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[1]

severity categories (moderate, serious and severe) and those with “other injuries” are available among hospitalisations and those reported to police. Since the data sets were linked, the hospital controls are a proper subset of the police reported controls.

Neither helmet use nor distance travelled by bicycle is available for NSW during the study period. The most recent estimates of helmet wearing for NSW were 74% for children and 83% for adults (Smith and Milthorpe 1993).

ESTIMATES OF HELMET EFFECTIVENESS

The data extracted from the Seattle and Victorian studies are given in Table 2. In each case, odds ratios were computed using hospital controls (Eq.1) and the relative risk using the estimated proportion of helmet wearers (Eq.3). With one exception, the relative risk is uniformly smaller (i.e., greater estimated helmet effectiveness) than the odds ratio. For cycling head injury, the relative risks vary from 0.333 to 0.444 for head injury of any severity and 0.339 for serious head injury. Additionally, these estimates of helmet effectiveness are smaller than Zeeger's estimates using incorrect data.

We chose a helmet wearing rate of 25% for Victoria in our analysis although it was clear helmet wearing changed dramatically during the study period and differed substantially among subgroups. Estimates for each subgroup are not possible since injury and helmet wearing data are available in disaggregation. As a sensitivity analysis, we plotted the estimated relative risks by proportion of helmet wearing (see Figure 1). Since the overall helmet wearing rate in Victoria was not below 20% during the study period, all possible relative risk estimates are smaller than the odds ratio estimates using hospital controls.

Regarding the Dutch data, it is not possible to recreate the counts of injuries for cyclists who did not use racing, mountain or hybrid bicycles. Additionally, the distance travelled is unknown for cycling types by helmet use. It is therefore unreasonable to compute the incidence rate ratio for helmet effectiveness for sport or other cyclists. However, the odds ratio for helmet effectiveness for those using racing, mountain or hybrid bikes is 0.37 (95% CI: 0.166, 0.828, p=0.013) which is similar to other studies.

Injury data for Seattle across all ages and NSW cyclists in a motor vehicle crash is given in Table 3. In each instance, the odds ratios of helmet effectiveness using hospital controls are similar to controls taken from a larger cohort of cyclists.

DISCUSSION

There are many methodological challenges in estimating bicycle helmet effectiveness. The primary reason lies with lack of randomisation followed by a lack of large cohort studies of cycling injury. Case-control studies are the norm in this research area with a recent meta-analysis of 40 studies estimating odds reductions of 51% for head, 69% for serious head, 33% for face and 65% for fatal

head injuries (Olivier and Creighton, in press). Due to the challenges involved in estimating helmet effectiveness, it is reasonable to investigate whether these estimates are overstated.

A recent paper claims odds ratios using hospital controls overestimate helmet effectiveness (Zeegers 2015). In a careful review of this article, we found the reported data were usually in conflict with the source material and, when corrected, the relative risks generally estimated greater reductions in head injury than odds ratios. Similarly, odds ratios of head injury were similar whenever using hospital controls or alternative controls taken from a larger cycling cohort regardless of injury severity. The incidence rate ratio, as computed by Zeegers, is likely incorrect since travel distances were not estimated by helmet use and cycling type.

It has long been argued by injury epidemiologists that odds ratios using hospital data underestimate the true effectiveness of helmet use since most cycling crashes are not reported (Thompson et al. 1989). Furthermore, recent research suggests helmet effectiveness estimates are underestimated due to either wearing a damaged helmet or the helmet is worn incorrectly (Bromelland Geddis, 2017). This is an important finding as other researchers have found poorly fit helmets do not perform well (Romanow et al. 2014). Helmet fit is rarely if ever accounted for in case-control studies and it is likely some injured cyclists identified as helmet wearers in case-control studies wore their helmet incorrectly

Our knowledge of bicycle helmet effectiveness could be greatly improved with other study designs. The most recent review was far larger than the penultimate analysis (40 vs 20 studies, 64K vs 19K injured cyclists) and the summary results were similar to past reviews for head and face injury of any severity and serious head injury. That is, more data largely confirmed previous results for cyclists in a crash or fall

Two important, unanswered research questions are whether helmet use is associated with a crash or fall and whether helmet effectiveness differs for different cycling types. These questions cannot be thoroughly examined from previously used study designs. Case-control studies cannot estimate the probability of a crash or fall while there is a paucity of research examining the link between helmet use and crashes through a possible mediating mechanism such as risk compensation. For countries that routinely collect all hospital data, incidence rates could readily be computed if exposure data were also collected by helmet use and demographic variables. However, cycling type is not identifiable in the various versions of the International Classification of Diseases and (ICD) accurate identification of cases would require more resources

Irrespective of existing challenges, the best available evidence suggests helmet use is an effective measure of reducing cycling head injury. There is also a paucity of evidence suggesting helmet use increases injury of any kind. Therefore, strategies to increase cycle helmet use should be explored until more and better data demonstrates the opposite.

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Table 1: 2×2 contingency table for a case-control study of helmet effectiveness

	Case	Control
Helmet	a	b
No Helmet	c	d

Table 2: Odds ratios and relative risks for Seattle and Victorian studies

	Cases		Controls		Prop			Zeegers'
Study	H	NH	H	NH	Helmet	OR	RR	Estimate
Thompson et al (1989)+	3	140	12	190		0.339		1.28
May 1987 Survey					0.046		0.444	
September 1987 Surve					0.065		0.308	
McDermott et al (1993)								0.66
Head Injury	55	468	206	876	0.250	0.500	0.353	
Serious Head Injury	7	62	206	876	0.250	0.480	0.339	

+School aged children only

Table 3: Numbers of injured NSW cyclists in a motor vehicle collision by helmet use and head injury severity

	Cases		Hosp		Alt		OR	
	H	NH	H	NH	H	NH	Hosp	Alt
Thompson et al (1989)+								
Head Injury	17	218	103	330	130	428	0.250	0.257
Serious Head Injury	4	95	103	330	130	428	0.135	0.139
Bambach et al (2013)*								
Head Injury	372	267	924	296	4715	1391	0.446	0.411
Serious Head Injury	139	133	924	296	4715	1391	0.335	0.308

Alternative controls were collected from (+) surveys and (*) police reported cycling crashes with a motor vehicle

Figure 1: Estimates of relative risk for cycling head and serious head injury by proportion of helmet use for Melbourne & Geelong, Victoria (1987-1989)