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School based bicycle safety education and bicycle injuries in children: a case-control study

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Abstract

***Objectives*—To evaluate possible benefits of a school based bicycle safety education program ("Bike Ed") on the risk of bicycle injury in children.**

***Methods*—A population based case-control study was undertaken in a region of Melbourne, Australia. Cases were children presenting at hospital emergency departments with injuries received while riding bicycles. Controls were recruited by calling randomly selected telephone numbers. Data were collected by personal interview.**

***Results*—Analysis, based on 148 cases and 130 controls aged 9 to 14 years, showed no evidence of a protective effect and suggested a possible harmful effect of exposure to the bicycle safety course (odds ratio (OR) 1.64, 95% confidence interval (CI) 0.98 to 2.75). This association was not substantially altered by adjustment for sex, age, socioeconomic status, and exposure, measured as time or distance travelled. Subgroup analysis indicated that the association was strongest in boys (OR 2.0, 95% CI 1.1 to 3.8), younger children, children from families with lower parental education levels, and children lacking other family members who bicycle.**

***Conclusions*—It is concluded that this educational intervention does not reduce the risk of bicycle injury in children and may possibly produce harmful effects in some children, perhaps due to inadvertent encouragement of risk taking or of bicycling with inadequate supervision.**

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Keywords: bicycle injuries; education; case-control study

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Bicycles are responsible for a substantial proportion of injury related morbidity experienced during childhood. Australian surveillance data indicate that on-road injuries leading to hospital attendance by children aged 0–14 occur at a rate of 27/10 000 per year, and off-road injuries at a rate of 14/10 000 per year.[1] Lower rates of bicycle related injury were found in two Canadian studies,[2 3] whereas studies in the US report higher rates, with estimates ranging from 67 to 88/10 000 per year.[4 5] Such comparisons are complicated by the use of different age groups and differing patterns of attendance for treatment at hospital emergency departments versus community based care. In the Australian study, bicycle injuries comprised 7.5% of all injury attendances and 7.6% of all injury admissions.[1]

Against this background there has been remarkably little study of factors that may be associated with risk of bicycle injury in children. Much recent research has focused on the role of helmets in providing protection against head injury for children involved in crashes,[6–8] but little work has been done on antecedents of the injury event itself. There have also been few studies of bicycle injuries in which control groups are used; most studies have been limited to case series with various selection biases. Because control groups have rarely been examined, there has been little scope to determine the relative importance of potential risk factors, especially those that may be modifiable. Most injuries result from falls, usually on the road, but without the involvement of motor vehicles, although the more severe injuries typically arise from collisions.

This study aimed to investigate subject level factors that may predict injury risk, using a case-control method. A major focus was whether exposure to a school based bicycle safety education program ("Bike Ed") was associated with a reduced risk of injury. In discussing strategies for the prevention of bicycle injuries, many of the studies cited above have called for improved education and training of the child cyclist. During the 1980s and early 1990s the state of Victoria made an extensive commitment to Bike Ed and the program has since been taken up by a number of other Australian states and New Zealand. The course was first introduced in 1980, motivated in particular by efforts to increase the use of bicycle helmets.[9] By the late 1980s it was estimated that about one third of Victorian primary schools were offering Bike Ed in some form,[10] and over 20 staff were employed to promote the course and train school teachers.

The Bike Ed course is based on a package of teaching materials (developed by VicRoads, formerly the Victorian Road Safety and Traffic Authority) that cover aspects of safe riding skills, traffic knowledge and skills, and basic bicycle mechanics.[11] The specific implementation of the program varies from school to school, but three key stages can be identified. At the first level, students are taught basic traffic rules in the classroom, often using models and toy vehicles to simulate road environments. At the second level, children practise riding bicycles in the school yard, with exercises aimed at improving handling skills and at learning safe traffic behaviour by simulating on-road situations. Basic bicycle maintenance topics (for example, checking brakes and tyres, and assessing the fit of the bicycle) are also discussed at this level. At the third level, children are taken in supervised groups onto local streets and carry out further traffic exercises, after which a road test may be taken by each child.

