University of Alberta

Bicycle helmet use and bicyclists head injuries before and after helmet legislation in Alberta Canada

by

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Dedication

I dedicate this work to my dear wife Mrs. Fatemeh Keshtkarjafary who supported me generously over the last eight years and my dear daughters Zahra and Mina.

Abstract

Bicycle activity in Canada is common and unfortunately, can result in injuries, hospitalization and even death. Bicycle helmets reduce severe head injuries. Both promotional activities and helmet legislation have been used in several countries to increase helmet wearing among bicyclists. The results of different studies have demonstrated that although promotional activities increase helmet use to some extent, sustainable effects occur following the implementation of helmet legislation.

Bicycle helmet use was studied in this thesis prior to (2000-2001) and after (2003-2006) helmet legislation in Alberta. A significant increase in helmet use was observed post-legislation in Alberta by youth <18 (target age group for provincial legislation). St. Albert, an urban community in Alberta, implemented a by-law requiring cyclists of all ages to wear a helmet in 2006 and helmet wearing rose among youth <18; an encouraging but not statistically significant increase occurred among adults (18+).

We examined the rate of bicycling per unit of observation time pre- and post-legislation and demonstrated that bicycling activities among youth <18 decreased only in schools and commuter routes, with no change at other locations.

Since preventing head- and brain-related injuries is the main purposes of helmet wearing, the trend of bicyclist head injuries (HI) in Alberta was examined. Before doing so, in a reliability/validity study we demonstrated that bicycle injuries are coded in a reliable and valid manner in both ICD-9-CM and ICD-10-CA by emergency department (ED) coders.

Examining the HI rates per 100,000 population and proportion of HI among bicyclists who presented to EDs or who were hospitalized, we demonstrated a significant decline among the legislated target age groups (<18) which was not obvious in adults. This decline was larger than expected, based on analysis of pedestrians with head injuries as a control group.

We conclude that helmet legislation increased bicycle helmet use and deceased bicycle-related head injuries among the target age groups in Alberta.

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1 CHAPTER 1

GENERAL STATEMENT

Injuries are one of the major health concerns in all developed and developing counties (1). Researchers have long argued that injuries are not *accidents*. They are convinced that, like other diseases, most injuries follow a distinct pattern and are both predictable and preventable (2-6). No longer would researchers call morbidity and mortality resulting from injuries “bad luck”, “chance”, or “accidents” as some people might traditionally believe (5). Since the early 1960s, there has been a substantial shift from descriptive thinking of injuries to categorizing them in etiologic terms. Earlier epidemiological studies on causes of injuries had suggested a thorough investigation of each event to recognize the agent, mechanism of activation of agent, and interaction between agent, host, and environment leading to morbidity and mortality (5, 6).

1.1 Injury epidemiology

Pioneers in injury epidemiology described injuries as occurring through two mechanisms. One is interference with normal energy exchange and the other is delivery of external energy to the body in an amount that is greater than the body’s threshold for tissue damage (7). Examples for the first mechanism include drowning, strangulation, carbon monoxide inhalation and cyanide poisoning. In the second mechanism, damage to the body occurs due to: 1) mechanical energy, resulting from moving objects such as bullets, knives and falling objects or when a moving body collides with relatively stationary structures, as in falls, and plane and auto crashes; 2) thermal energy such as burns; 3) electrical energy such as electrocution; 4) ionizing radiation as would occur from misuse or malfunction of a radioisotope reactor; 5) chemical energy such as plant or animal toxins, inorganic and organic compounds (7). Although the number of causes of injuries or agents (e.g. heat, electricity, poisons) is not as frequent as infective agents (bacteria and viruses) in the environment, due to frequent human exposure to the cause of injury in daily life there are very many chances for interaction between agent, host, and environment in the case of injuries (7).

It has been shown that the toll of injuries can be prevented or minimized by intervention at three phases. The first phase is preventing the etiologic agent from reaching the susceptible host (e.g., minimizing mechanical forces to a level lower than the threshold for tissue damage in car crashes). The second phase involves the interaction between the etiologic agents and susceptible structures after failure in prevention. For example, safety measures in vehicles (e.g. seat belts, air bags, reinforced cabin, etc) to protect the body during crashes. The third phase includes arresting tissue damage once harmful energy exchange has affected the body. For instance, rapid and expert emergency response at the scene, intermediate treatment at emergency departments, definitive surgical and medical care in hospitals, and rehabilitation care after discharge (5). William Haddon introduced his well-known two-dimensional matrix for etiologic analysis of the different phases of injury and human or environmental factors in 1968 (5). The author suggested that most of the injury problems can be categorized in this matrix (5). Table 1-1 is an example of the application of the matrix to cycling injuries.

1.2 History of injury prevention programs

The World Health Organization (WHO) has suggested safety is a fundamental human right and introduced eight statements as main strategies for safety promotion for all community programs in 1998 (8). As a result, many injury prevention programs have been established to increase safety behaviours (9).

1.2.1 Earlier strategies for safety promotion

Studies have shown that safety measures in passenger cars can prevent injuries. For instance, it has been shown that head restraints reduce the frequency of driver neck injury claims (10). Another study also demonstrated that lap/shoulder belts are effective in reducing fatalities to drivers and right front passengers (2); however, there are also examples of non-successful modification in the vehicles such as buzzer-light reminder systems in passenger cars to increase safety belt use (11).

1.2.2 Educational interventions

Educational interventions can be directed at individuals, communities, or society as a whole. Studies have demonstrated that pure educational interventions have limited impact on injury reduction in the short term (12). For instance television campaigns to increase the use of safety belts in motor-vehicles (M-V) were not considered a successful prevention program (13). A review article also reported that educational activities in schools and counselling programs in physician's offices have had limited impact on bicycle helmet use unless accompanied by some incentives and a comprehensive community-based program (14).

1.2.3 Legislative intervention

Many jurisdictions later decided to implement legislation for maximizing safety of all road users (especially vulnerable road users) or changing the rules in sport and recreation (15-18). In a systematic review, it has been shown that legislation for some groups of road users such as drivers (e.g., drunk-driving, night-time driving restrictions for young drivers), motorcyclists (e.g. helmet use), and imposing specific regulatory controls in sport and leisure (e.g. using face protectors in football and hockey) are the most effective policies in reducing unintentional injuries (12). Later, other studies showed that mandatory seat belt (19), motorcycle helmet (20) and bicycle helmet use (21, 22) were further considered as successful injury prevention programs. A Canadian study comparing ice hockey injuries in Alberta (body checking is permitted) versus Quebec (body checking is not permitted) demonstrated that body checking increases the risk of severe injury and concussion 3-fold among 11-12 year old ice hockey players (23).

1.3 Preamble

Unintentional injuries are the leading cause of death among those under age 35 in Canada (24). Injury also places a tremendous economic burden on Canadians, conservatively estimated at $19.8 billion annually in direct ($10.72 b) and indirect ($9.06 b) costs (25). Among all provinces, Alberta had the highest economic burden of injury costs equivalent to $918 for every citizen (26).

Bicycling is a popular means of transportation, an enjoyable recreational activity, and good exercise. Not surprisingly, participation has nearly doubled over the last 20 years in Canada (27). Cycling injuries alone resulted in $242 million in direct and over $201 million in indirect costs in Canada for the year 2004 (28). The rate of motor-vehicle ownership per capita in Canada is one of the highest rates in the world. It is estimated that almost 80% of casualties of road users are amongst motor-vehicle occupants; vulnerable road users comprise 20% of these casualties (29). Of this 20%, pedestrians are the most vulnerable road users accounting for 61% of fatal and 52% of serious injuries. The second rank belongs to motorcycle and moped riders with 28% and 33% of fatal and serious injuries. Finally, bicyclists comprise 11% of fatally injured and 15% of seriously injured crash victims (29).

Transport Canada indicated that between 2003 and 2007, 45 to 73 cyclists were killed each year as a result of collisions with motorized vehicles (M-V). Thus, bicyclists represent 2.5% of fatalities and 3.3% of all serious injuries among all road users (30).

1.4 Statement of the problem

There were 6,801 bicyclists who presented to the emergency department (ED) due to bicycle injuries in Alberta in 2008 (31). In other words, 1 cyclist visited an ED in Alberta every 80 minutes (19 visits per day); however, confining the number of injuries to a typical cycling season (May 1 to September 30) this equates to nearly 1 ED visit every 30 minutes (31). Alberta Transportation reported that over the five-year period from 2004-2008, there were 3828 M-V collisions involving 3847 bicycles; approximately 75% of the collisions resulted in either death or injury to the cyclist. Of those, a total of 30 cyclists were killed (average=6 per year; range 3-11) and 2926 were injured (average=585 per year; range 513-641) (32). This accounted for approximately 1.4% (95% CI: 0.6-2.2%) of M-V fatalities and 2.4% (95% CI: 2.1-2.7%) of M-V injuries (33). A study in Ontario revealed that over 75% of bicyclist fatalities are due to head injuries (34). In the USA, between 1984 and1988, 2985 head injury deaths occurred due to bicycling (62% of all bicycling deaths). In the same period 905,752 bicyclists visited the ED as a result of head injuries; representing 32% of bicycling injuries treated at an ED (35). While alarming, these data under-estimate the true burden of bicycling head injuries, since many minor concussions are not reported and disability may be long-lasting.

Consequences of bicycling head injuries can be prevented or minimized by wearing a standard bicycle helmet. A meta-analysis of cases control studies from several countries published from 1987 to 1998 demonstrated that helmet use is effective in decreasing head injuries by 60% (95% CI: 45 to 71%), brain injuries by 58% (95% CI: 33 to 74%), facial injuries by 47% (95% CI: 27 to 61%), and fatal injuries by 73% (95% CI: 29 to 90%) (36). Another systematic review on cases control studies has shown that bicycle helmets are capable of reducing head, brain and severe brain injury risk by 63%-88% for all ages (37).

Despite the effectiveness of helmets in bicycling injuries, rider use has been sub-optimal. Many promotional activities such as education, media campaigns, and community incentives have been used to increase bicycle helmet use (38-42). Some jurisdictions have implemented helmet legislation for all ages (43) or bicyclists under 18 years of age (44). In a study in East York, a health district of Metropolitan Toronto, during the six years (1990-1995) before helmet legislation (implemented in 1995) targeting children and youth <18 years of age, helmet use increased from 4 to 44%. However, helmet use rose rapidly to 68% (1996) and 66% (1997) in the two years following legislation (45). Leblanc et al. studied four years of bicycle helmet use in Halifax, Nova Scotia, Canada. This study demonstrated that helmet use was 36% in 1995 and 38% in 1996 (before legislation) but increased to 75% and 86% in 1997 and 1998 (after legislation), respectively (46).

