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Trends in head injuries associated with mandatory bicycle helmet legislation targeting children and adolescents

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ABSTRACT

Background: Bicycling related head injuries (HIs) can be severe. Helmet use reduces head injury risk; however, there are few controlled studies of the effect of helmet legislation. We conducted this study to investigate changes in HIs after bicycle helmet legislation targeting those <18 in Alberta, Canada in 2002.
Methods: Bicyclist and pedestrian (control) HI rates and HIs as a proportion of all injuries were compared for the three years (1999–2001) before and four years (2003–2006) after bicycle helmet legislation in three age groups (children: <13, adolescents: 13–17, and adults: 18+).
Results: There were 41,270 ED visits and 2782 hospitalizations for bicyclists and 9836 ED visits and 2029 hospitalizations for pedestrians (excluding the legislation year 2002). The rate of ED HIs declined for child bicyclists and child pedestrians, while the rate of non-HIs declined in adult bicyclists and child pedestrians. The rate of hospitalized HIs declined in child bicyclists and all ages of pedestrians while non-HI rates declined for child and adult pedestrians. Non-HI rates for adolescent and adult bicyclists increased. After adjusting for sex and location, the proportion of ED bicycle HIs declined by 9% (APR = 0.91; 95% CI: 0.86, 0.95) in children, was unchanged among adolescents and increased in adults (APR = 1.08; 95% CI: 1.01, 1.15). The proportion of bicycle HI related hospitalizations decreased by 30% (APR = 0.70; 95% CI: 0.55, 0.90) in children, 36% (APR = 0.64; 95% CI: 0.49, 0.84) in adolescents and 24% (APR = 0.76; 95% CI: 0.63, 0.91) in adults. There were no observed changes in the proportion of pedestrian HIs resulting in ED visits or hospitalizations.
Interpretation: Our data indicate significant declines in the proportion of child bicyclist ED HIs and child, adolescent and adult bicyclist HI hospitalizations. This is in contrast to no significant trends in the proportion of ED or hospitalized HIs among pedestrians and the unexpected increases in the proportion of ED HIs for adult bicyclists. Comparing bicyclist and pedestrian trends in the proportion of child and adolescent HIs suggests a bicycle helmet legislation effect.

1. Introduction

Bicycling is a popular means of recreation and transportation and studies have shown that children (Cushman et al., 1990; Agran and Winn, 1993; Grimard et al., 1995; Linn et al., 1998; Puranik et al., 1998; Durkin et al., 1999; Shah et al., 2007), adults (Yelon et al., 1995; Rosenkranz and Sheridan, 2003; Davidson, 2005; Canadian Institute for Health Information, 2006), and older adults (Scheiman et al., 2010) are at risk of serious injuries from cycling crashes. Head injuries (HIs) are often the most severe cycling injuries, accounting for one-third of bicycling related emergency department (ED) visits, two-thirds of bicycling hospital admissions, and three-quarters of bicycling deaths (Thompson et al., 1999). Bicycle helmet use prevents head, brain and facial injuries (Thompson et al., 1999; Attewell et al., 2001) and is a cost effective safety measure (Ginsberg and Silverberg, 1994; Taylor and Scuffham, 2002). This evidence has advanced the call for mandatory helmet legislation in Canada and elsewhere (Karkhaneh et al., 2006; Macpherson and Spinks, 2008).

Previous research on the effects of bicycle helmet legislation has been conflicting (Karkhaneh et al., 2006). Some studies have found a decrease in bicycle-related mortality (Grant and Rutner, 2004;

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Wesson et al., 2008) and HIs (Robinson, 1996, 2001; Povey et al., 1999; Scuffham et al., 2000; LeBlanc et al., 2002; Macpherson et al., 2002; Lee et al., 2005; Ji et al., 2006) following bicycle helmet legislation; however, few of these studies formally account for trends in road traffic injuries by using a control group of similarly vulnerable road users (e.g., pedestrians or adult bicyclists not covered by legislation) and few have reported simultaneously on ED and hospitalization data. Indeed, in their Cochrane systematic review on the effects of bicycle helmet legislation, Macpherson and Spinks noted a "paucity of high quality evaluative studies assessing the effect of helmet legislation on bicycle related head injuries. . ." (Macpherson and Spinks, 2008) and identified only 3 studies (Macpherson et al., 2002; Lee et al., 2005; Ji et al., 2006) that met their rigorous methodological criteria, two of which (Macpherson et al., 2002; Lee et al., 2005) demonstrated significant reductions in head injuries with helmet legislation. Consequently, debate continues on the justification for legislating helmet use for cyclists (Colby, 1993; De Marco, 1993; Mackie, 1993; Chipman, 2002; Wardlaw, 2002; Robinson, 2007).

Alberta mandated helmet use for all bicyclists less than 18 years of age effective May 1st, 2002 (Government of Alberta, 2002). We have shown an increase in helmet use after legislation among children under 13 (75–92%) and adolescents 13–17 years (30–63%) with less impressive increases for adults (52–55%) not affected by legislation (Karkhaneh et al., 2011a,b). The purpose of this investigation is to compare the proportion and *incidence* rates of HIs resulting in an ED visit or hospitalization among bicyclists before and after helmet legislation in Alberta. We used the pattern of pedestrian HIs as an indicator of trends in the road safety environment independent of bicycle helmet use and legislation (Cook and Sheikh, 2003).