The only previous study of the effectiveness of Bike Ed as a teaching program was performed in Newcastle, Australia and showed that it appeared to be successful in producing an improvement in both bicycle riding knowledge and riding performance when compared with a control group.[12] Whether these gains can be translated to reductions in the risk of injury is an important question that our study sought to answer.

Methods

Details of the study design have been reported previously,[13] and are summarized here. The study was based on incident cases of injury in children between the ages of 5 and 14 riding bicycles (without training wheels) either on the road or the sidewalk or on other public thoroughfares. All cases occurring in a defined region in the north western suburbs of Melbourne, and presenting to either of two major hospital emergency departments serving this region were eligible for inclusion. At the 1991 census the population in the study region was 487 000, with 13.5% between 5 and 14. The region spans a broad cross section of Melbourne suburbia, with an over-representation of areas of lower socioeconomic status. Previous work indicated that the two hospitals involved provide care for 85–90% of children living in the study area who are admitted to a public hospital with injury.[14] Bicycle related injuries occurring in backyards and other environments not subject to public traffic were excluded.

Control subjects were recruited from the same population base as the cases, using a sample of randomly selected telephone numbers. Each number was called at least three times, at different times of the day, to find households with a child in the age range 5–14 who had ridden a bicycle at least once in the previous week. If more than one eligible child was available in the household, a random selection was made and the parent and child were invited to participate in the study. No matching of controls to cases was performed. Both cases and controls were told that the study was about factors associated with the risk of sustaining an injury while bicycling, and Bike Ed was not mentioned at the time participation was requested.

Information was collected by personal interview with the child and at least one of the parents, in their home (or occasionally in the hospital for more severe injuries). Cases and controls were interviewed using a consistent protocol for both groups, and a short questionnaire elicited specific details of the injury event from case subjects. In an attempt to minimize recall problems, interviews were generally conducted within two weeks of the injury event, for cases, or within two weeks of their last bicycle activity, for controls. Usually this time interval was much shorter. The interview collected data on the child's bicycle riding for the week before the injury (cases) or before their last ride (controls).

Information was obtained on sociodemographic factors such as age, sex, birth order, sibship size, and the family's socioeconomic status as indicated by their approximate gross income, the parents' level of education, and the Daniel scale of occupational prestige, which provides a scale value between a minimum of 1 for the highest prestige occupations (for example judge) and a maximum of 7 for unskilled labourers.[15] The child was questioned for details of their knowledge and practice in relation to bicycle safety (including helmet use) and traffic rules, length of bike riding experience, and exposure to the Bike Ed program, classified by the highest level reached. Parents were asked about the extent to which they set limits on the child's bike riding and whether other members of the family rode bicycles. Detailed exposure data were also collected, subdivided by type of bicycle use (travel or play) and type of road/path, for the one week period preceding the date of the injury (cases) or the date of the last ride (controls).[13] To verify the information supplied by families about the child's Bike Ed experience, all schools in the study area were approached with a questionnaire seeking details of any Bike Ed courses offered at the school during the period relevant to this study.

Statistical analysis was performed using the software package Stata,[16] and used standard methods for case-control studies; in particular, odds ratios (ORs) with 95% confidence intervals (CIs) were obtained, and logistic regression was used to allow for potential confounding factors. Stratified analysis was performed to produce ORs and CIs within subgroups of the population in order to investigate possible effect modification.

Results

Between April 1993 and January 1996, a total of 241 cases and 232 controls were interviewed. Injury incidence (and hence recruitment) during the months December to April (summer and early autumn) was approximately double that in the remainder of the year. Of 363 cases of injury identified as eligible for the study, 86 (24%) were unable to be included primarily because of scheduling difficulties caused by temporal clustering of cases and illness/absence on leave of the interviewer, and 36 (10%) refused, resulting in a participation rate of 66%. The controls were recruited from a total of 5175 telephone numbers; no contact was made with 765 (15%) of these and 283 (5.5%) resulted in the respondent ending the call abruptly. Of the remaining 4127 with whom successful contact was made, 3296 (80%) reported having no children in the age range 5–14 years and a further 502 (12%) were ineligible for various reasons including not having a child who rode a bike or not having a child who had ridden in the previous week. Of the remaining 329 eligible households, 245 (74%) agreed to participate and 232 were interviewed.