A systematic review of comparative studies revealed that bicycle helmet legislation can increase helmet use from 5% to 54% (22); however, the effectiveness varies based on baseline helmet use, age (youth <18 vs adults 18+), time since legislation (observation time points), and methodology (before-after vs. non-equivalent control group methods). Using the two quasi-experimental non-randomized intervention studies in all included studies has shown the limited option for such community-based interventional studies. In these methods intervention (e.g., helmet legislation) is introduced at the group level (community) and outcome (e.g., helmet use) is measured at the individual level (direct observation or telephone survey). Both methods are subject to some degree of bias estimates due to “history” and “maturation” (47). “History” refers to events occurring concurrently with the intervention (co-intervention) that can affect the outcome. Maturation is a natural development over time in the society which could be confused with the effect of an intervention. In the before and after studies, both history and maturation are of concern and weaken any systematic review. Non-equivalent non-randomized comparison group are stronger because there is no time trend (maturity) issue; however, selecting a non-equivalent control group with different societal characteristics could also create a source of bias (history).

On May 1st, 2002 Alberta passed a law mandating bicyclists less than 18 years of age wear helmets (48). The results of an observational survey in 2000 (two years before helmet legislation) in Alberta revealed that the prevalence of helmet use was 75% (95% CI: 71 to 78%) in children (<13), 29% (95% CI: 23 to 34%) in adolescents (13-17), and 52% (95% CI: 49 to 55%) in adults (18+). This comprehensive study was conducted in the two largest cities of Alberta (Calgary and Edmonton) and surrounding communities within 50 km from either city center with populations exceeding 9,500 (i.e., Airdrie, Cochrane, Fort Saskatchewan, Leduc, Okotoks, Sherwood Park, Spruce Grove, and St. Albert). Overall, the sample area represented 60% of Alberta’s total population of 2,819,423 (49). In this study, trained observers recorded general bicyclist general characteristics including approximate age group in three groups of children <13, adolescents (13-17) and adults (18+), sex, helmet use (correct/incorrect), riding companion(s) and their helmet use based on direct observation in six strata of schools (35%), campus/colleges (15%) parks (17%), commuter routes (17%), designated cycling paths (17%), and residential areas (17%) from June 1st to September 30th. Time of observation was fixed (one hour at schools, campus/colleges, and parks and two hours at commuter routes, designated cycling paths, and residential areas) (49).

Two years after legislation implementation (2004), a similar study design limited to Edmonton only, replicated the survey of bicyclist helmet use at those sites where at least 10 riders were observed in 2000 (22 of 23 eligible sites) (50).

The results of this study demonstrated that the prevalence of helmet use in children and adolescents <18 increased from 28% (95% CI: 22 to 35%) to 83% (95% CI: 68 to 92%); however, in adults (18+) the prevalence remained approximately the same at 49% (95% CI: 45 to 54%) and 48% (95% CI: 41 to 54%), respectively. This study demonstrated that, after adjustment for covariates, the prevalence of helmet use in <18 age group increased significantly (PR [prevalence ratio]=3.69; 95% CI: 2.65, 5.14); however, there was no change among the adult age group (PR=1.17; 95% CI: 0.95, 1.43) (50).

Summary

Bicycling is a part of active living and commuting in Canada; however, like pedestrians, bicyclists are vulnerable road users. It has been shown that wearing a standard bicycle helmet can prevent or at least minimize the severity of head injuries among cyclists and minimize the social and economical burden for society. Some community stakeholders have encouraged cyclists to wear helmets, a strategy that was marginally effective at increasing helmet use, albeit falling far short of producing acceptable levels of helmet use. Helmet education and media campaigns appear not to be sufficiently effective to convince people in different age groups to use helmets in every cycling instance. For more sustainable effects, some jurisdictions have used legislation to increase the level of helmet use. Alberta is one province in Canada that legislated bicycle helmet use for youth aged <18 years old. After four years of legislation in Alberta, it is an opportune time to comprehensively examine the effectiveness of helmet legislation. Most importantly, there is a need to evaluate the role of legislation and its effectiveness at increasing helmet use and reducing head injuries among injured bicyclists. The results of this study could reassure other jurisdictions without bicycle helmet legislation to use this strategy for increasing safe cycling and preventing unnecessary casualties among bicyclists.

1.5 Proposed investigation in this research

This is a paper-based thesis and consists of a literature review (Chapter 2), five papers (Chapter 3-7) and general discussion and conclusions (Chapter 8).

1. Chapter 3 was a repeated comprehensive observational survey six years after the first survey and four years after bicycle helmet legislation in Alberta to evaluate changes in bicycle helmet prevalence. Our second survey in 2006 was methodologically similar to the first survey in many aspects.
2. Chapter 4 assessed helmet use in St. Albert, Alberta (a suburban community northwest of Edmonton with a population of 57,000). In February 2006, St. Albert City Council passed a traffic by-law amending the Provincial helmet legislation to include all age groups effective from July 1st 2006. Given the legislative differences between St. Albert and the rest of the province, we compared St. Albert helmet wearing data to other areas of Alberta to measure the effectiveness of the by-law requiring all age groups to wear helmet.
3. Chapter 5 examined bicycling exposure after helmet legislation. One of the important potential consequences of legislating helmet use is a change in cycling behaviour among bicyclists, especially those in the target age groups <18. In this investigation, bicycling frequency was compared before and after helmet legislation in Alberta.
4. Chapter 6 was an ICD-9 to ICD-10 bridge coding study. Alberta implemented the Canadian enhancement of the 10th revision of International Classification of Diseases (ICD-10-CA) for deaths on January 1st 2000 and for hospitalization and emergency room data on April 1st 2002. Simultaneous implementation of transition from ICD-9-CM to ICD-10-CA with Alberta helmet legislation might have itself created an artificial trend in the number of bicycle injuries recorded in EDs and hospitals across Alberta. Evaluating any trends in bicycle injuries or hospitalizations, we investigated the validity of ED codes and reliability of ED coders in applying ICD-9-CM and ICD-10-CA external cause of injury codes for bicyclists before and after transition.
5. Chapter 7 evaluated the rate of head and other injuries among bicyclists before and after helmet legislation in Alberta. The main purpose of bicycle helmet wearing is to protect the heads and brains of bicyclists during a crash incident. Assuming increasing helmet

use after legislation, we also planned to investigate any change in bicycle injuries, with particular attention to head injuries, after the implementation of helmet legislation in Alberta and used pedestrian injuries to factor out trends in general road safety unrelated to bicycle helmet legislation (e.g., motor vehicle speed reduction measures).

1.6 Student contribution

The following summarize my contribution to the PhD thesis:

- Chapter 1: design, acquisition of the information, completion of the chapter, and revision after critical review by the supervisors.
- Chapter 2: design, acquisition of the information, completion of the chapter, and revision after critical review by the supervisors.
- Chapter 3: acquisition of primary data, analysis, interpretation, drafting and revision of the article for important intellectual concept, and final submission to a peer reviewed journal.
- Chapter 4: acquisition of primary data, analysis, interpretation, drafting and revision of the article for important intellectual concept, and final submission to a peer reviewed journal.
- Chapter 5: concept and design, acquisition of primary data, analysis, interpretation, drafting and revision for important intellectual concept.
- Chapter 6: concept and design, acquisition of the primary data, analysis, interpretation, drafting and revision of the article for important intellectual concept, and final submission to a peer reviewed journal.
- Chapter 7: concept and design, acquisition of the primary data, analysis, interpretation, drafting and revision for important intellectual concept, and getting final approval of the supervisors.
- Chapter 8: design, acquisition of the information, completion, and revision after critical review by the supervisors.

Table 1-1 Haddon matrix (bicycle example)

Component / **Phase**	Host	Equipment	Environment – physical	Environmental-social
Pre-crash	Bicycle training and fitness	Speed, risk taking, bike	bicycle paths, distractive signs	enforcement, policing
Crash	Age, co-morbidities	bicycle helmet, knee, elbow pads	Surface, guard rails for solid structure, soft shoulders along roadside	NA
Post-crash	access to 911,	Life saving action	Location relative to EMS, ED	community response

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2 CHAPTER 2

REVIEW OF LITERATURE

2.1 Bicycling in Canada

The Canadian Community Health Survey, a nationwide cross-sectional survey that collects information related to health status, health care utilization and health determinants for the Canadian population each year (every other year before 2007) demonstrated that in 2000/01 bicycling (19%) was the fourth most popular physical activity after walking (65%), gardening (41%), and home exercise (24%) in Canada (1). Despite lower average temperature and often extreme winter weather conditions, the overall proportion of bicycle-related work trips in Canada in 2000/2001 was approximately three times (1.2 vs. 0.4%) greater than those in the United States (2). In a comparison of the percentage of trips in urban areas made by bicycling between North America and nine European countries in 1995, the United States had the lowest percentage of trips (~7%); Canada ranked second lowest with ~12% of trips in urban areas by bicycle (3). Of the reasons for more frequent bicycling in Canada than the United States, Pucher and Buehler highlighted higher urban densities, shorter trip distance, lower income, higher cost of owning and parking a car, safer cycling conditions and more cycling infrastructure and training programs (2).

This chapter will review Canadian studies on bicycle injuries, bicycle helmet use with and without helmet legislation and rate of bicycling, published in the past 20 years.

2.2 Search strategy for the review of literature

Cycling research in Canada was examined by searching in major electronic databases including: Medline, EMBASE, HealthSTAR, PUBMED, CINAHL, PsycInfo, Cochrane Database, SCOPUS, Web of Science, and Google Scholar. For each section of this thesis, appropriate terms were developed in consultation with librarians. Specific terms were used for all the chapters included “bicycle”, “cycle”, “cycling”, “bike”, “helmet”, “head protection”, “bicycle helmet”, “legislation”, systematic review”, “metaanalysis”, and “review”. In addition, reference lists of the relevant articles were also searched for other studies, reports and unpublished works. Websites of governmental and non-governmental institutions such as the Canadian Institute for Health Information (CIHI) and Centers for Disease Control and Prevention (CDC) were also checked. In the case of unpublished work or to obtain additional information authors were contacted through email.

2.3 Bicycling injuries

This section will present a review of bicycle-related injuries abstracted from 10 studies in Canada since 1975. Table 2-1 at the end of this section will show a brief summary of their general description and common results.

2.3.1 Bicycle injury hospitalization

Examining head injury hospitalizations during 10 years (April 1st 1994 to March 31st 2004) CIHI reported 44,577 bicycle-related hospitalizations accounting for 2% of all hospitalizations in Canada during this period (4). CIHI mandates reporting from all hospital admissions in Canada, except those resulting from poisonings by drugs and gases or due to adverse effects of drugs or medicine. Of the total hospitalizations, 10,568 (24%) were due to head injuries, of which 7,036 (67%) occurred among children and youth 5-19 years old.

CIHI also investigated major sport and recreation hospitalizations among 46 participating centers in Canada during the fiscal year of 2004-2005. Bicycling injuries accounted for approximately 27% of major sports and recreational injury hospitalizations (5). In another evaluation of all injury hospitalizations in Canada for the fiscal year of 2001-2002, CIHI reported that 6% of all-injury hospitalizations among children and youth less than 20 years old were due to bicycling; however, only 2% of all age injury hospitalizations were due to bicycling (6).

