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.

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 comitant 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.2–5 Although some authors have argued against the efficacy of helmets,6,7 published systematic reviews6,7 and a meta-analysis8 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 Ontario11 (68% of children wearing helmets since legislation) and in Nova Scotia13 (>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 external injury code) were included. Other variables in the database include age, gender, primary discharge diagnosis (International Classification...
Mandatory Helmet Legislation and Bicycle-Related Head Injuries in Children

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

<table>
<thead>
<tr>
<th>Province</th>
<th>Date of Adoption of Legislation</th>
<th>Midyear Population (5–19 Years)</th>
<th>Head Injury Rates by Year (Rate per 100,000)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Legislation provinces</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ontario</td>
<td>October 1995</td>
<td>2,178,015</td>
<td>16.25</td>
</tr>
<tr>
<td>New Brunswick</td>
<td>December 1995</td>
<td>133,275</td>
<td>22.18</td>
</tr>
<tr>
<td>British Columbia</td>
<td>September 1996</td>
<td>745,030</td>
<td>24.03</td>
</tr>
<tr>
<td>Nova Scotia</td>
<td>July 1997</td>
<td>186,275</td>
<td>15.57</td>
</tr>
<tr>
<td>Subtotal legislation provinces</td>
<td></td>
<td>3,262,595</td>
<td>18.27</td>
</tr>
<tr>
<td>No-legislation provinces</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Newfoundland</td>
<td></td>
<td>124,800</td>
<td>27.24</td>
</tr>
<tr>
<td>Prince Edward Island</td>
<td></td>
<td>30,150</td>
<td>13.27</td>
</tr>
<tr>
<td>Quebec</td>
<td></td>
<td>1,410,965</td>
<td>19.77</td>
</tr>
<tr>
<td>Manitoba</td>
<td></td>
<td>241,655</td>
<td>7.45</td>
</tr>
<tr>
<td>Saskatchewan</td>
<td></td>
<td>235,100</td>
<td>23.39</td>
</tr>
<tr>
<td>Alberta</td>
<td></td>
<td>611,415</td>
<td>15.54</td>
</tr>
<tr>
<td>Yukon, NWT</td>
<td></td>
<td>15,900</td>
<td>31.45</td>
</tr>
<tr>
<td>Subtotal no-legislation provinces</td>
<td></td>
<td>2,669,985</td>
<td>18.35</td>
</tr>
<tr>
<td>Canada</td>
<td></td>
<td>5,932,580</td>
<td>18.31</td>
</tr>
</tbody>
</table>

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 13.35 per 100,000 in 1997–1998). A χ² test for trend between groups found that the decline was significantly greater (P = .001) in legislation provinces. There was no significant difference in the
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
cycling less. A time series study in Victoria, Australia, reported such a reduction in cycling after the introduction of mandatory helmet legislation. Another similar study, conducted in 1 health district in Canada, found no reduction in cycling postlegislation. To control for this, we compared the ratio of cycling less. A time series study in Victoria, Australia, reported such a reduction in cycling after the introduction of mandatory helmet legislation. Another similar study, conducted in 1 health district in Canada, found no reduction in cycling postlegislation.

Table 3: Comparison of Injured Cyclists in Legislation Provinces and No-Legislation Provinces

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

SD indicates standard deviation.

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. We had no information on helmet promotion activities in provinces. Many jurisdictions have promoted bicycle helmet use in the absence of legislation. Although these efforts have increased the helmet use rate, they have not been as effective as legislation 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 of agreement for both primary diagnosis and demographic information. 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.

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 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.

ACKNOWLEDGMENTS

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