Impact of Mandatory Helmet Legislation on Bicycle-Related Head Injuries in Children: A Population-Based Study

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ABSTRACT. *Objective.* **Childhood bicycle-related head injuries can be prevented through the use of helmets. Although helmet legislation has proved to be a successful strategy for the adoption of helmets, its effect on the rates of head injury is uncertain. In Canada, 4 provinces have such legislation. The objective of this study was to measure the impact of helmet legislation on bicycle-related head injuries in Canadian children.**

Methods. **Routinely collected data from the Canadian Institute for Health Information identified all Canadian children (5–19 years) who were hospitalized for bicycling-related injuries from 1994–1998. Children were categorized as head or other injury on the basis of *International Classification of Diseases, Ninth Revision*, codes. Rates of head injuries and other injuries were compared over time in provinces that adopted legislation and those that did not.**

Results. **Of the 9650 children who were hospitalized because of a bicycle-related injury, 3426 sustained injuries to the head and face and the remaining 6224 had other injuries. The bicycle-related head injury rate declined significantly (45% reduction) in provinces where legislation had been adopted compared with provinces and territories that did not adopt legislation (27% reduction).**

Conclusion. **This country-wide study compared rates of head injury in regions with and without mandatory helmet legislation. Comparing head injuries with other non–head-injured children controlled for potential differences in children's cycling habits. The strong protective association between helmet legislation and head injuries supports the adoption of helmet legislation as an effective tool in the prevention of childhood bicycle-related head injuries. *Pediatrics* 2002;110(5). URL: http://www.pediatrics.org/cgi/content/full/110/5/e60; *helmet legislation, bicycling injuries, head injuries, pediatrics, prevention.***

ABBREVIATIONS. CIHI, Canadian Institute for Health Information; E-code, external injury code; *ICD-9*, *International Classification of Diseases, Ninth Revision*; SES, socioeconomic status; CI, confidence interval.

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Bicycling is a popular pastime and mode of transportation for children. Bicycle-related injuries, however, are common. For example, the annual mortality rate for bicycle-related injuries in children in Canada (1990–1992) was 6 per 100 000 children, with a concomitant annual hospitalization rate of 51 per 100 000.[1] From 1994–1997, almost 10 000 Canadian children were hospitalized because of bicycle-related injuries. Of these admissions, 35% were because of injuries to the head.

Bicycle helmets have been shown to be effective in preventing head, brain, and facial injuries to cyclists.[2,3] Although some authors have argued against the efficacy of helmets,[4,5] published systematic reviews[6,7] and a meta-analysis[8] demonstrated that helmets protect children from head injuries. The Cochrane Collaboration systematic review reported that helmets reduce the risk of head injury by up to 88% and reduce the risk of facial injury by 65% among child cyclists.

Bicycle helmet legislation has been adopted around the world, including in Australia, New Zealand, parts of the United States, and 4 Canadian provinces (Ontario, New Brunswick, British Columbia, and Nova Scotia). Where evaluated, helmet use has increased since legislation.[9–12] For example, in Canada, compliance with legislation has been reported in Ontario[11] (68% of children wearing helmets since legislation) and in Nova Scotia[13] (>80% of cyclists helmeted since legislation). Most of the evaluative studies, however, have focused on helmet use rather than on head injury as the primary outcome. Only 2 published studies have used head injuries as the primary outcome, and both used a time series design without a concurrent comparison group. Therefore, for these studies, any reduction in head injury rates could be attributed to a general downward trend in head injury rates.[14,15] The objective of this study was to measure the impact of mandatory bicycle helmet legislation on the incidence of bicycle-related head injuries among Canadian children.