Table 1 Distribution of sociodemographic factors in cases and controls, with estimated ORs for association with injury risk (OR of 1.0 indicates referent category)

	Cases (%) (n=148)	Controls (%) (n=130)	OR (95% CI)
Sex			
Girls	21	30	1.0
Boys	79	70	1.6 (0.94 to 2.8)
Age (years)			
9–11	48	49	1.0
12–14	52	51	1.1 (0.66 to 1.7)
Income*			
<$20 000	28	13	3.2 (1.5 to 6.6)
$20–30 000	25	25	1.6 (0.80 to 3.1)
$30–40 000	24	28	1.3 (0.70 to 2.6)
>$40 000	22	34	1.0
Parent's education†			
Primary	23	19	3.3 (1.5 to 7.4)
Secondary	67	54	3.3 (1.7 to 6.4)
Tertiary	10	27	1.0
Occupational prestige score‡			
1–3.9	24	39	1.0
4–4.9	40	31	2.0 (1.1 to 3.7)
5–7	36	30	1.9 (1.0 to 3.5)

*Response obtained for 139 cases, 126 controls; ranges expressed in Australian dollars.
†Refers to parent answering questionnaire (mother in 81% of subjects). Response obtained for 147 cases, 129 controls; "secondary" category includes completion of technical (trade) certificate.
‡According to Daniel scale[15]; highest category chosen if both parents' occupations reported and most recent job used if currently unemployed; response obtained for 144 cases, 129 controls. Cut-points correspond to approximate tertiles in this population.

Table 2 Distribution of principal measures of (weekly) exposure for cases and controls, with ORs and 95% CIs

	Cases (%) (n=146)	Controls (%) (n=129)	OR (95% CI)
Total time (min/week)			
0–60	41	43	
61–180	30	30	0.93 (0.54 to 1.6)
> 180	29	29	1.4 (0.74 to 2.5)
Total distance* (km/week)			
0–4	31	35	1.0
4–12	36	32	1.3 (0.69 to 2.4)
> 12	32	33	1.1 (0.59 to 2.1)
Total distance on sidewalks† (km/week)			
0–2	36	48	1.0
3–5	28	28	1.3 (0.63 to 2.7)
>5	36	24	2.0 (0.95 to 4.0)

*Based on 121 cases, 113 controls; excludes subjects with no measurable distance travelled (only play use of the bike reported).
†Based on 94 cases, 82 controls; excludes subjects with no measurable distance travelled on sidewalks/footpaths.

Table 3 Comparison of cases and controls on Bike Ed exposure, with OR unadjusted and adjusted for potential confounding factors

	Crude OR	95% CI	Adjusted* OR	95% CI
Bike Ed (any)†	1.64	(0.98 to 2.75)	1.57	(0.91 to 2.71)
Bike Ed by level				
In school only	1.46	(0.78 to 2.73)	1.37	(0.71 to 2.64)
On-road	1.96	(0.92 to 4.16)	1.94	(0.88 to 4.29)
Bike Ed (validated)‡	1.65	(0.89 to 3.07)	1.63	(0.84 to 3.16)
Bike Ed (any, omitting cases with minor injuries§)	1.38	(0.77 to 2.48)	1.32	(0.71 to 2.44)

*Adjusted using multiple logistic regression for age, sex, and income category.
†Exposure defined as having participated in a Bike Ed program at school according to parent report.
‡Analysis restricted to cases (n=106) and controls (n=97) where the parent report of participation in a Bike Ed program was validated by independent information confirming the existence of such a program at the school.
§Minor injury defined as an injury at the lowest severity level to one body part only, that is injury severity score = 1 (n=54 cases).