In a four-year (1994-1998) study using CIHI data, Macpherson et al. reported that 9367 children aged 5-19 were hospitalized for bicycle-related injuries (7). Of these, 21% occurred in rural areas, 18% in mixed rural, 17% in mixed urban, and 44% in urban areas. In a survey in the Alberta Children’s

Hospital in Calgary, Alberta (April 1st 1991 to September 30th 1993; ~2.5 years) there were 699 bicycle-related hospitalizations (8).

Overall, bicycling injuries are an important cause of hospitalizations in Canada.

2.3.2 Bicycle-related injuries presented to emergency departments (ED)

A five-year (1991-1995) study at the British Columbia Children's Hospital (BCCH) using data from the Canadian Hospitals Injury Reporting and Prevention Program (CHIRPP) was conducted among children ages 1-19 (9). CHIRPP is a national, and predominantly pediatric ED-based surveillance system. The study demonstrated that bicycle injuries comprised 4% of all injuries among these children (9). This study found the proportion of children hospitalized for bicycle injuries (12.7%) was significantly higher than for non-bicycle-related injuries (7.9%) in children during the same period (OR=1.96; 95% CI: 1.44, 1.99) (9). The highest proportion of bicycle injuries involved upper extremities (46.4%), then head and face injuries (38.9%) and lower extremities (32.5%); the other injuries were between 0.1 and 4.9% (9).

A 2-year study at the Children's Hospital of Eastern Ontario (CHEO) was conducted to assess bicycle-related injuries between May 1st and September 30th 1988 (10). Of the bicyclists brought to the CHEO ED during this time, 48% were <10 years old and only 2% of injured cyclists wore a helmet at the time of incident with 19% hospitalized (10).

Overall, an important proportion of ED visits in Canada result from injuries sustained while cycling.

2.3.3 Head injuries among hospitalized bicyclists

During a 4 years study (1994-1998) using CIHI data, Macpherson et al. reported that of 9650 bicycle-related hospitalizations among children (5-19), 35% were head and face injuries (11). In a 10-year study in Canada it has been shown that the largest risk ratio (RR) of head injury hospitalization (RR=9.8) was among children 10-14; RR<5 for all other age groups 0-9, 15-19, and 20-34 (age ≥ 35 was reference) (p<0.001) (4).

In a study examining urban/rural variation of bicyclist head injuries, the average annual incidence rate in children living in rural areas was 18.49 per 100,000 compared with 17.38, 15.49, and 10.93 per 100,000 per year for those living in mixed rural, mixed urban, and urban areas, respectively (7). It was also shown that the risk of a bicycle-related head injury admission in rural areas was 1.67 times greater than urban areas. This risk for mixed rural and mixed urban were 1.59 and 1.42 times greater than urban areas, respectively (7).

Another study also demonstrated that of the 738 bicycle-related injuries presented to the ED, 25% were due to the head/face; however, among those hospitalized 49% had head and skull injuries (10). In a 12-month survey on bicycle injuries among three major hospitals in Calgary, Alberta (from July 1972 to June 1973) there were 107 bicycle injuries in total, of which 67% were due to head injuries (12).

Overall, an important proportion of hospitalizations in Canada result from head injuries incurred following cycling crashes.

2.3.4 Factors associated with bicycle injuries

Ten studies in Canada focusing on bicycle-related injuries demonstrated that the number of males hospitalized due to bicycle-related injuries was at least twice as high as females, with 64% to 84% of injuries occurring in males (Table 2-1); however, there was no indication whether bicycling exposure was two times higher in males compared to females in these studies. In a British Columbia (BC) study, there was higher percentage of males (13.8%) presenting to the EDs than females (10.2%); however, this did not reach statistical significance (OR=1.41; 95% CI: 0.97, 2.05) (9).

Most of the studies have found not wearing a bicycle helmet to be a risk factor for bicycle-related head injuries. In the same BC study, the majority (70%) of injured bicyclists reported no helmet use and also hospital admission was more frequent among those children who did not wear helmets (OR=2.23; 95% CI: 1.39, 3.62) (9). Moreover, the odds of head and face injuries was 55% greater among children with no helmet (OR=1.55; 95% CI: 1.18, 2.04); however, the odds of minor head injuries were not significantly different between users and non-users (OR=1.10; 95% CI: 0.60, 2.06). Additionally, almost all concussions (57 out of 62) happened among non-helmet users (OR=4.04; 95% CI: 1.55, 11.47). One fatality was reported due to severe head injury; however, there was no indication of helmet use status (9).

Finvers et al. reported that of 699 hospitalized children due to bicycle injuries only 13.7% (n=96) wore helmets; no difference between helmet use in males and females (13.6% vs 14%) was observed. In the same study, and approximately 38% of injuries were the result of head injuries. This study also reported that of the 76 children who sustained serious head injuries, only 4 (5%) were known to be wearing a helmet at the time of the event. Moreover, this study has shown that prevalence of helmet use among other injury hospitalization was 15%, therefore, the odds of **not** wearing helmet were more than 3-fold higher (OR=3.12; 95% CI: 1.13, 8.75) for bicyclists who sustained serious head injuries (8). The results from a 12-month survey among three hospitals in Calgary in 1975 demonstrated that none of cyclists hospitalized due to bicycle-related head injury wore helmets while bicycling and 4% died due to subdural hematoma (12).

It has been shown that interaction between cyclists and motorized vehicles (M-V) was a frequent contributor to bicycle-related injuries. Linn et al. indicated that the highest proportion of admissions were among those bicyclists involved in road traffic crashes at 21.5%, comparing with all other non-bicycle-related injuries (OR=5.4; 95% CI: 3.4, 8.5) (9).

Other risk factors for bicycle injuries have also been evaluated. Cushman et al. reported that poor riding skills or careless riding, leading to loss of control, was the cause of incidents in 62% of the cases; mechanical failure occurred in 11% and environmental hazard in 9% of the cases (10).

2.3.5 Bicycle fatality and risk factors

A thorough investigation of bicyclists' deaths from medico-legal documents in Ontario Canada was conducted between 1986 and 1991. The authors found that 53% of fatally injured bicyclists were under 20 years old and

91% of deaths resulted from collisions between a M-V and bicyclesMoreover, 68% of these cyclists died at the scene or in the EDs (13). Over 75% of the bicyclist deaths involved head injuries; however, only 4% of those with head injuries were known to be wearing a helmet (13). Bicyclist deaths occurred between 8 am and 8 pm in 69% of the cases and 15% occurred from midnight to 8 am. In 91% of the cases bicyclists were struck by a M-V; all children <10 and 88% of youths 10-19 years of age were involved in a M-V collision. The main cause of crash was bicyclist error in 66% and motorist error in 41% of the collisions. Midblock ride out (children <10) and sudden turning or swerving into the path of a M-V (youth 10-19) were the main circumstances of collisions among younger age groups. Failure of the motorist to detect the cyclist (43% of the cases) and falls (18% of the cases) were the main circumstances among older age groups. Intoxication was observed in 7% of cyclists; however, 14% of motorists also had signs of alcohol use. Alcohol use was observed in 30% of those motorists who failed to detect the bicyclist (13).

2.3.6 Bicycle helmet use and head injury

There are two well-known systematic reviews assessing the relationship between bicycle helmets and head injuries. The first was a Cochrane review which demonstrated that bicycle helmets provide 63% to 88% reduction in the risk of head, brain and severe brain injuries and 65% reduction in risk of upper and mid facial injuries for all-age bicyclists (14). Based on another systematic review, bicycle helmets were found to reduce the risk of head and brain injuries between 58% and 73% and facial injuries by 47% (15). Consequently, strategies to increase helmet use are important and likely play a substantial role in reducing the toll of bicycling related head injuries.

2.3.7 Helmet legislation and bicycle injuries

The relationship between helmet legislation and rate of bicycle-related hospitalization was evaluated in Canada. It has been shown that in those provinces with bicycle helmet legislation, head injury hospitalization risk decreased by 17% compared with non-legislative provinces during the period of 1994-1995 to 2003-2004 (4). In a Canadian study from 1994 to 1998, the rate of head injuries declined 45% in legislated provinces; however, the decline was only

27% in non-legislated provinces (p=0.001) (11).This protective effect of legislation was estimated to be 23% (OR=0.77; 95% CI: 0.69, 0.85) (11). Reporting 58 bicyclist deaths during the same period, this study indicated that the rates of death were 3.38, 1.83, 0.61, and 1.83 per 1 million children in legislated provinces from 1994 to 1998 respectively; consistently lower than non-legislated provinces during four years, 4.12, 2.20, 3.38, and 2.62, respectively (11).

2.3.8 Community interventions for increasing helmet use

There have been two main strategies to increase helmet use by cyclists. One is educational promotional activities and the other is legislation. It has been shown that promotional activities such as education, media campaigns, and community incentives increased helmet use in the communities although only to a limited extent (16-25). Also some jurisdictions implemented helmet legislation for all ages (26, 27) or bicyclists less than 18 years of age (28, 29). Due to the importance of this issue, in the following sections (**2.4**) the extent of bicycle helmet use in Canada will be evaluated in detail. Also in the last section (**2.5**) a systematic review of bicycle helmet legislation will examine the effectiveness of helmet legislation in increasing bicycle helmet use.

Main conclusions for the literature review of bicycling injuries in Canada

Overall, the evidence in Canada suggests that ED visits; hospitalizations and deaths resulting from bicycling injuries are common, especially given the limited cycling seasons in many parts of the country. In summary:

1. Bicycle injuries represent approximately 2% of hospitalizations in Canada among all age groups and 4% among youth <20;
2. Bicycling injury hospitalization can reach 27% among sport and recreation injuries in Canada;
3. Bicycle injuries occur more often in males than females;
4. Hospitalizations for head injuries occur in 24% to 67% of bicycle injuries presenting to EDs;
5. Overall, head injuries represent 25% to 39% of bicycle injuries presenting to EDs;

6. Up to 75% of bicycling deaths are due to head injuries;
7. Helmet wearing was as low as 0-5% among head injury cases requiring hospitalization;
8. Helmet use for bicyclists presenting to EDs ranged from 2% and 21%; for those with concussion helmet use was as low as 8%;
9. In the provinces with bicycle helmet legislation, head injuries declined by 45% compared with non-legislative provinces which declined by 27%, indicting 23% greater decline or protective effect.

Important questions that remain to be answered

1. What is the rate of head injuries among bicyclists in Alberta before and after helmet legislation?
2. Are there differences in the rate of head injuries between age groups targeted and not targeted by helmet legislation?
3. Are there any differences in trends in head injury rates between bicyclists and other vulnerable road users over a time period involving the implementation of bicycle helmet legislation?