2. Methods

Data on ED visits (Ambulatory Care Classification System – ACCS) and hospitalizations (Discharge Abstract Database – DAD) were obtained from Alberta Health and Wellness (AH&W) for all injuries sustained by bicyclists and pedestrians from February 1999 to March, 2007. Both international classification of diseases versions 9, (ICD-9-CM up to March 31st, 2001) and 10 (ICD-10-CA from April 1st, 2002) were used for tracking bicyclist and pedestrian head and non-head injuries (Alberta Health and Wellness, 2004; Wang et al., 2006). Individuals seen in the ED, and subsequently admitted to hospital would be in both datasets.

2.1. Definitions

In ICD 9-CM, we included pedal cyclists with external causes of injury codes (E-codes) E800–807 with .3 extension, E810–E825 with .6 extension, 826.1, E827.1, E828.1, and E829.1. After April 1st, 2002, pedal cyclists were captured using ICD10-CA codes (V10–V17 with a .0–.5 and .9 extension, V18.0–V18.1, V18.9, V19.0–V19.6, V19.8, and V19.9). Pedestrian codes for ICD 9-CM included E-codes E800–E807 with a .2 extension, E810–E825 with a .7 extension, and E826–E829. ICD10-CA pedestrian codes included V01–V06, V09 with extensions .0, .1, and .9, V09.2 and V09.3.

We only used the first injury in the database for each individual to avoid the issue of correlated outcome data. For ICD9-CM, there were up to 4 ACCS fields containing cause of injury E-codes and up to 6 diagnosis code fields. For ICD9-CM DAD, there were up to 16 fields containing both E-codes and diagnostic codes. After April 1st, 2002 using ICD-10-CA, ACCS captured up to ten fields containing both diagnosis and E-codes with up to 25 fields containing both diagnosis and E-codes in DAD.

ICD9-CM codes for head injuries included 800–804.9 (fractures), 850–854.1 (intracranial), 870–873.9 (open wound), 920–921.9 (contusion), 959.01 and 959.09 (unspecified head injuries). Codes for other injuries included 800–940 and 950–959.09, excluding previously specified head injuries. ICD10-CA codes for head injuries included S00–S09 (superficial, open, fracture, dislocation/sprains/strain, eye/orbit, intracranial, crush, amputation, other), T020–T0201 (fractures – head with neck), T030 (dislocation/sprains/strains – head with neck), T040 (crush – head with neck), T060 (brain/cranial nerve with nerve/spinal cord at neck level). Other injuries included S00–S99 and T00–T149, excluding previously specified head injuries. The occurrence of any of the head injury codes in the relevant database fields were defined as head injuries, regardless of other injuries. We also conducted a sensitivity analysis with the outcome of more severe head injuries (e.g., skull fractures and intracranial injuries) consistent with the codes used by the Canadian Institute of Health Information in a 2006 report on head injuries in Canada (Canadian Institute for Health Information, 2006).

2.2. Analysis

Incidence rates (IR) of head and non-head injuries (new cases in a year per 100,000 population), for the three years before (1999–2001) and four years after (2003–2006) bicycle helmet legislation stratified by activity (bicycling vs. pedestrians) and age group as well as rate differences with 95% confidence intervals (CIs) between periods are reported. Injury denominators were estimated from the Alberta population from 1999 to 2006 based on Canadian Census data (Statistics Canada, 2010). We used the predicted population for the years between census years as the best estimate available (Statistics Canada, 2010).

The primary outcome was HIs as a proportion of all injuries (defined as HI divided by HI + non-HI) and proportion ratio (PR) post- to pre-legislation (with 95% CIs). These estimates were presented within subgroups of activity (bicycling/pedestrians), age group (<13, 13–17, 18+), sex, and urban/non-urban areas. These variables were chosen as studies have suggested differences in bicycling injury risk according to these factors (Friede et al., 1985; Acton et al., 1995; Powell and Tanz, 2000; Macpherson et al., 2004; Berg and Westerling, 2007; Mehan et al., 2009), differences have been found in Alberta bicycle helmet prevalence by these age groups (Karkhaneh et al., 2011a,b) and pedestrians represented our similarly vulnerable road user control group. The data from 2002 were excluded, since legislation was introduced mid-way through the year.

We used Poisson regression analysis to directly model HI proportions and proportion ratios (Kuhn et al., 1994; Greenland, 2004) with the robust (sandwich or Huber–White) standard error estimator (Rogers, 1993). We estimated the proportion of HIs post- to pre-legislation with covariates of sex and location (urban/non-urban area) in the model. Interaction terms between year (post- to pre-legislation), activity (bicycling vs. pedestrians) and age (<13, 13–17, 18+) were incorporated into the model as age was found to modify the helmet legislation effect in previous work (Hagel et al., 2006; Karkhaneh et al., 2011a, b). Separate analyses were conducted for ED visits and hospitalizations. STATA/IC version 11.1 was used for analyses (STATA, 2009).

3. Results

From 1999 to 2006, there were 41,097 and 9525 ED visits for bicyclists and pedestrians, respectively. The average annual IR of HIs for child bicyclists presenting to Alberta EDs decreased significantly from 136.3 to 115.1 per 100,000 in the post-legislation