METHODS

Data on Canadian children who were hospitalized because of bicycle-related injuries for the fiscal years 1994–1998 inclusive were obtained from the Canadian Institute for Health Information (CIHI). There is mandatory reporting of all hospital admissions to CIHI. All children (5–19 years) with an external injury code (E-code) related to a pedal cyclist injury (E800–E807 with .3 extension, E810–E825 with .6 extension, E826.0–E826.9, E827.1, E828.1, and E829.1) were included. Other variables in the database include age, gender, primary discharge diagnosis (*International Classifica-*

tion of Diseases, Ninth Revision [*ICD-9*], code), date of admission to the hospital, and postal code of residence.

Individual-level data on income and education are not included in the CIHI database. Therefore, neighborhood socioeconomic status (SES) based on postal code of residence was obtained from census information collected by Statistics Canada. The neighborhood variable used in the analysis was the percentage of families living below the poverty line. This approach to estimation of SES has been shown to be valid in Canada.[16]

Children with bicycle injuries were categorized as "head" injury or "other" injury on the basis of *ICD-9* codes. All *ICD-9* codes for injuries to the head, face, and brain were defined as head injuries. Injuries to all other parts of the body were classified as other injuries. Children for whom the discharge diagnosis was missing were excluded from the analysis. Denominator data (population of children 5–19 years in each province) were obtained from the 1996 Canadian census.

We conducted our analysis using 2 approaches. First, we examined the trends in bicycle-related injury rates over time in the legislation provinces and no-legislation provinces. The 4 provinces that adopted mandatory helmet legislation during the study period (irrespective of timing) were combined to form the legislation provinces. As a comparison group, the remaining 8 provinces/territories were combined to form the no-legislation provinces. Annual rates of bicycle-related head injuries and other injuries for the 4 years of the study (1994–1998) were calculated for the 2 groups (legislation and no-legislation provinces). The χ^2 test for trend was used to test for differences over time in head injury rates and other injury rates between the 2 groups. In addition, for each year of the study, the ratio of head injuries to other injuries for each group (legislation and no-legislation provinces) was calculated.

Combining the provinces that adopted bicycle helmet legislation, irrespective of the timing of legislation, was done for methodologic reasons. In essence, this approach meant that numerator and denominator data were more consistently estimated over the study period. In other words, we believed that if helmet legislation was adopted during the calendar year, then it would be difficult (if not impossible) to delineate clearly pre- and postlegislation numerator data (bicycle-related injuries) and denominator data (the provincial childhood population). Last, in the context of examining the effect of helmet legislation on bicycle-related head injury rates, it could be argued that this was a conservative approach, given that legislation was adopted by the provinces at different times after the study began.

Second, to take into account potentially confounding variables, multivariable logistic regression analysis was used to model the odds of head injury among injured bicyclists, while controlling for other covariates. Therefore, the primary outcome for the logistic regression analysis was head injury (yes/no). The independent variable was mandatory helmet legislation on the date of the hospital admission (yes/no). Covariates, identified from previous research on bicycle-related injuries, included individual level variables (age and gender) and ecologic variables (SES based on residential postal code). The interactions between age and legislation and between SES and legislation were tested. Analyses were conducted using SAS software.[17]

Children who died in the hospital as a result of a bicycle-related injury were included in our database, but children who died before admission to the hospital were not. We conducted a secondary analysis of these events. Because of small numbers, there was insufficient statistical power to test for trends. Descriptive statistics on the rates of bicycle-related deaths in legislation and no-legislation provinces, however, are reported.

RESULTS

During the 4 years, there were 9769 admissions because of bicycle-related injuries among Canadian children. Information on discharge diagnosis was missing for 119 children (1%). Table 1 contains information about the Canadian provinces and territories, including the date when mandatory bicycle helmet legislation was adopted, the number of children 5 to 19 years of age, and the hospitalization rate for bicycle-related head injuries for each year of the study. Table 2 includes similar information for other bicycle-related injuries. The rates varied between provinces, and rates in smaller provinces and territories were fairly unstable because of the small population and low numbers of injuries.