2.4 Extent of bicycle helmet use in Canada

Having discussed the burden of head injuries related to bicycling, it is important to examine the prevalence of helmet use as an effective head injury prevention strategy. Helmet use research in Canada was examined with a similar search strategy as previous sections. Searching electronic databases, we searched for published articles reporting data on roadside observations of helmet use across Canada. Of the 14 published studies found, five from 1995 to 2004 (26-30) investigated bicycle helmet use post-helmet legislation in four provinces of Alberta, British Columbia, Nova Scotia, and Ontario; five from 1992 to 1996 (16-20) examined bicycle helmet use after promotional activities in two provinces of Ontario and Quebec; and four from 1990 to 2003 (31-34) evaluated bicycle helmet use as baseline or single study in three provinces of Alberta, Manitoba, and Ontario (Table 2-2, 2-3, 2-4).

2.4.1 Bicycle helmet use pre- to post-legislation in Canada

Of five studies reviewed in this section two were conducted in Ontario which introduced a helmet law in 1995 mandating all cyclists <18 to wear a helmet (28, 30). During two periods of time, sequential observational surveys were conducted in East York, a health district of Metropolitan Toronto since 1990. The earlier study (28) examined helmet use trends among children 5-14 from 1990 to 1997. Helmet prevalence (HP) increased from 4% in 1990 to 44% in 1995, however, in the two years following the helmet law (1996 and 1997), helmet use reached 68% and 66%, respectively. It was also demonstrated that children 5-14 were more likely to wear helmets post-legislation (relative risk (RR) = 1.47; 95% CI: 1.37, 1.58). The later study reported that HP among children 5-14 changed from 45% in 1995 to 68% in 1997; however, returned back to the pre-legislation level of 46% in 2001 (Table 2-2) (30).

British Columbia was another Canadian province that pioneered legislation in 1996 mandating bicyclists of all ages wear a helmet when riding on public roadways (27). A second observational survey in 1999 was a repeat survey using the same methodology of the baseline study in 1995. It has been shown that HP increased in all age groups post-legislation. Children 1-5 had the highest baseline HP, 60% which then increased to 78% in the second survey; the post-legislation odds of helmet use among children was more than twice the pre-legislation period (odds ratio [OR]=2.32; 95% CI: 1.14, 4.71). HP approximately doubled (35 to 61%) in school age children and younger teenagers 6-15 (OR=2.93; 95% CI: 2.38, 3.61). For cyclists 16-30, HP increased from 47 to 69% (OR=2.52; 95% CI: 2.18, 2.90). For those 31-50 years old, helmet use increased from 52 to 75% (OR=2.74; 95% CI: 2.29, 3.27), and for those 51+ the proportion increased from 41 to 71% (OR=3.85; 95% CI: 2.65, 5.59) (Table 2-2) (27).

Helmet legislation in Nova Scotia targeting cyclists of all ages was passed in December 1996 and proclaimed six months later. Repetitive observational surveys were conducted in 1995/96 (before legislation), 1997, and 1998/99 (after legislation) in Halifax (26). HP was reported for three age groups of children, adolescents, and adults. HP in children was 49% (1995/96), 95% (1997), and

84% (1998/99). Corresponding HP for adolescents was 29%, 68%, and 70%, and for adults were 36%, 75%, and 86%, respectively (Table 2-2).

Alberta joined the group of bicycle-helmet-legislation provinces mandating bicyclists <18 to wear helmets when cycling on a public road in 2002. A baseline observational survey examined pre-legislation HP in 2000 (31) (see section 2.4.6 and Table 2-4). A methodologically similar observational survey, though geographically limited to the city of Edmonton, was conducted in Alberta in 2004 (29). This study revealed that HP in Children <13 increased from 44% in 2000 to 100% in 2004. Comparing actual rates (number of helmeted/total number of cyclists observed) pre- to post-legislation, this study reported that rate of helmet use post-legislation among children was 128% greater than pre-legislation survey (prevalence ratio [PR]=2.28; 95% CI: 1.58, 3.29). Corresponding HP for adolescents changed from 17% to 75% (PR=4.32; 95% CI: 2.53, 7.39), while for adults there was little change: 49% to 48%. (PR=0.97; 95% CI: 0.79, 1.19). In a multivariate analysis, helmet use increased 3.7-fold among cyclists <18 two years after legislation (PR=3.69; 95% CI: 2.65, 5.14) while those 18+ did not show a significant change post-legislation (PR=1.17; 95% CI: 0.95, 1.43) (29) (Table 2-2).

2.4.2 Factors associated with bicycle helmet use after legislation

Sex: Four of the five Canadian studies evaluated the relationship between sex and helmet use following legislation and demonstrated that females wore helmets more than males (Table 2-2). In East York, Ontario throughout the eight years of study females were 43% more likely to wear a helmet than males; relative risk (RR)=1.43; 95% CI: 1.36, 1.50) (28). The later East York study also reported that females were more likely to wear a helmet than males through the study period (RR=1.7; 95% CI: 1.5, 1.8) (30). In British Columbia, helmet wearing behaviours four years post-legislation were significantly improved among males; showing that odds of wearing helmet were more than twice among males (OR=2.61; 95% CI: 2.34, 2.90) and more than three times among females (OR=3.2; 95% CI: 2.68, 3.82) post-legislation (27). In a study limited to Edmonton, Alberta two years post-legislation helmet prevalence increased in males (38%) and females (54%) from pre-legislation to 48% and 67% respectively, post-legislation. However, by adjusting for sites as clusters corresponding prevalence ratio (PR) did not show statistically significant changes in either male (PR=1.27; 95% CI: 0.95, 1.71) or female (PR=1.24; 95% CI: 0.96, 1.59) cyclists (29).

Income level: Both studies in East York, Ontario examined the relationship between HP and average family income in three distinct areas of low, middle and high income level (28, 30). In the earlier study (1990-1997), children (5-14) in low (RR=1.86; 95% CI: 1.64, 2.11) and mid (RR=1.58; 95% CI: 1.39, 1.80) income areas were more likely to wear helmets post-legislation. In high-income areas, the increase in helmet use post-legislation was not statistically significant (RR=1.06; 95% CI: 0.96, 1.17) (28) that might be an indication of a ceiling effect (35). In the later study (1995-2001) it was shown that in 1995 (pre-legislation), children (5-14) in high (relative likelihood (RL)=2.2; 95% CI: 1.9, 2.5) and middle (RL=1.5; 95% CI: 1.2, 1.7) income areas were more likely to wear helmets than low income areas. In the post-legislation period this higher probability of helmet use in high and middle income areas relative to low income was consistent. For instance, in 2001 children in high income areas were more than twice (RL=2.6; 95% CI: 2.2, 3.0) as likely and in mid income areas 50% more likely to wear helmets than low income areas (RL=1.5; 95% CI: 1.2, 1.9) (30).

Summary

A review of helmet legislation studies has shown that bicycle helmet use have increased in four provinces after implementation of a helmet law. Two provinces with universal (all-age) helmet legislation have experienced consistent increases in helmet use among all age groups (26, 27). Of the two provinces with <18-targeted legislation one was a study (29) for all age groups (<18 and 18+) and the other was a study for only <18 (28). Both studies demonstrated increase of helmet use in the target age group (<18) and one study failed to identify HP changes among non-targeted age groups (Table 2-2) (29) .

2.4.3 Bicycle helmet use without legislation in Canada

There have been nine observational studies conducted from 1990 to 2003 evaluating bicycle helmet use with no legislation (16-20, 31-34). Of these nine studies five (16-20) were accompanied by promotional activities in the community and four (31-34) were baseline or single cross-sectional studies (Table 2-3).

2.4.4 Bicycle helmet use before and after promotional campaign

Four of five studies, (17-20) examining the effects of promotional campaign on bicycle helmet use, were conducted in the geographical areas of Barrie, East York, and Ottawa, Ontario and one (16) was conducted in Montérégie, Quebec. Designs of three of five promotional studies (16, 17, 19) were non-equivalent/non-randomized control group studies and two (18, 20) were repeated observational surveys (before/after interventional studies).

Three non-equivalent control group studies conducted promotional campaigns among intervention groups in school children aged 5-12 (16) or 5-14 (17, 19) with no such activities in the control groups. Strategies used for promoting helmet use in the controlled studies included at least education, poster/pamphlets, take home messages, community awareness, and bicycle helmet subsidy programs. In these three non-equivalent control group studies, both intervention and control groups demonstrated increases in helmet use pre- to post-intervention. These studies reported some degree of contamination between intervention and control groups as the reason for simultaneous increase of helmet use in control groups. The contamination was apparently the result of programs such as a national bicycle helmet promotion campaign, national helmet discount coupon offer administered through the offices of primary care physicians (sponsored by Canadian Medical Association), sporadic media coverage, and the early development of a children's bicycle helmet coalition (16, 17, 19).

In Montérégie, Quebec promotional activities in schools was accompanied by a statistically significant increase of helmet use by students in comparison with that in the control students (OR=1.78; 95% CI: 1.10, 2.89), although the difference is not appreciable due to contamination. This study reported that helmet use in the intervention group was 1.3% at baseline in 1990 and then increased to 33% in 1993. In the control group baseline helmet use was not available but tripled between the second year (1991) and 1993 (16).

In the earlier study in East York, Ontario, helmet use increased four-fold from 3.4% in 1990 to 16% in 1991 post-intervention at all observational sites (p-value<0.001) (19). A later study at the same areas reported that the trend in helmet use in the area that received education and subsidy during the period 1990 through 1992 (4% to 18%) was not statistically significantly different from control areas (3% to 19%) (p-value=NS); however, the overall helmet use rate, which was 16% in 1991 rose to 28% in 1992 (p-value<0.001) (17).

In the two *observational surveys* of promotional campaigns and helmet use (18, 20) similar strategies including media campaign, education in schools, community awareness, and bicycle helmet subsidy programs were applied. An observational study in Barrie, Ontario demonstrated that after promotional activities helmet use increased significantly from 5.4% in 1990 to 15.4% in 1991 (p-value<0.001) (18). During a similar campaign in Ottawa, Ontario a significant increase in helmet use occurred over the course of three years (1988 to 1991) (10.7% to 32.2%; p-value<0.0001) (20) (Table 2-3).

2.4.5 Factors associated with helmet use after promotional activities

Sex: Four out of five studies evaluating helmet use after promotional activities reported subgroup analysis for sex (16-19). In Montérégie, Quebec, girls were 1.54 times more likely to wear helmets than boys (OR=1.54; 95% CI: 1.26, 1.88) (16). In East York in 1995 before implementing helmet legislation (and similarly in 1993) there was no significant difference between helmet use for boys (37%) and girls (41%) in high-income areas (p-value=NS); conversely in low-income area girls (30%) wore helmets significantly more than boys (16%) (p-value<0.001) (17, 19). In Barrie, girls (15.7%) wore helmets twice as often as boys (8.1%) (OR=2.12; 95% CI: 1.27, 3.51) (18).

