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Short communication

Changes in head injury with the New Zealand bicycle helmet law

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Abstract

It was claimed that the bicycle helmet law in New Zealand reduced head injuries to adult cyclists by 28% (Povey, L.J., Frith, W.J., Graham, P.G., 1999. Cycle helmet effectiveness in New Zealand. Accident Analysis and Prevention 31, 763–770). However, the pre-law increase in adults wearing helmets (from 30% in 1990 to 43% in 1993) was accompanied by a fall of 45 head injuries per 100 limb injuries (i.e. − 3.47 for every 1% increase in helmet wearing) compared with a fall of 11 when wearing increased from 43 to 93% with the law (− 0.23 for every 1% increase in wearing). Unless voluntary wearing is 15 times more effective in reducing head injuries, it seems likely that the apparent effects (as described by Povey et al., 1999) were an artefact caused by failure to fit time trends in their model. Such inconsistency of effects over periods of substantial change compared with periods of little change in helmet wearing may be a useful indicator of the presence of trends. Because the large increases in wearing with helmet laws have not resulted in any obvious change over and above existing trends, helmet laws and major helmet promotion campaigns are likely to prove less beneficial and less cost effective than proven road-safety measures, such as enforcement of speed limits and drink-driving laws, education of motorists and cyclists and treatment of accident black spots and known hazards for cyclists.

Keywords: Bicycle; Helmet; Law; Head injury; Trend; Bias

1. Introduction

Povey et al. (1999) fitted an exponential multiplicative model to the ratio of numbers of head injuries to numbers of limb fractures (HI/L) of cyclists admitted to hospitals in New Zealand. They postulated that this model, stated to imply a 'diminishing returns' relationship for helmet use, fitted the data well because of a volunteer effect whereby keen adopters were more likely to wear their helmets correctly and hence more effectively than more reluctant wearers. Though this may be true, huge variations in the efficacy of helmets depending on whether a cyclist is among the first 40% to wear helmets or the last 50% seem somewhat implausible and would have profound implications for policy concerning helmet laws. In Australia, helmet laws reduced cycle use by approximately 30% (Robinson, 1996). Helmet laws would, therefore, be extremely counter-productive if most of the reduction in head injuries could be achieved with voluntary wearing.

It is, therefore, useful to review the results of Povey et al. (1999) using data kindly supplied by the authors. Fig. 1 shows the proportion of head injured adult cyclists after crashes not involving motor vehicles (figure 4 of Povey et al., 1999) together with the proportion of adult cyclists wearing helmets. Data for primary school children are shown for comparison. Though the changes in helmet wearing over time are very different for the two groups, head injury percentages show almost identical patterns ($r = 0.955$), making it somewhat implausible that the changes in head injury for each group were due solely to changes in helmet wearing. A previous analysis of New Zealand data (Scuffham and Langley, 1997) was not able to detect a significant reduction in serious head injury before the law as cycle helmet increased voluntarily, only a trend over time. In contrast, Povey et al. (1999) did not fit a

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Table 1
Numbers of head injuries and limb fractures to adult cyclists admitted to hospitals in New Zealand, following crashes not involving motor vehicles, percentages with head injury, predictions of the ratio of head to limb injuries according to the model of Povey et al. (1999) and from fitting a trend derived from the ratio of head to limb injuries in children, and the percentage of adults wearing helmets

Year	Number of			Head injured (= 100 HI/T) (%)	Ratio head/limb (R = HI/L)	Predictions of R		Helmet wearing (%)
	Head injuries (HI)	Limb fractures (L)	Total injuries (T = HI + L)			Povey	Trend	
1990	127	91	218	58.3	1.40	1.19	1.25	30
1991	107	98	205	52.2	1.09	1.14	1.15	36
1992	95	89	184	51.6	1.07	1.11	1.16	41
1993	120	127	247	48.6	0.94	1.09	1.00	43
1994	101	117	218	46.3	0.86	0.79	0.80	92
1995	93	112	205	45.4	0.83	0.78	0.85	93
1996	87	113	200	43.5	0.77	0.82	0.75	87
Changes								
1990–1993			29	−9.7	−0.45	−0.10	−0.25	13
1993–1995			−42	−3.2	−0.11	−0.31	−0.15	50