Of the 9650 children included in the analysis, 3426 (35%) sustained head injuries; the remaining 6224 (65%) had other injuries. Annual rates of bicycle-related hospitalizations per 100 000 in legislation provinces (Ontario, New Brunswick, British Columbia, and Nova Scotia) compared with no-legislation provinces are presented in Fig 1. The head injury rate was similar in both groups (legislation and no-legislation provinces) before legislation (18.27 and 18.35 per 100 000 for legislation provinces and no-legislation provinces, respectively). There was a 45% reduction in the rate of bicycle-related head injuries in legislation provinces (from 18.27 per 100 000 in 1994–1995 to 9.96 per 100 000 in 1997–1998). This reduction was greater than the 27% concurrent decline in no-legislation provinces (from 18.35 per 100 000 in 1994–1995 to 13.33 per 100 000 in 1997–1998). A χ^2 test for trend between groups found that the decline was significantly greater ($P = .001$) in legislation provinces. There was no significant difference in the

TABLE 1. Bicycle-Related Head Injury Rates (Children 5–19 Years) by Province, 1994–1998

Province	Date of Adoption of Legislation	Midyear Population (5–19 Years)	Head Injury Rates by Year (Rate per 100 000)			
			1994–1995	1995–1996	1996–1997	1997–1998
Legislation provinces						
Ontario	October 1995	2 178 015	16.25	11.85	10.51	8.36
New Brunswick	December 1995	153 275	22.18	22.18	13.70	18.27
British Columbia	September 1996	745 030	24.03	20.00	15.30	13.69
Nova Scotia	July 1997	186 275	15.57	12.35	3.76	6.98
Subtotal legislation provinces		3 262 595	18.27	14.22	11.37	9.96
No-legislation provinces						
Newfoundland		124 800	27.24	30.45	23.24	22.44
Prince Edward Island		30 150	13.27	13.27	3.32	9.95
Québec		1 410 965	19.77	17.29	15.59	15.73
Manitoba		241 655	7.45	9.10	8.28	8.69
Saskatchewan		235 100	23.39	16.16	17.86	9.78
Alberta		611 415	15.54	14.07	12.43	9.65
Yukon, NWT		15 900	31.45	18.87	12.58	0.00
Subtotal no-legislation provinces		2 669 985	18.35	16.29	14.60	13.33
Canada		5 932 580	18.31	15.15	12.83	11.48

TABLE 2. Bicycle-Related Other Injury Rates (Children 5–19 Years) by Province, 1994–1998

Province	Date of Adoption of Legislation	Midyear Population (5–19 Years)	Other Injury Rates by Year (Rate per 100 000)			
			1994–1995	1995–1996	1996–1997	1997–1998
Legislation provinces						
Ontario	October 1995	2 178 015	23.78	21.17	20.48	20.98
New Brunswick	December 1995	153 275	32.62	25.44	27.40	40.45
British Columbia	September 1996	745 030	36.24	41.61	28.19	31.81
Nova Scotia	July 1997	186275	24.16	31.67	23.62	22.01
Subtotal legislation provinces		3 262 595	27.06	26.63	22.74	24.42
No-legislation provinces						
Newfoundland		124 800	42.47	43.27	32.85	32.85
Prince Edward Island		30 150	23.22	9.95	23.22	19.90
Québec		1 410 965	31.75	24.52	26.51	26.01
Manitoba		241 655	26.48	23.59	24.83	18.62
Saskatchewan		235 100	38.71	31.90	32.33	30.63
Alberta		611 415	31.89	30.75	21.43	21.75
Yukon, NWT		15 900	44.03	44.03	44.03	37.74
Subtotal no-legislation provinces		2 669 985	35.52	29.98	28.58	27.52
Canada		5 932 580	29.46	26.95	24.23	24.72