Income level: Three of these five studies assessed the relationship between income at a geographical level and compliance with bicycle helmet promotional campaigns (16, 17, 19). In Montérégie, Quebec areas of observation were divided into two groups of poor and average-rich municipalities. The results demonstrated that promotional activities, on average, were 3-times more effective in the average-wealthy than in poor municipalities (16).

During the earlier study in East York, helmet use in high-income intervention areas rose dramatically from 4% in 1990 to 36% in 1991 post-intervention; however, a smaller increase from 4% to 15% was observed in the high-income control areas (p-value<0.001). In the same study helmet use in low-income intervention areas increased from 1% to 7% somewhat different from low-income control areas (3% to 13%) (7% vs. 13%, p-value=0.01). The authors concluded that their program was successful in high- but not in low-income areas (19). The more recent study in East York, Ontario demonstrated that helmet use was not different between low-income intervention or control areas (18% vs. 19%); no statement was made regarding comparison with high income areas (17).

Companionship: One of five reviewed studies examined the relationship between helmet use and companionship after a helmet campaign (17). This study indicated that children were more likely to wear helmets when accompanied by an adult rather than other children in both high and low income areas (p<0.001). It also reported that children in high income areas were more likely to wear helmets when they were alone than those in low income areas. If children were riding with other helmeted children, they were more likely to wear helmets; 80% in high and 63% in low income areas. These rates were larger, 89% in high and 83% in low income areas, when they were riding with at least one helmeted adult showing a statistically significant positive influence in both income areas (p<0.001).

Summary

A review of non-legislative studies demonstrated that all five promotional studies conducted in four cities (Barrie, East York, Montérégie, and Ottawa) across two provinces in Canada was accompanied by increases in helmet use. Three studies with concurrent control group demonstrated that although helmet use in the control areas increased during the course of study due to contamination, the rate of increase in intervention groups was more often greater than the no-intervention groups. They also revealed that sex of the rider and income level of geographical area could change the results of the intervention.

2.4.6 Cross-sectional bicycle helmet use studies in Canada

There were four cross-sectional studies in Canada that were either used as baseline surveys (31, 34) for later studies (20, 29) or was a single observational study (32, 33) (Table 2-4).

A study in Edmonton, Alberta in 2000, bicycle helmet use even without any promotional campaign or legislation was 75% in children <13. Adolescents (13-17) had the lowest HP (29%) and adults wore helmet in 52% of the cases (31).

The result of an observational survey in Winnipeg, Manitoba in 1996, demonstrated that total helmet use was 21.3%. The highest HP was in children <8 (43.9%). HP in other age groups was as follows: 8-11 (16.7%), 12-15 (7.3%), 16-19 (8.3%), and >19 (23.6%) (32).

The results of an observational survey in Sudbury, Ontario in 1992, demonstrated that overall helmet use was 20%. This study revealed that children <10 and young adults 20-40 wore helmets more frequently, than teenagers 10-19 (p-value<0.05) (33).

An observational survey in Ottawa, Ontario in 1988 demonstrated that 10.7% of all cyclists wore helmet. Subgroup analysis showed that HP in commuters was highest with 17.9%, followed by recreational areas with 14.3% (95% of these cyclists were adults). Students had the lowest HP with 1.9% significantly different from the rest of bicyclists in commuters and recreational areas (p-value<0.0001) (34).

2.4.7 Factors associated with helmet use in cross-sectional studies

Sex: In the Edmonton study HP among females (64%) was higher than males (50%). In subgroup analysis it was shown that children (OR=1.18; 95% CI:

1.01, 1.37) and adult (OR=1.33; 95% CI: 1.20, 1.47) males were more likely not wearing a helmet when biking than females (31). The results from Winnipeg also reported that HP in males (18.9%) was significantly lower than females (26.3%) (p-value<0.0001) (32).

Companionship: The results of an Edmonton survey demonstrated that not having a companion increased the odds of not wearing a helmet in children (OR=1.75; 95% CI: 1.27, 2.41) and adolescents (OR=1.31; 95% CI: 1.06, 1.62) (31). In Winnipeg, riding with adults was accompanied by greater helmet use in those 8-11, 12-15, and 16-19 years old (32).

Income: In subgroup analysis of the study in Winnipeg, it was demonstrated that living in low-income neighbourhoods was accompanied by lower helmet use in children <18 and adults>19 years old (32).

Urban/rural: In the Edmonton study, living in urban areas was accompanied by lower helmet use in children; conversely, urban adolescents had higher levels of helmet use (31). In Winnipeg, riding in rural areas was accompanied by lower helmet use in all age groups except those 12-15 years old (32).

Summary

Review of cross-sectional studies in Canada demonstrated that baseline helmet use (similar to promotional studies) is low, particularly in teenagers. Males tend to wear helmets less often than females and adult companions have a positive influence on younger age group for helmet use.

Main conclusions for the extent of bicycle helmet use in Canada

Overall, the evidence in Canada suggests that helmet use is low before implementing helmet legislation or promotional activities. These studies have demonstrated that helmet use among bicyclists would increase temporarily after educational or community-wide incentive programs; however, legislation caused a more sustained and appreciable increase in helmet use in associated communities, particularly among the target age groups. These studies revealed also that helmet use varies among both sexes after promotional programs or legislation; in most of the studies females were more likely to wear helmets than males either in pre- or post-intervention. HP among bicyclists in high income areas almost always are greater than mid- or low- income areas; highlighting the important role of family income in response to public safety programs. Moreover, companionship has demonstrated to have a positive influence on child bicyclists to wear helmet, particularly when riding with a helmeted peer or adult.

1. Baseline helmet use in Canada, before any promotional activity or helmet legislation, varied widely (1 to 75%);
2. Helmet use gradually increased in some jurisdictions with promotional activities; however, remained less than 50% in most cases;
3. After helmet legislation studies demonstrated that helmet use increased appreciably up to 80% among target age groups.

Important questions that remain to be answered

Alberta implemented helmet legislation in 2002 to increase HP among target age groups (<18). The aim of this study is to examining the trends of HP pre- to post-legislation in Alberta. The results of this study should provide a better understanding of community response to legislative interventions and also important factors associated with any changes in HP in Alberta. The main questions to be answered are including:

1. What is the trend of helmet use in Alberta pre- to post-legislation targeting children and adolescents under the age of 18?
2. Are there differences in helmet use between those age groups affected by legislation compared with those age groups not affected?
3. Is there any carry over effect with respect to helmet wearing between targeted and non-targeted age groups following legislation?

2.5 Systematic review of bicycle helmet legislation

Our research group conducted a systematic review assessing the effectiveness of bicycle helmet legislation to increase helmet use (36). Included studies were required to be community-based and use one of the following designs: cohort studies, controlled before/after studies, interrupted time series studies, or non-equivalent controlled group studies. No restriction for age, sex, or the extent of coverage of helmet legislation was applied. A thorough literature search was performed using electronic databases along with other sources such as grey literature, reviewing reference lists, and contact with the authors of unpublished work found through the review process. Two reviewers independently selected studies based on the inclusion/exclusion criteria and extracted data from included studies (36).

Twelve studies from Australia (n=1), Canada (n=4), New Zealand (n=1), and the United States (n=6) met inclusion criteria and the results from each were extracted. The pre-legislation rate of helmet use varied between 4% and 59% and this range after legislation was 37% to 91%. After introduction of helmet legislation, one study demonstrated less than a 10% increase in helmet wearing proportions while four studies reported a 10%-30% increase and seven studies reported an increase of more than 30% (36).

Collectively, there were 47,417 observations from ten observational before/after studies and 22,193 observations from two non-equivalent control group studies. Pooled estimates from all included studies demonstrated that helmet use was more than four times greater following helmet legislation (OR: 4.60; 95% CI: 2.87 to 7.36). Considering the high degree of heterogeneity (I^2 = 99%) among included studies, we performed subgroup analysis based on methods of the studies. The subgroup results showed that studies with before-after methods presented a smaller effect size (OR: 4.13; 95% CI: 2.45 to 6.97) than the non-equivalent control groups designs (OR: 7.8; 95% CI: 6.45 to 9.44). No clear differences were found among communities with legislation targeting children < 16 (OR: 4.22; 95% CI: 2.03 to 8.76) and those targeting all-age cyclists (OR: 5.35; 95% CI: 2.74 to 10.47) (36). Sex was not shown to be an influential factor for the effect of helmet legislation on the prevalence of helmet use (OR: 5.27; 95% CI: 4.20 to 6.62 for men vs OR: 5.61; 95% CI: 4.90 to 6.42 for women). The relationship between the OR of individual studies and the corresponding baseline proportion of helmet use demonstrated a negative, although not statistically significant, trend (r = -0.51; p = 0.11). This sub-group analysis implies that higher baseline proportions of helmet use may be associated with smaller subsequent intervention effectiveness.

Main conclusions from this review

1. Based on available data it appears that any legislation will increase the use of bicycle helmets;
2. The effectiveness of legislation varies among different jurisdictions; the larger effect sizes were observed in studies with lower baseline rates of helmet use;
3. The larger effect estimates were generated from studies with a smaller sample size.

Important questions that remain to be answered

1. What is the relationship between helmet legislation and exposure to cycling after implementing helmet legislation?
2. Is there any association between bicycle helmet legislation and the incidence of bicycle-related head injuries?

2.6 Methodological concerns for community-based interventional studies

All preceding studies examining the effect of promotional and legislative interventions on bicycle helmet use were either pre/post (repeated cross-sectional) or non-equivalent control group (concurrent cross-sectional) study designs. While these two methods are accepted and feasible quasi-experimental studies for examining community interventional programs, they are susceptible to internal and external validity issues. Internal validity can be jeopardized in these designs by selection and information biases and also uncontrolled confounding. External validity can be jeopardized in these designs by studying a selected or small group in the target population and not providing equal opportunity to all participants to be evaluated for the exposure and outcome status under examination (37, 38).

Level of selection bias in such studies depends on how similar the two comparison groups are to one another. In the before/after studies, the sample population are usually exactly the same although some characteristics can change over the long term. Conversely, in non-equivalent group study designs, two samples may have some inherent similarities or differences. The more differences exist between the two, the more selection bias might threaten the validity of the results (37, 38).

Low accuracy or systematic errors in data collection (information bias) can be another source of bias in these two methods of study. This bias can be minimized during the data collection process through improving data recording and management. Using standard data collection form (e.g., moving from subjective interpretation to objective data recording) and comprehensive educational program for data collectors would help to minimize selection bias. Equalizing circumstance related to intervention and outcome among exposed and unexposed groups (e.g., time and place of data collection, environmental and societal factors) are critical to minimize other biases.

The results of such community-based interventional studies can also be distorted by known and unknown confounding factors. Our literature review revealed that different studies have attempted to control for known confounding factors including sex, income level, companionship, and rural/urban residence in their design and statistical analyses. Due to the nature of such studies, however, unknown confounding factors are often not equally distributed between intervention/control and helmeted/not-helmeted bicyclists.