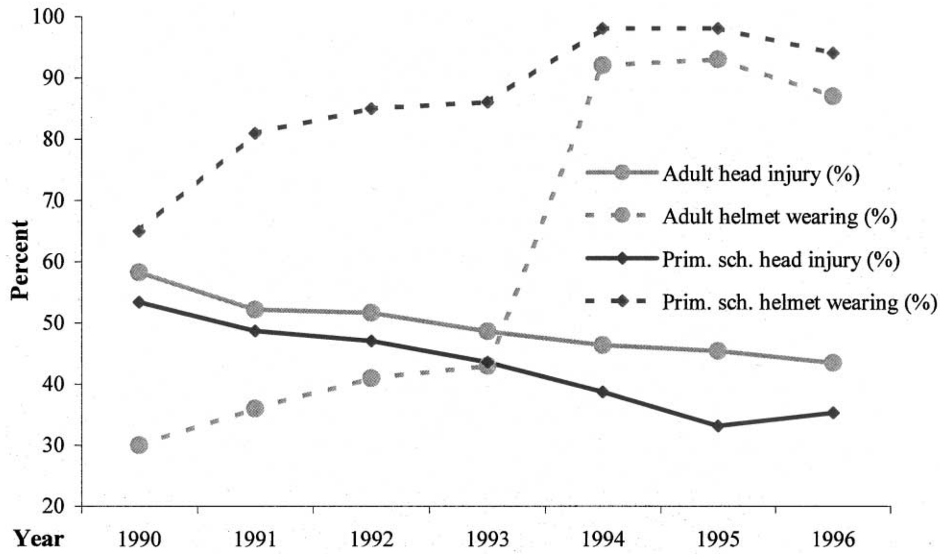

Fig. 1. Percentages of adult and primary-school child cyclists wearing helmets in New Zealand by year, and percentages with head injury following in accidents not involving motor vehicles.

time trend in their models and suggested that, in Scuffham and Langley's analysis, the time effect might have captured the helmet effect.

2. Distinguishing trends from effects of helmet wearing

One way to distinguish between time trends and the effect of helmet wearing is to examine the consistency of the effect of helmets on head injuries over a period when helmet wearing increased substantially compared with a period with little change in helmet wearing. In New Zealand, adult helmet wearing showed the greatest response to the law, increasing from 43 to 92% in a single year (Fig. 1), compared with a very gradual increase from 30 to 43% in the 4 years pre-law, making this the most appropriate dataset to distinguish trends from the effect of helmets.

Povey et al. (1999) postulated that numbers of limb fractures may be used as an estimate of accident exposure. Because the percentage with head injury changes smoothly and consistently over time (Fig. 1), it is appropriate to estimate the pre-law effect by a simple comparison of 1990 with 1993. To guard against any potential transition effects affecting the first year of the helmet law (1994), the effect of the law was estimated by a comparison of 1993 with 1995. Head injuries per 100 limb fractures fell smoothly from 140 in 1990 to 94 in 1993 (Table 1). This corresponds to a fall of 3.47 for every 1% increase in helmet wearing. From 1993 to 1995, the fall was from 94 to 83 head injuries per 100 limb fractures (Table 1) — a fall of only 0.23 for every 1% increase in helmet wearing. Thus, if the data contain no time trends, every 1% increase in voluntary helmet wearing before the law was 15 times more effective in reducing head injuries than a 1% increase due to the law. Such a remarkable discrepancy suggests either the presence of trends in the data or that helmets worn purely because of a legal requirement are of very little benefit.