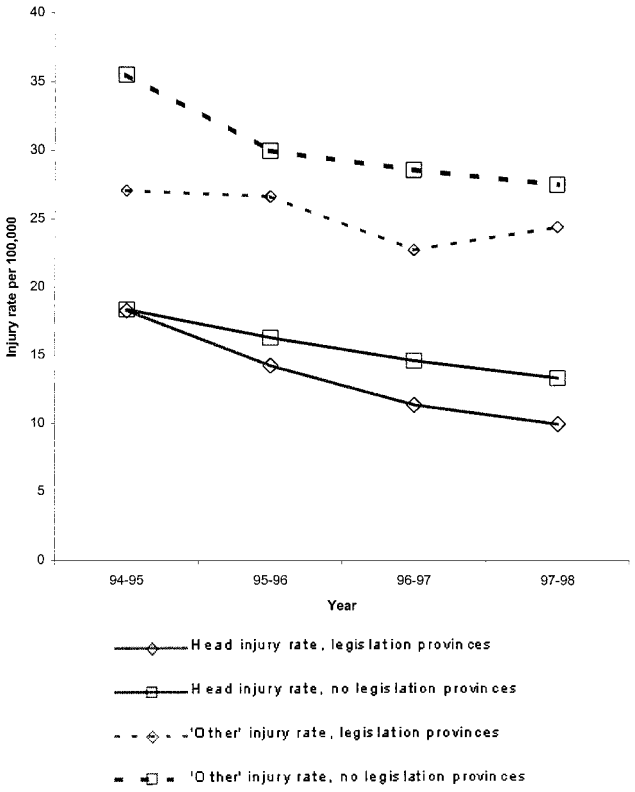

Fig 1. Comparison of changes in head injury and other injury rates in legislation and no-legislation provinces.

change over time in other injuries between legislation provinces and no-legislation provinces ($P = .11$).

The ratio of head injuries to other injuries decreased in legislation provinces from 0.67 in 1994 to 0.41 in 1998. The ratio difference of 0.26 (95% confidence interval [CI]: 0.25–0.27) represents a 38% decrease during the study period. The ratio of head to other injuries also decreased in no-legislation provinces from 0.52 in 1994 to 0.48 in 1998 (difference: 0.04; 95% CI: 0.03–0.05), an 8% decrease.

Table 3 shows the characteristics of injured children in legislation and no-legislation provinces. There were no significant differences between the groups on age and gender distribution or in the proportion of the population below the poverty level or the average length of the hospital stay. Children who lived in provinces without legislation were somewhat more likely to be involved in a collision with a motor vehicle (17.4% compared with 14.5%).

The logistic regression analysis showed that legislation was the only significant variable. A significant protective effect of legislation on head injury among injured cyclists was noted (odds ratio: 0.77; 95% CI: 0.69–0.85).

During the 4 years of the study, 58 children died in the hospital from bicycle-related injuries. The annual bicycle-related death rates per 1 million children (1994–1998) were 3.38, 1.83, 0.61, and 1.83, respectively, in legislation provinces. The concomitant death rates during the same time period for no-legislation provinces were consistently higher at 4.12, 2.20, 3.38, and 2.62, respectively, per 1 million children.

DISCUSSION

This study identified a significantly greater decline in the head injury rate in provinces where legislation had been adopted, compared with provinces that did not adopt legislation. Other injuries also declined; however, there were no significant differences between provinces with and without legislation. The general decline in all types of bicycle injuries is consistent with the decline in the overall childhood injury rate in Canada.[1]

Our study design attempted to account for temporal trends in bicycle injuries. The presence of a concurrent control group in the provinces/territories without legislation allowed for analysis of the effectiveness of mandatory helmet legislation while controlling for temporal trends. Bicycle-related injury rates have declined over time in many developed countries, including Canada. Without a concurrent comparison group, it would not be possible to identify the independent effects of legislation, time, or other unknown factors.