All subsequent analysis reported in this paper is restricted to 278 subjects (148 cases, 130 controls) who were aged over 9 years, since Bike Ed is offered only from the fourth year of full time schooling (during which most children are turning 9).

Most of the injuries were relatively minor; nevertheless 16% required hospital admission. Forty two per cent of injuries occurred while the child was using the bike for play rather than for transport, where the latter included any purposeful journey with a specific destination or route, beyond the immediate vicinity of the home. Forty six per cent occurred on roads, 32% on footpaths (sidewalks), and 22% in other locations (bike paths, parks, etc). Thirteen per cent of injury events were motor vehicle collisions, 7% collisions with other bicycles, and 2% collisions with pedestrians, while 15% involved collision with a stationary object; the remaining 63% were bike only incidents.

There were considerably more boys than girls in both the case and control groups, reflecting greater bicycle use among boys, and, furthermore, there was a slightly greater proportion of boys in the case series, corresponding to an OR of 1.6 for comparing risk in boys with that in girls (table 1). There was no evidence of an age trend in injury risk across the range of 9 to 14 years considered here. There were clear trends to higher numbers of cases than controls in children of families with lower socioeconomic status, whether measured by income category, parent's education level, or occupational prestige. Of other socioeconomic factors examined, there was also a significant excess of cases in families with single parents, but there was no apparent association with number of siblings in the home or with non-English speaking households.

Analysis of exposure measures (table 2) is included for comparison with our interim analysis[13] and indicated generally weak relationships with injury risk, suggesting that these measures provided only a crude indication of true risk exposure. Consistent with our previous results, there was, however, some indication of an association between footpath (sidewalk) cycling and increased risk.

A crude bivariate analysis of the effect of Bike Ed showed a positive association of marginal statistical significance between Bike Ed exposure and injury risk: 36% of cases had participated in Bike Ed compared with 25% of controls (OR = 1.64; table 3). There was no evidence for a more beneficial effect of Bike Ed among those receiving an on-road component of the course; in fact, the trend was in the opposite direction. The estimated OR of 1.6 remained substantially unaltered by adjustment for potentially confounding effects of age, sex, and sociodemographic and exposure factors, and was also unchanged when the analysis was restricted to subjects for whom there was independent verification of Bike Ed exposure from the schools concerned. There was a slightly reduced association between Bike Ed and injury risk when the 54 most trivial injuries were omitted from the analysis (table 3).

Table 4 examines the possible modification of the association between Bike Ed and injury risk by other factors characterizing the child and family. The results show that the indication of a possibly harmful effect of exposure to Bike Ed is strongest in boys, in younger children, in children of parents with lower educational background, and in children where other members of the family do not bicycle, or where the parents do not place restrictions on where the child may ride. The analysis by exposure

Table 4 Stratified ORs estimating the association of Bike Ed with injury risk within subgroups of the population

	OR	95% CI	p Value*	OR (boys)	OR (girls)
Sex			0.32		
Boys	2.0	(1.1 to 3.8)		—	—
Girls	1.1	(0.43 to 3.0)		—	—
Age (years)			0.41		
9–11	2.1	(0.97 to 4.4)		2.3	1.8
12–14	1.3	(0.66 to 2.70)		1.9	0.43
Maternal education			0.39		
Primary	1.9	(0.64 to 5.7)		3.0	1.2
Secondary	1.9	(0.94 to 3.7)		2.1	1.4
Tertiary	0.63	(0.16 to 2.6)		1.1	—
Other family members bicycle			0.04		
Yes	1.1	(0.56 to 2.0)		1.2	1.0
No	3.4	(1.4 to 8.3)		5.0	1.3
Parents restrict range			0.17		
Yes	1.4	(0.78 to 2.4)		1.7	0.90
No	4.0	(1.0 to 15.3)		4.8	2.3
Exposure (km)			0.59		
Play only	1.4	(0.42 to 4.8)		1.1	2.3
0–4	2.9	(1.0 to 8.6)		4.2	—
5–12	1.6	(0.59 to 4.1)		1.9	0.86
> 12	1.1	(0.40 to 2.8)		1.5	—
Activity			†		
Play	2.0	(0.98 to 4.3)		2.4	1.9
Travel	1.5	(0.82 to 2.9)		2.0	0.4
Location			†		
Road	1.2	(0.58 to 2.4)		1.4	0.8
Sidewalk	1.8	(0.84 to 3.9)		2.1	1.2
Other	2.3	(0.87 to 5.9)		2.6	2.3