External validity or representativeness of the community-based interventional studies can be improved by equal distribution of data collection to the entire community. If possible random sampling of the unit of population would be additional methodology strength for generalizability of the results from the population that are sampled (39).

Summary

Bicycling is a popular mode of transportation and recreation in Canada. Children and youth most often bicycle as a recreation activity; however, adults use it as transportation ***and*** recreational activities. Interaction between cyclists and motorized vehicles has been recognized as a frequent contributor to bicycle-related injuries and a frequent factor involved in bicycle-related presentations to EDs and hospitalization. Limb injuries with or without bone fractures are the most common injuries among bicyclists seen in the ED; however, head injuries are the most serious injuries that may cause disability and even death. It has been widely accepted that bicycle helmets can prevent or at least minimize serious head injuries.

Different strategies have been implemented in an effort to increase helmet use in various communities. Most jurisdictions started with promotional activities such as education in schools, media campaigns, community awareness, and helmet subsidies for encouraging people to buy and use bicycle helmet especially among younger age groups. Other jurisdictions started with or added legislation to the promotional activities aiming at higher percentage of helmet use by bicyclists. Both promotional activities and legislation have been demonstrated to be effective in increasing the prevalence of helmet use among all age groups, particularly children; however, legislation has been shown to be more effective and more sustainable strategy than promotional activities.

Community-based interventional studies are susceptible to internal and external flaws that can be minimized through appropriate selection of unit of data collection in the original population (external validity), appropriate and standard method in: conduction of the study, collection and analysis of the data, and finally interpretation of the results.

Table 2-1 Summary on bicycle-related injury and hospitalization in Canada

Study	Year of study	Study design	Data source	Age (years)	Mal e	Bicycle injuries	Head injury	Hospital stay (days)	Died
CIHI [a], 2006	FY 1994-2003 [b]	Survey (NTR MDSd)	Head injury hospitalization in Canada: a decade of change	Mean=25 (SD=19)	79%	2%	24%	7 (SD=21)	n =19 ; 2.3%
CIHI [a], 2006	FY 2004-05[b]	Survey (NTR CDSc)	Sport & recreation major injuries in participating hospitals in Canada	Mean=32	84%	27 %	NR f	14	16%
CIHI [a], 2004	FY 2001-02	Survey (NTR MDSd)	All injury hospitalization in Canada	NR	NR	2%	NR	NR	1%
Macpherson, 2004	FY 1994-98	Survey (NTR MDSd)	All injury hospitalization among children in Canada by urban/rural	Range= 5-19	NR	NR	NR	NR	NR
Macpherson, 2002	FY 1994-98	Survey (NTR MDSd)	All injury hospitalization among children in Canada	Range= 5-19	73%	n =9650	n=3426; 35%	Mean=3. 7	n=58; 0.6%
Linn, 1998	1991-95	Survey (CHIRPPe)	All completed surveys in British Columbia (BC) Children's Hospital, BC, Canada	Range=1-19; mean=8.9	71%	n=1462; 4%	n=568; 38.9%	NR	n=1; 0.1%
Finvers, 1996	April 1991 to September 1993	Survey (CHIRPPe)	All completed surveys in Alberta Children's Hospital, Calgary, Alberta Canada	Range=3-16	64%	n=699	38%	NR	NR

Rowe, 1995	1986-91	Case series	All bicyclists deaths recorded in Coroner's Information System, Ontario Canada	Mean=26	78%	n=212	75%	NR	100%
Cushman, 1990	May to September 1988	Survey	All bicycle-related injuries in Children's Hospital of Eastern Ontario	Mean=9.4; range 1-17	70%	n=738	n=182; 25%	9.4	NR
Guichon, 1975	July 1972 to June 1973	Survey	All bicycle-associated injuries in three major hospital in Calgary, Alberta	Range=0-66	NR	n=107	N=73; 67%	Mean=3.6	N=4; 4%

a- Canadian Institute for Health Information; b- Fiscal year started from 1st of April to 31st of March in the next year; c- National trauma registry comprehensive data seta from 46 participating facilities in 8 provinces of Canada; d- National trauma registry minimal data set across all acute care facilities in Canada (a subset of hospital morbidity database); e- Canadian Hospitals Injury Reporting and Prevention Program is a national emergency department based injury surveillance program; f- NR=not reported; g- n=frequency

Table 2-2 Summary of bicycle helmet use and helmet legislation in Canada

Study	Study period; province	Study design	Legislation year & target age group	observation sites (n)	Total observation (n)	Helmet use change by age group in %	Helmet use change by sex in %	Helmet use change by location in %
Hagel, 2006	2004 (June 1st to September 30th); Alberta	Repeated cross-sectional	2002; <18 years old	School, college, park, cycling path, commuter R (road), and residential area (274)	271	(2000→2004) <13=44 →100 13-17=17 →75 18+=49 →48	(2000→2004) M=38→48 F=54→67	(2000→2004) College=36→31 Park=63→59 Cycling path=52→57 commuter R=37→53 Residential=35→62
Macpherson, 2006	1995-2001; Ontario	Repeated cross-sectional	1995; <18 years old	School, park, major intersections, residential area (111)	4999	Only 5-14: (1995)=45 (1997)=68 (2001)=46	NR	NR
Parkin, 2003	1990-1997 (April to October); Ontario	Repeated cross-sectional	1995; <18 years old	School, park, major intersections, residential area (111)	9768	Only 5-14: (1990)=4 (1991)=16 (1992)=25 (1993)=45 (1994)=44 (1995)=44 (1996)=68 (1997)=66	Overall for 8 years: M=33 F=47	NR
LeBlanc, 2002	1995-1999; Nova Scotia	Repeated cross-sectional	1997: all ages	Commuter R, residential R, recreational area	(95/96)= 1494 (1997)= 636 (98/99)= 672	(95/96): child=49; adolescent=29; adult=36 (1997): child=95; adolescents=68; adult=75 (98/99): child=84; adolescents=70; adult=86	(95/96) M=34; F=42 (1997) M=72; F=85 (98/99) M=84; F=84	NR
Foss, 2000	1995 to 1999 (July-August); British Columbia	Repeated cross-sectional	1996: all ages	Commuter R, recreational, neighborhood, community (116)	(1995)=3950 (2000)= 4246	(1995→1999): 1-5 =60→78 6-15= 35→61 16-30=47→69 31-50 =52→75 51+=41→71	(1995→1999) M=44→68 F=50→76	(1995→1999) Commuter =60→75 recreational =48→74 neighbourhood=39→72 community =39→60

Table 2-3 Summary of bicycle helmet use before and after promotional activities in Canada

Study	Study period; province	Study design	Promotional activity	observation sites (n)	Total observation (n)	Helmet use by age group in % a	Helmet use by sex in %	Helmet use change by location in %
Farley, 1996	1990-1993; Quebec	Quasi-experimental with non-random control group	Poster, pamphlet, educational guide, coupon, and free helmet	School, path/lane, local route (NR)	8112	(1991→1993) (study g.) 5-8=19→48 9-12=7→24 (control g.) 5-8=8→21 9-12=2→12	(1991→1993) (study g.) M=8→29 F=12→39 (control g.) M=4→13 F=4→18	(1991→1993) (study g.) school=9→27 path/lane=28→42 local st.= 5→33 (control g.) school=3→15 path/lane=8→30 local st.= 4→12
Parkin, 1995	June to October 1992; Ontario	Non-equivalent control group	School-based education, helmet subsidy	School, park, major intersection, residential (NR)	1861	Only 5-14: (1990)=3 (1991)=16 (1992)=28	M=16 F=30	(1990→1992) All schools=3→27 NR for other locations
Morris, 1994	(May & October) 1990-1991; Ontario	Survey	Media, education in community and school, helmet subsidy	School, college (10)	851	(1990)=5 (1991)=15	(1990) M=6; F=4 (1991) M=11; F=30	(1991) Elementary=11 secondary=5 college=16

Parkin, 1993	June to October 1991; Ontario	Non-equivalent control group	School-based education, helmet subsidy	School, park, Major intersection, residential (NR)	1885	Only 5-14 (1990→1991) H_income [b] I: 4→36 [c] C:4→15 [d] L_income [b] I: 1→7 [c] C:3→13 [d]	(1990→1991) H_income [b] M=20 F=26 L_income [b] M=8 F=21	(1990→1991) school yard H_income [b] I: 4→48 [c] C:5→34 [d] L_income [b] I: 4→8 [c] C:3→14 [d]
Cushman, 1992	September 1988 & 1991; Ontario	Repeated survey	Media, education, helmet subsidy	School, recreational, commuter	(1988) 1963 (1991) 3253	All age (1988→1991) 11→32	NR	(1988→1991) school=2→21 recreation=14→31 commuter= 18→45

a- Numbers were rounded; b- High income area versus low income area; c- intervention group; d- control group

Table 2-4 Summary of cross-sectional bicycle helmet studies in Canada

Study	Study period; province	Study design	observation sites (n)	Total observation (n)	Helmet use by age group in % [a]	Helmet use by sex in %	Helmet use change by location in %
Nykolyshin, 2003	2000 (June 1st to September 30th); Alberta	Cross-sectional observational survey	College, park, cycling path, commuter R, and residential area (22)	4141	<13=75 13-17=29 18+=52	As baseline: M=50 F=64	School:64 College=37 Park=58 Cycling path=53 commuter R=44 Residential=45
Harlos, 1999	May 28th to August 20th 1996; Manitoba	Cross-sectional observational survey	School, park, major intersection (220)	2629	<8=44 8-11=17 12-15=7 16-19=8 >19=24	M=19 F=26	NR
Rowe, 1995	August 1st to September 15th 1992; Ontario	Cross-sectional observational survey	Residential & main street (28)	1134	All ages: 20	NR	NR
Cushman, 1990	September 1988; Ontario	Cross-sectional observational survey	School, recreational, commuter	1963	All ages 11	NR	school=2 recreation=14 commuter= 18

a- Numbers were rounded

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3 CHAPTER 3

BICYCLE HELMET USE FOUR YEARS AFTER THE INTRODUCTION OF HELMET LEGISLATION IN ALBERTA, CANADA (1)

Abstract

Background: Bicycle helmets reduce fatal and non-fatal head and face injuries. This study evaluated the effect of mandatory bicycle helmet legislation targeted at those less than 18 years old on helmet use for all ages in Alberta.

Methods: Two comparable studies were conducted two years before and four years after the introduction of helmet legislation in Alberta in 2002. Bicyclists were observed in randomly selected sites in Calgary and Edmonton and eight smaller communities from June to October. Helmet wearing and rider characteristics were recorded by trained observers. Poisson regression adjusting for clustering by site was used to obtain helmet prevalence (HP) and prevalence ratio (PR) (2006 vs. 2000) estimates.