One potential explanation for a decrease in head injury after helmet legislation is that children are

TABLE 3. Comparison of Injured Cyclists in Legislation Provinces and No-Legislation Provinces

Variable	Injured Children in Legislation Provinces (N = 5029)	Injured Children in No-Legislation Provinces (N = 4621)
Age (*n*, %)		
5–9 y	1754 (34.8)	1712 (37.0)
10–14 y	2268 (45.1)	2040 (44.1)
15–19 y	1007 (20.0)	869 (18.8)
Male (*n*, %)	3706 (73.7)	3294 (71.2)
Motor vehicle-bicycle crash (*n*, %)	770 (15.3)	849 (18.3)
Population below poverty level (mean, SD)	14.5 (7.0)	17.4 (8.5)
Average length of hospital stay (mean, SD)	3.27 (7.1)	4.22 (12.9)

SD indicates standard deviation.

cycling less. A time series study in Victoria, Australia, reported such a reduction in cycling after the introduction of mandatory helmet legislation.[18] Another similar study, conducted in 1 health district in Canada, found no reduction in cycling postlegislation.[19] To control for this, we compared the ratio of head injuries with other injuries in legislation and no-legislation provinces. If the number of bicycling children declined during the study period, then the number of children with head injuries and other related injuries should decline in a similar manner. Our study found that legislation was associated with a reduction in head injuries but not in other bicycling-related injuries. Therefore, the significant protective effect of helmet legislation on bicycle-related head injuries shown in our study was not likely because of a reduction in bicycling by children.

In relation to confounding variables, there were no significant baseline differences between provinces with and without legislation on the age, gender, or SES of children who were admitted because of a bicycle-related injury. Logistic regression analysis also showed that legislation was the only significant variable. We considered logistic regression to be a valid approach to quantify the effect of potentially confounding variables. A similar approach was used in a study of injured cyclists in New Zealand.[15]

We had no information on helmet promotion activities in provinces. Many jurisdictions have promoted bicycle helmet use in the absence of legislation.[20–25] Although these efforts have increased the helmet use rate, they have not been as effective as legislation[9,12] in increasing helmet use. In any event, the effect of promotion of bicycle helmet use in provinces without legislation would have been to bias the results toward the null.

This study used a database of all Canadian children who were hospitalized because of bicycle-related injuries. Therefore, a population-based analysis of a large number of children was possible. As such, there was adequate statistical power to detect subtle associations between legislation and head injuries. We undertook additional analyses of the data in each province with legislation to determine whether the protective effect of bicycle helmets was consistent. The significant protective association remained in each province with legislation except Nova Scotia. This province adopted legislation recently (Table 1), and there were few hospitalizations subsequent to the adoption of legislation. We therefore may have lacked statistical power to detect a significant difference in this province.

Our analysis used hospital discharge summary data. Although we could not validate the data regarding diagnosis and demography, other studies of the same database have found high rates (74%–96%) of agreement for both primary diagnosis and demographic information.[26] In addition, no information was available about whether the child was wearing a helmet at the time of the injury. Last, although we used a proxy measure to estimate SES, the use of census data for this purpose has been validated in Canada.[16]

The children in this study all had been hospitalized for bicycle-related injuries. Children who died before being admitted to the hospital were not included in the database. We also did not capture children who were treated in an emergency department or those who sought medical advice from their own doctor. A case-control study of bicycle helmet effectiveness conducted by Thompson et al[27] reported protective effects of 74% for children who presented to the emergency department with bicycle-related head injuries and 69% for children who were admitted to the hospital with head injuries. We hypothesize, therefore, that our estimate of the effectiveness of helmet legislation on head injury rates is conservative.

This country-wide study compared rates of bicycle-related head injury in provinces with and without bicycle helmet legislation. The methodology controlled for differences in exposure to cycling in different parts of the country and for temporal trends in injury rates. Head injuries declined after the adoption of legislation. Bicycle helmet legislation, however, is not the only strategy needed to prevent bicycle-related injuries. Other measures, including environmental modification (eg, separate lanes on the roadway for bicyclists) and measures that target drivers of motor vehicles rather than bicyclists, also need to be evaluated. The finding of a strong protective association between helmet legislation and head injuries using both concurrent and historical comparison groups supports the adoption of legislation as an effective tool in the prevention of bicycle-related childhood head injuries.

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