*χ^2 Test for homogeneity of the OR across strata.
†Control groups for these subgroup analyses overlap, so a standard test of homogeneity between the ORs is not possible.

suggests that the Bike Ed "risk" may be confined to a group that rides small measurable distances, but is not confined to play riding only. Similarly, the harmful effect, if real, was more evident in relation to off-road (sidewalk and other locations such as nature strips, parking lots, and bicycle paths) than on-road accident risk.

Finally, given the close connection between the genesis of Bike Ed and campaigns to increase helmet wearing,[9] we examined self reported helmet use in our study groups. Comparing children who had received Bike Ed with those who had not, there was no difference in the proportions who reported wearing a helmet "most" or "all" of the time when riding (70% *v* 73% respectively in the control group, which should be representative of the population, and 60% *v* 67% in the case group). Examining the pattern of injury among the cases, although there were significantly more head injuries in those who were not wearing a helmet at the time of injury (24% *v* 10%, p=0.02), there was no significant difference in frequency of head injury between those exposed to Bike Ed and those not so exposed (13% *v* 18%, p=0.46).

Discussion

The principal conclusion from this study is that no evidence could be found that participation in the bicycle education program, Bike Ed, at primary school led to a reduced risk of bicycle related injury in subsequent years. In fact there was some evidence suggestive of an unexpected effect in the opposite direction. Our study appears to be unique in its attempt to perform an analytic epidemiological investigation of the association between a traffic safety education program for children and actual injury incidence.

Other studies have examined intermediate endpoints, such as changes in knowledge and behaviour, and have focused on safety with respect to traffic (whereas the present study involved mainly non-traffic injuries). It has been widely accepted that changes in knowledge and attitudes such as may be achieved through educational interventions do not necessarily translate to behavioural changes that might have an influence on safety.[17] A recent review concluded there was "little reliable evidence that children can be successfully trained to avoid injury on the roads",[18] although some studies have shown that specifically targeted instruction can change behaviour in selected areas. For example, Ampofo-Boateng *et al* showed (in an uncontrolled trial) that children as young as 5 could be trained in finding safe places to cross the road,[19] and Young and Lee demonstrated that it was possible to improve visual timing skills through roadside training.[20]

In bicycle safety, a small randomized trial with 8 and 9 year old children suggested that it was not effective to attempt to train them to cope with dynamic traffic situations using formal priority rule systems.[21] An early evaluation of Bike Ed showed, on the other hand, that its broad approach to bicycle safety appeared to produce significant improvements, not only in knowledge but also in behaviour as measured in a riding performance test.[12] Experience with several broader, community based, rather than purely school based, educational interventions to increase the use of bicycle helmets has been similarly mixed. There remains little evidence that education alone, without additional incentives such as legislation or price manipulation, has produced major changes.[22–24]

Our findings with respect to the association of injury risk with sex and socioeconomic status are consistent with other research. Many studies have found an excess of injuries in boys compared with girls, and also increased rates of injury in children of poorer families.[17 25] We have shown that these effects do not explain the positive association found in our data between exposure to Bike Ed and injury risk. Adjusting for socioeconomic status is especially important because it is likely that our study was subject to some selection biases, especially in the recruitment of controls.

There was only a slight reduction in the OR for the association between Bike Ed and injury risk when the most trivial injuries were omitted, suggesting that the association did not differ substantially by severity of injury, and also indicating that presentation bias among the case group was not a major factor. Another possible bias relates to the decision to include as controls only children who had ridden a bicycle in the week before being approached, which could have led to some under-representation in the control group of children with low bicycling frequency (such children were eligible to be cases). Any such bias appears to have been small since there were in fact very few cases who had not ridden their bike in the previous week on at least one occasion other than that of the injury. Further, for such a selection bias to affect our findings, it would be necessary for Bike Ed exposure to be associated with subsequent reduced frequency of bicycling, an implausible possibility.

