and observational studies of HRT, it can be very difficult to disentangle effects of confounded variables. The obvious confounding of helmet wearing with socioeconomic status, attitude to risk and other factors associated with less frequent and lower impact bike/motor vehicle collisions leads to considerable difficulties in the interpretation and understanding of case-control data for helmet wearing.

A majority of brain injuries >AIS2 are caused by bike/motor vehicle collisions. Traffic calming, enforcement of drink-driving laws, cyclist and driver education, or other measures to reduce the frequency and severity of bike/motor vehicle collisions, may therefore represent more cost-effective ways of reducing serious head injuries to cyclists than helmet laws. Indeed, countries with the lowest fatality rates per cycle-km also have the lowest helmet wearing rates.

Information from all sources is required to reach a consensus on whether helmet legislation is beneficial—case-control data, studies of helmet laws and experimental data (Corner et al., 1987; Gennarelli et al., 1972; Janssen and Wismans, 1985). All costs and benefits need to be considered, including the cost of reduced cycling, reduced enjoyment of cycling, reduced safety in numbers, and the ability of helmets to protect against minor and serious brain injuries. These need to be compared to the cost of other road safety initiatives to reduce the incidence of bike/motor vehicle collisions that cause a majority of >AIS2 brain injuries.

Consensus can be reached if future research considers all relevant aspects of the problem. Adherence to the principles described above would allow relevant concerns to be addressed, resulting in the most cost-effective way of increasing the safety and popularity of cycling and maximising both health and environmental benefits.

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