3. Biases from ignoring trends

Table 2 illustrates the potential for bias using an example based on hypothetical data containing no effect of helmet wearing, but only a simple linear trend in which the ratio of head to limb injuries falls by 0.1 every year. For simplicity, a linear model was fitted as

$$\text{ratio} = \alpha + \beta(\%\text{helmet wearing}) + \text{error} \quad \text{(Model 1)}$$

Table 2
Example of bias from fitting a simple linear model ($R = \alpha + \beta$(NZ %helmet wearing) + error) to simulated data containing only a linear trend for the ratio, R, of head to limb injuries, but no effect of helmets

Year	NZ %helmet	Simulated data (R)	Fitted values
90	30	1.40	1.305
91	36	1.30	1.264
92	41	1.20	1.230
93	43	1.10	1.217
94	92	1.00	0.885
95	93	0.90	0.879
96	87	0.80	0.919
Changes			
1990–1993	13	−0.30	−0.088
1993–1995	50	−0.20	−0.338

where ratio is the head to limb injury ratio in the hypothetical dataset (containing nothing but a linear trend) and %helmet wearing is the observed adult helmet wearing rates from 1990 to 1996 in New Zealand. Fitting model (1) yielded a highly significant estimate of -0.0676 (S.E. 0.0146) for every increase of 10 percentage points in helmet wearing. Thus, according to this (invalid) model, the increase from 43 to 93% of adults wearing helmets resulted in a fall of 0.338 (95% confidence interval 0.150–0.526) in the ratio of head to limb injuries (Table 2).

The estimate is, of course, spurious. The data contained no effect of helmet wearing, only a linear trend. As in the real data from New Zealand (Table 1), the inconsistency of the effect of increased helmet wearing before, and with the law, is an indicator of inadequate fit. From 1990 to 1993, the simulated data show a change of $-0.30/13 = -0.023$ for every increase of 1% point in helmet wearing (Table 2). From 1993 to 1995, the change was $-0.20/50 = -0.004$. Thus, in the simulated data, pre-law increases in helmet wearing appeared to be six times more effective in reducing head injury than increases with the law. This represents a less extreme case than for the real data shown in Table 1. However, any estimate of grossly different effects of helmet wearing in the pre-law period compared with effects due to the law (whether 6-fold or 15-fold) should be treated as an indication of inadequate fit for a model in which head-injury rates were assumed to depend only on the helmet wearing percentage with no allowance for trends.

Another indication of biases from the model can be seen by comparing changes in data and fitted values from 1990 to 1993 (when helmet wearing changed little) with 1993–1995 (corresponding to a large increase in helmet wearing). The actual change from 1990 to 1993 in the simulated data was -0.30, which is substantially under-estimated by the change of -0.088 in fitted values (Table 2). In contrast, the change in fitted values of -0.338 from 1993 to 1995 considerably over-estimates the change of -0.20 in the simulated data (Table 2). It may, therefore, be concluded that fitting an effect of helmet wearing to data containing only a linear trend may result in a highly significant estimate for helmet wearing, but that the model will considerably under-estimate the changes for a period when helmet changes very little and over-estimate the changes when there are considerable increases in helmet wearing, e.g. because of a helmet law.

Similar biases can be seen in the fitted values from the model of Povey et al. (1999). Fitted values were calculated as $\text{HI/L} = \exp(\alpha + \beta \times \text{helmet})$, using the estimates of α and β, published by Povey et al. (1999). Compared with an actual change of -0.45 in adult HI/L from 1990 to 1993, the prediction from the model of Povey et al. (1999) was merely -0.10 (Table 1). In contrast, the model predicts a decline of 0.31 with the law, compared with the actual decline of 0.11. Given the generally smooth nature of the lines in Fig. 1, a simple comparison of 1993 with 1995 would provide a more realistic and robust estimate of the effect of the helmet law. Though the latter estimate is biased upwards by the trends in the data, the exaggeration is nowhere near as gross as using the model of Povey et al. (1999). Indeed, the 28% fall in head injuries claimed by Povey et al. (1999) is remarkably similar to the fall of 28% in the fitted values from 1993 to 1995 (Table 2) from incorrectly applying model (1) to simulated data containing no effect whatsoever for helmet wearing.

4. Trends — a better fit

Trends, if present, should be common to all cyclists. It, therefore, seems appropriate to use the mean HI/L for primary and secondary school children as an estimate of trend. Fitted values for adult HI/L, calculated by simple linear regression of mean children's HI/L, are shown in Table 1. The mean squared error, calculated as mean(predicted-actual)^2/(number of cases) was 0.0056 based on prediction from trend, compared with 0.0111 using predictions from the model of Povey et al. (1999). Thus, in terms of mean squared error, the trend is a much better fit with approximately half the mean squared error.