Other methodological difficulties encountered revolve mainly around the difficulties of measuring exposure, both bicycling exposure (time and distance) and Bike Ed exposure. The latter was handled by an extensive effort to validate Bike Ed information by comparing parent reports against information supplied directly by schools, thereby addressing the possibility of recall or interviewer bias. When the analysis excluded those subjects for whom verification was not obtained the results were unchanged. The measurement of bicycling exposure proved difficult and there is undoubtedly considerable misclassification in these data, the effect of which is hard to estimate. It seems unlikely, however, that these problems could conceal a confounding effect that would be sufficient to obscure a putative protective effect of Bike Ed.

It is possible there may be unmeasured confounders present in our data: for example, there may be variation in the inherent safety of neighbourhoods in the study area that is related to the presence of Bike Ed in local schools. If the provision of Bike Ed was prompted by schools recognising an enhanced risk of bicycle injury, this could bias our results in the direction observed. Discussions with Bike Ed coordinators in the relevant road safety authority (VicRoads) indicated, however, that the uptake of Bike Ed was more related to the interest of particular individuals within schools than to school policy decisions or local safety. We also found that Bike Ed was widely dispersed over the study area (70 of 141 schools in the area reported having offered some version of the program over the study period). Finally, it is important to remember that most of the injuries in this study were not traffic related, so risk is unlikely to be strongly related to neighbourhood traffic characteristics.

In an attempt to better understand our findings, we examined variation in the apparent association between Bike Ed and injury risk across various subgroups. Although the statistical power to detect effect modification was low, there were trends apparent in the results that seem to provide useful insights into the main results. Indeed, the fact that subgroup analyses revealed trends that could be plausibly interpreted appears to strengthen the likelihood that the positive OR of 1.64 may be real rather than a chance finding (which latter possibility cannot, however, be ruled out at the conventional 0.05 significance level). In particular, the finding that a possible negative effect of Bike Ed was present only for boys, and only for families of lower educational background, leads us to hypothesize that the program may inadvertently lead susceptible children to undertake risky behaviour on their bicycles.

It may be that in some families, Bike Ed is misinterpreted as providing "immunization" against injury or a licence for unrestricted bicycle use (supported by the greatly increased OR for Bike Ed in families where the parents do not make rules about where the child may bicycle). This may in turn be a particular problem in families where there is inadequate ability to reinforce the message, either because of the parents' preoccupation with day-to-day struggles related to low income, lack of adequate parental education, or lack of other bicycling experience in the family. These results have an interesting parallel in the literature on driver training for young people, where it has been shown that high school training programs led to earlier licensing of young drivers and a consequent increase in crash incidence.[26]

Finally, we found in addition to the lack of benefit with respect to injury risk, that there was no evidence that Bike Ed had produced an intermediate benefit in terms of increased rates of helmet wearing. This is of particular concern given the well documented benefits of helmets in the prevention of head injury.[6 8]

Our analysis implicitly assumed that the Bike Ed program as implemented in the schools included in the study was a reasonably homogeneous course following the guidelines set down in official VicRoads publications and training courses. Given that Bike Ed is conducted by local teachers in each school, there is, in fact, anecdotal evidence of considerable variation in its quality. Our results may indicate a need to monitor the implementation of the course more closely. More importantly, they suggest placing a greater emphasis in such courses on safety culture, including adequate reinforcement in the home, rather than on behavioural skills, which may lead to inappropriate removal of parental restrictions, overconfidence, or risk taking.

On the other hand, the results also suggest that substantial investments in educational programs like Bike Ed must be carefully reviewed, preferably with full and thorough controlled evaluation of program effectiveness before implementation. Legislative and environmental interventions may provide more cost effective injury prevention strategies.

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