Results: There were 4,002 bicyclists observed in 2000 and 5365 in 2006. Overall, HP changed from 75% to 92% among children, 30% to 63% among adolescents and 52% to 55% among adults. Controlling for city, location, companionship, neighborhood age proportion <18, socioeconomic status, and weather conditions, helmet use increased 29% among children (PR=1.29; 95% CI: 1.20 to 1.39), over 2-fold among adolescents (PR 2.12; 95% CI: 1.75 to 2.56), and 14% among adults: (PR=1.14; CI: 1.02 to 1.27).

Conclusions: Bicycle helmet legislation was associated with a greater increase in helmet use among the target age group (<18). Though HP increased over 2-fold among adolescents to an estimated 63% in 2006, this percentage was approximately 30% lower than among children <13.

3.1 Introduction

3.1.1 Background

Based on a Canadian study among 14 hospitals in 2006, of the 1,850,948 recorded injuries among patients aged one year and older, there were 3993 bicyclist injuries (3.4%), of which 11% were admitted to hospital; 1.5 times the hospitalization rate of other injuries (7%) (2). In Alberta five bicyclists were killed and 538 were injured in 2008, based on police traffic collision reports (3). Young bicyclists (10-14 and 15-19) were most frequently involved in bicycle crashes (3.7 and 3.3 per 10,000 population, respectively) (3). Bicycle-related head injuries caused nearly 15% of all pediatric trauma deaths in Ontario in 1993 (4). Approximately 20% of cyclist emergency department visits are for head injuries (5) though head injuries make up 75% of bicyclists fatalities (6). Based on a Cochrane review, helmets provide 63% to 88% reduction in the risk of head, brain and severe brain injury and 65% reduction in risk of upper and mid facial injury for bicyclists of all ages (7). Results of another systematic review revealed that helmets reduce the risk of head and brain injury between 58% and 73% and facial injuries by 47% (8).

3.1.2 Interventional studies

Promotional activities such as education, media campaigns, and community incentives have been used to increase bicycle helmet use (9-13). Some jurisdictions have implemented helmet legislation for all ages (14) or bicyclists under 18 years of age (15). Systematic reviews have shown that helmet legislation increases use from 5% to 54% (16) and decreases head injury rates; although, there were very few high quality studies evaluating head injuries after bicycle helmet legislation (17). Few studies have examined trends in bicycle helmet use for age groups not covered by mandatory use legislation; an approach that may account for temporal trends in helmet use independent of helmet laws (18).

Based on the Highway Traffic Bicycle Safety Helmet Amendment Act, as of May 1st, 2002, all cyclists under age 18 in Alberta were required to wear approved helmets. The penalty for not wearing an approved helmet is $69 (19). A comprehensive study in Alberta in 2000 showed that the prevalence of helmet use was 55% among all age groups (20). Two years after legislation in 2004, a study in Edmonton, Alberta revealed that the prevalence of helmet use among bicyclists <18 years old increased from 28% to 83% with little associated change for adults 18 and older (18).

3.1.3 Aim

The present study was designed to evaluate the HP rate among all age groups four years after the implementation of helmet legislation in Alberta requiring only children and adolescents to wear bicycle helmets. This study used direct observation for collecting data regarding cyclist helmet use and basic personal characteristics.

3.2 Methods

3.2.1 Study population

To compare bicycle helmet use before and after legislation in Alberta, we employed the same methodology as the 2000 project (20). Direct observations of cyclists were made in Alberta's two largest cities (Calgary and Edmonton with populations of 1,079,310 and1,034,945, respectively) as well as eight surrounding communities within 50 KM of either city center, each with a population exceeding 9500 (e.g., Airdrie, Cochrane, Fort Saskatchewan, Leduc, Okotoks, Sherwood Park, Spruce Grove, and St. Albert) (20). St. Albert was excluded from our analysis because they introduced a new municipal by-law in 2006 mandating bicyclists of all ages wear helmet and this local legislation was different from the rest of the province.

3.2.2 Helmet use data

We selected our observation sites from a pool of potential sites from six strata of residential areas, schools, colleges, parks, commuter routes, and designated cycling paths in both 2000 and 2006. In 2006 we added 236 new sites (110 in Calgary, 87 in Edmonton, and 39 in other communities) to our sample based on random selection from all new potential sites because of socio-demographic changes which happened over the study period. Therefore, a total 506 sites were visited for the first time or revisited (246 in Calgary, 191 in Edmonton, and 69 in other communities) in 2006.

Observation days were scheduled for each observer and time of observation was one hour at schools, parks, and campuses and two hours at roadways, cycling paths and residential areas. If no more than 3 cyclists were observed within 30 minutes at a site, observations were discontinued. Cyclists who used tricycles or who were walking with their bikes were excluded, but information on those riding with training wheels was included. Observations at school sites were performed during weekdays in the morning and afternoon based on student arrival and departure. Observations at parks and residential areas were conducted during the week and on weekends. Observation start times at non-school sites were 7:00, 9:00, 11:00, 13:00, 17:00, or 19:00. All cyclists within the visual range of the observer were eligible for inclusion. For those cyclists riding in a group, observers alternated between selecting the first, second and third front-most positions with others considered as accompanying riders.

3.2.3 Geographical data

We obtained weather conditions for sites at the time of observation through Environment Canada (21). Average temperature for each observation time and weather conditions (wet=any rain≥1 mm; dry=no rain or rain<1 mm) were available from the archived data tables.

Population demographics and estimated socio-economic status (SES) of the observation sites were obtained at the dissemination area (DA) level from Statistics Canada (SC) (22, 23). DAs are small areas made up of 400 to 700 persons that cover the entire country of Canada and are the smallest geographical unit for which census data are available (24). There is evidence for the use of area census based SES data as a proxy for individual SES data in the Canadian population (25) and has been used in another study evaluating urban/rural variation in children's bicycle-related injuries (26). We estimated the SES of the population using household annual income (in quintiles of median income of our sample frame) and low income families (five-categories of percentage of low income families in each DA in our sample frame). As the proportion of those under the age of 18 may increase the number of bicyclists in neighborhoods, we used census data to calculate the proportion of potential bicyclists <18 years old in each DA in 2000 and 2006 and developed quintiles of the distribution of our sample frame to control for younger versus older populations in our analysis.

3.2.4 Analysis

Data were analyzed by Stata/SE version 10 (27). The change in HP among observed bicyclists was compared between 2000 and 2006 stratified by age group, sex, city, location type, ridership, quintiles of DA percent under age 18, SES by quintile of household median annual income in Canadian dollars and percent low income in the neighborhood in 5 categories, weather conditions, and temperature (See Tables). We performed a reliability sub-study examining the information by observers at a limited number of sites.

Given that our outcome was a count variable (number of bicyclists who wore a helmet), we used Poisson regression analysis with the robust (sandwich or Huber-White) estimator to correct the standard error of the estimates for clustering by site (18, 28). From the Poisson regression model, we can obtain HP (%, with 95% CIs) and prevalence ratio estimates (PRs, with 95% CI) comparing the post- to the pre-legislation period (29, 30). Prevalence rates and ratios using this approach are more conservative estimates compared with odds and odds ratios from a logistic regression analysis. If the risk (or prevalence in this situation) is low (e.g., less than 10%), then the odds ratio will approximate the risk (prevalence) ratio; otherwise odds ratios will overestimate the risk or prevalence ratio (31).

As 'age' was previously shown to be an effect modifier for the relationship between 'year of observation' and HP (18), we stratified our analysis by three age groups: children (<13), adolescents (13-17) and adults (18+).

To account for missing values, we used multiple imputation (32). We then performed multiple regression analysis using the imputed file to compare the change in helmet use between 2000 and 2006 among the three age groups as was done in the complete case analysis.

3.3 Results

3.3.1 Sample characteristics

To compare prevalence of bicycle helmet use in 2006 to 2000 and to keep the principle of random selection of sites in 2006, we randomly selected 269 sites (Calgary 125, Edmonton 103, Other 41) from a pool of all eligible sites (new in 2006 and all sites from 2000) and performed the univariate and multiple regression analysis. Because the results based on only the revisited sites were similar to the new random sample in 2006, we elected to present only the random sample results (revisit site sample results available upon request). We had 13 sites in 2000 and 67 sites in 2006 without any observations.

3.3.2 Data reliability

Consistency of the cyclist information was evaluated by comparing data collected among 10 Calgary and 7 Edmonton sites by two independent observers. The discrepancy between observers at the same sites was only 1% for helmet use, 1 to 6% for age, and 0 to 3% for sex and riding companions.

3.3.3 Univariate results

In the two studies, there were 9367 observations in total: 4,002 (42.7%) in 2000 and 5365 (57.3%) in 2006. Overall, HP for children was 75% in 2000 and increased to 92% in 2006 (PR=1.22; 95% CI: 1.14, 1.31). Similarly, HP for adolescents was 30% in 2000 and increased to 63% in 2006 (PR=2.12; 95% CI: 1.71, 2.62). Finally, adult HP was 52% in 2000 and there was a non-significant increase to 55% in 2006 (PR=1.07; 95% CI: 0.96, 1.19) (Table 3-1, 3-2, 2-3). Limited changes were observed in HP between 2000 and 2006 based on other population characteristics, regardless of age group (Tables 3-1, 3-2, 2-3).

3.3.4 Multiple Poisson regression results

In the multiple Poisson regression analysis, controlling for all other variables in the model, the effect of year was statistically significant for all three age groups. Child helmet use was estimated to increase 29% (PR=1.29; 95% CI: 1.20, 1.39). Adolescent helmet use increased more than 2-fold from 2000 to 2006 (PR=2.12; 95% CI: 1.75, 2.56), while adult helmet use increased 14% (PR=1.14; 95% CI: 1.02, 1.27) (Table 3-4).

Controlling for other factors, female children (PR=1.06; 95% CI: 1.02, 1.10), and adults (PR=1.25; 95% CI: 1.16, 1.34) were more likely to wear helmets than males by 6 and 25%, respectively, but no difference between males and females in adolescents (PR=1.12; 95% CI: 0.98, 1.28) was detected (Table 3-4). Child bicyclists in Edmonton and other smaller communities were less likely to wear helmets than bicyclists in Calgary. Adult cyclists in Edmonton were also less likely to wear helmets than cyclists in Calgary (Table 3-4).

Adolescents were more likely to wear helmets at school sites compared with residential areas (PR=1.42; 95% CI: 1.11, 1.82). Adults were more likely to wear helmets in parks (PR=1.25; 95% CI: 1.09, 1.44) and on cycling paths (PR=1.20; 95% CI: 1.03, 1.40) compared with residential areas (Table 3-4).

Children, adolescents and adults were more likely to wear helmets if riding with at least one other helmeted person compared with riding alone. However, all three age groups were less likely to wear helmets if riding with others who did not wear helmets compared with those riding alone (Table 3-4). Compared with the lowest quintile, HP was higher among adults in the higher (3^{rd}, 4^{th}) income quintiles. The proportion of children <18, proportion of low income families, weather conditions and temperature did not appear to be related to HP (Table 3-4).