5. Evidence of trends in cyclist head injury data

Time trends in cyclist head injury data are not an unusual phenomenon. Hendrie et al. (1999) showed that, in Western Australia, the percentage of hospitalised cyclists with head injury followed almost exactly the same trends as those for vehicle drivers and vehicle passengers and pedestrians. Robinson (1996) showed the percentages of cyclists with head injury after collision with motor vehicles in Victoria followed by a very similar trend to those for pedestrians. For New Zealand, Scuffham et al. (2000) reported a large and significant trend in head injury as a proportion of total admissions for both cyclists and non-cyclists, both of which decreased over time.

Povey et al. (1999), however, reported that the time trends in HI/L for cyclists were not explained by variation in the HI/L ratio for non cyclists. One possible explanation for the discrepancy between the results of Scuffham et al. (2000) for head injuries as a proportion of all hospital admissions and those of Povey et al. (1999) for the ratio of head to limb injuries is that the latter may be substantially influenced by other factors not likely to influence the age groups most often involved in cycling or road accidents in general. For example, osteoporosis awareness programs directed at the elderly may make a difference to the number of limb fractures.

Furthermore, a trend unrelated to helmet wearing was, in fact, evident in the New Zealand data on cyclist hospital admissions — a gradual and almost linear decrease in the percentage of cyclist injuries involving a motor vehicle from approximately 30% of total in 1990–1991 to 21% in 1996. A similar steady decrease in motor-vehicle involvement (from 24.6 in 1987–1988 to 18.9% in 1992–1993) was reported by Marshall and White (1994) for South Australia. These clearly evident long-term gradual trends may reflect a trend in the popularity of different types of cycling and types of bikes ridden, such as increased popularity of mountain bikes and a decrease in cycling for transport and an increase in recreational cycling. If so, it is quite possible such changes would affect the risk of head injury for cyclists even after accounting for motor vehicle involvement, independently of the changes in HI/L for non cyclists. Scuffham et al. (2000) modelled the effect of helmets on the proportion of cyclist hospital admissions with head injury. If trends were fitted, the effect of helmets was no longer significant. Scuffham et al. (2000) did not, however, discuss why the effect was presumed to be due to increased helmet wearing, rather than trends, nor examine whether there was any way to differentiate between the two.

A reduction in head injury due to increased helmet wearing is plausible only if the change in head injury coincides with the increase in helmet wearing. This was not the case for adults, so we must conclude that trends were the most likely cause. Because child helmet wearing increased more gradually, it is more difficult to distinguish between trends and the effect of helmets. However, it is hard to comprehend why helmets should be effective for children, but no beneficial effect be observed with the increase in adult wearing from 43 to 93%. Furthermore, the percentage of head injuries in both primary and secondary school children correlated more strongly with the percentage of head injuries in adults ($r = 0.955$ and 0.863) than their respective helmet-wearing rates ($r = -0.926$ and -0.850). Thus, rather than assume helmets work for children, but not for adults, it seems more plausible (as well as a better fit to the data) that similar trends affected all these age groups.

6. Costs and benefits

Hansen and Scuffham (1995) estimated that the cost of the New Zealand helmet law for adults was more than $15 million over a 3-year period, which was considered to be the protective life of an undamaged helmet in normal use. This represents a most substantial cost, for no clear benefit. For Western Australia, the helmet law (excluding any losses from reduced cycling) was estimated to cost more than twice any benefits from reduced head injury (Hendrie et al., 1999). Adding in the costs of alternative transport as well as the health and environmental costs of reduced cycling would have resulted in an even less favourable cost–benefit ratio.

Many road safety initiatives, including education of motorists and cyclists have been shown to result in large reductions in road trauma. For example, Durkin et al. (1999) describe a road safety-education program for child pedestrians and cyclists which reduced injuries by 36%. Powles and Gifford (1993) reported that the estimated saving of £100 million in Victoria in 1990 from a highly successful road safety campaign directed at speeding and drink-driving was many times the outlay of £2.3 million. Road-safety programs based on techniques, such as the above, have been shown to be exceedingly successful and cost effective, without disadvantages, such as discouraging cycling.

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