3.3.5 Missing data analysis

The frequency of missing data was generally low: 1.33% for age (n=129), 1.15% for sex (n=112), 0.02% for helmet use by bicyclists (n=2), 0.70% for riding companions (n=68), 0.57% for neighborhood age proportion <18 (n=55), 2.11% for median family income (n=205), and 0.57% for neighborhood low income percentage (n=55). Other variables did not have missing data.

In the multiple Poisson regression analysis using the dataset with imputed missing values, the effect of year on HP was consistent with the complete case analysis. Child, adolescent, and adult helmet use was estimated to increase by 28% (PR=1.28; 95% CI: 1.19, 1.37), 111% (PR=2.11; 95% CI: 1.75, 2.56), and 12% (PR=1.12; 95% CI: 1.01, 1.25), respectively.

3.4 Discussion

3.4.1 Findings

We replicated our 2000 provincial study in 2006. We compared HP between the observations from sites randomly selected in 2000 and the new, randomly selected sites in 2006. We considered the changes in HP between the first and second studies as an indication of the long-term effect of helmet legislation for Albertans.

We comprehensively examined the association between child, adolescent and adult helmet use after four years of bicycle helmet legislation targeting those under age 18. Adolescents demonstrated the greatest increase in helmet use over the study period with children showing a modest increase. There was little change in helmet use among adults. The smaller change among children was likely due to their higher level of use in 2000 (75%) and a potential ceiling effect in 2006 (92%).

The results of our study showed a significant association between legislation and bicyclist helmet use, generally without a concomitant enforcement initiative. Total tickets issued during the six years from 2003 to 2008 were 111 in Calgary and 77 in Edmonton (personal communication with Allison Bouthillier, Traffic Methods Analyst in Edmonton police Service and Allison Miller, Traffic Analyst in Calgary Police Service, both in May 2009).

In Ontario, where helmet legislation was introduced in 1995 for those <18, Macpherson et al. (33) reported that HP among children 5-14 increased from 45% in 1995 to 66% in 1997 (among low, middle, and high income areas). In 2001, HP returned to pre-legislation levels in low (33%) and middle income (50%) areas; however, remained above pre-legislation levels in high income areas (85%). We found that after 4 years of legislation, HP is still high among children (92%) and increased substantially in adolescents (63%); and a smaller change among adults (55%). In our study, we found some evidence of greater HP among adults in higher versus lower neighborhood income quintiles with similar, non-statistically significant trends among adolescents.

Two years after helmet legislation in Alberta, a limited study in Edmonton, Alberta revealed the short term trends in helmet use after legislation (18). In that study, overall HP increased from 43% in 2000 to 53%

in 2004 and the PR with adjustment for covariates significantly increased for those <18 (PR=3.69; 95% CI: 2.65, 5.14) but not for those 18 and older (PR=1.17; 95% CI: 0.95, 1.43). Although this study was conducted only in Edmonton and among those sites with at least 10 riders (22 of 23 eligible) in 2000 excluding schools (18) the trends are similar to our current, more comprehensive provincial study.

A systematic review (SR) of the effects of helmet legislation on bicycle helmet use, including 12 studies and reports, demonstrated increased helmet use (HP rise of 5% to 54% and odds ratios from 1.2 to 22) after the introduction of legislation. The review also showed that the effect of legislation was smaller in areas with a higher baseline helmet use (16). We demonstrated similar results in our study. HP was 30% among adolescents and 75% among children pre-legislation and increased to 63% and 92% post-legislation, respectively.

The results of four cycles of Canadian Community Health Surveys between 2001 and 2007 have shown that helmet use was much higher among provinces with helmet legislation; however, youth cyclists were significantly more likely to wear a helmet if legislation targeted all age groups (34).

In a Cochrane review the authors concluded that bike helmet legislation is effective in increasing helmet use and decreasing head injury (17). That SR examined the jurisdictions which implemented a helmet law for children and used adults as the control group. They concluded that only a few high quality evaluative studies were available; however, bicycle helmet use by children increased significantly following implementation of helmet legislation compared with adults as control groups. They also reported concomitant decreases in head injury rates (17). We similarly demonstrated that helmet use among children and adolescents showed a significant increase 4 years after legislation.

In Alberta the legislation was targeted at children <18, therefore, any change in adult bicyclists (18+) might be considered as non-legislation related temporal effects on bicycle helmet use. The results of this study showed that helmet use among adults was 14% higher post-legislation and that this effect was marginally statistically significant. This supports the hypothesis that the higher prevalence among bicyclists <18 is attributable to helmet legislation.

3.4.2 Limitations

There are some limitations associated with this study. Our observers did not stop bicyclists to obtain demographic information at the selected sites and they used their best estimate for age category, sex and other variables. This data collection approach may include some misclassification; however, we would argue that these errors were likely not systematically related to helmet use or year of the study. Because we compared the change in HP for those <18 affected by the helmet legislation with similar trends in adults, it is unlikely that our results could be explained by a concomitant increase in general traffic safety. There was also likely some non-differential misclassification of neighborhood average annual income as it did not modify the pre- to post-legislation helmet prevalence. These results differ from findings of Parkin et al. who noted a greater increase in the prevalence of helmet use post-legislation among low and middle compared to high SES areas (35).

3.4.3 Strength

Nevertheless, our study had several methodological strengths that should be reported. We directly observed the helmet use and other characteristics of people engaged in bicycling rather than relying on telephone or questionnaire surveys, thereby eliminating response bias (34) or using administrative data, which may be an unreliable source for a focused issue such as helmet use (36). We used pre-legislation observations as a control period in the same population using the same methods to observe bicyclist characteristics. Addressing some methodological concerns identified by others (37) in helmet use studies, we repeated observations at the same time of the day as our pre-legislation study and assessed the effect of legislation over a relatively long follow-up period of four years. To account for any modification of the legislation effect by age, we stratified our analysis into children, adolescents and adults. Using multiple Poisson regression analysis, we adjusted for sex, location of observation, companionship, weather conditions, and temperature. We also controlled for the potential non-independence of bicycle helmet use at particular data collection sites (i.e. clustered data) in the statistical analysis.

In 2006, we revisited all 2000 sites (n=269) except one school that had closed and we took a new random sample of sites. Our results demonstrate little difference in HP between the revisited sites and the new random sample, which suggests our results are robust (re-visited sample comparisons were not shown, but are available from the authors upon request).

In our study there was consistency between observers in recording bicyclist information as demonstrated in our reliability sub-study. Discrepancy did not exceed 6% for any inter-observer comparisons. We also imputed missing data and re-ran the analysis for each age group with no substantial influence on the effect estimates, which is another indicator of the robustness of our results.

3.5 Conclusion

Implementation of bicycle helmet legislation was associated with an increase in helmet use among those under the age of 18 targeted by the law. The minimal change in helmet use among adults suggests the changes seen in children and adolescents were a result of the legislation and unlikely due to non-legislation related changes in helmet use.

Table 3-1 Prevalence of helmet use and prevalence ratio 2006 versus 2000 for children (<13) in Alberta, Canada

Variable	2000		2006		PR (95% CI) cluster adjusted [a]
	n/N	% (95% CI)	n/N	% (95% CI)	
Overall	883/1174	75 (71-80)	564/614	92 (89-95)	1.22* (1.14 to 1.31)
Gender					
Male	552/769	72 (67-77)	393/433	91 (87-95)	1.26* (1.17 to 1.36)
Female	316/389	81 (76-87)	170/180	94 (91-98)	1.16* (1.07 to 1.26)
Missing [b]	15/16		1/1		
City					
Calgary	542/623	87 (85-89)	205/223	92 (87-97)	1.06 (0.99 to 1.12)
Edmonton	236/415	57 (49-66)	249/273	91 (87-95)	1.60* (1.38 to 1.86)
Other [c]	105/136	77 (71-84)	110/118	93 (85-100)	1.21* (1.08 to 1.36)
Location					
Residential	75/108	69 (58-83)	93/102	91 (85-98)	1.31* (1.08 to 1.60)
School	669/853	78 (73-84)	329/355	93 (88-97)	1.18* (1.09 to 1.28)
Campus	1/2	50 (7-100) ‡	6/8	75 (51-100)	1.50 (0.27 to 8.32)
Park	51/69	74 (62-88)	48/55	87 (78-97)	1.18 (0.97 to 1.44)
Cycling path	41/54	76 (64-90)	16/18	89 (76-100)	1.11 (0.89 to 1.38)
Commuter route	46/88	52 (37-73)	72/76	95 (89-100)	1.96* (1.44 to 2.68)
Companion helmet use					
Alone	586/809	72 (67-78)	415/452	92 (88-95)	1.27* (1.17 to 1.37)
Riding with ≥ 1 at least one helmeted [d]	244/262	93 (90-96)	133/136	98 (95-100)	1.05* (1.00 to 1.10)
Riding with ≥ 1 none of them helmeted [d]	44/92	48 (37-62)	8/17	47 (26-84)	0.98 (0.52 to 1.85)
Missing	9/11		8/9		
Neighborhood age proportion <18 [e]					
1st quintile	49/62	79 (73-85)	24/35	69 (50-95)	0.87 (0.63 to 1.19)
2nd quintile	176/225	78 (70-87)	44/48	92 (84-100)	1.17* (1.02 to 1.35)
3rd quintile	196/252	78 (70-86)	120/128	94 (89-99)	1.21* (1.07 to 1.35)
4th quintile	179/249	72 (61-86)	195/208	94 (89-99)	1.30* (1.08 to 1.57)
5th quintile	274/375	73 (65-82)	181/195	93 (88-98)	1.27* (1.12 to 1.44)
Missing	9/11				
Income [f]					
1st quintile	140/194	72 (59-88)	95/113	84 (76-93)	1.16 (0.94 to 1.45)
2nd quintile	128/208	62 (52-73)	106/121	88 (81-95)	1.42* (1.18 to 1.72)
3rd quintile	240/304	79 (70-89)	129/139	93 (87-99)	1.18* (1.03 to 1.34)
4th quintile	197/254	78 (70-86)	80/85	94 (89-99)	1.21* (1.08 to 1.37)
5th quintile	169/203	83 (78-89)	152/154	99 (97-100)	1.19* (1.10 to 1.28)
Missing	9/11		2/2		
Low income family in neighborhood (%) [g]					
0 to 0.1	534/682	78 (73-84)	114/121	94 (88-100)	1.20* (1.10 to 1.32)
0.2 to 10.0	68/104	65 (53-81)	331/353	94 (90-97)	1.43* (1.16 to 1.77)
10.1 to 20.0	134/173	77 (67-89)	53/64	83 (73-94)	1.07 (0.88 to 1.29)
20.1 to 30.0	55/84	65 (51-83)	42/47	89 (82-97)	1.36* (1.06 to 1.75)
30.1 to 100	83/120	69 (50-95)	24/29	83 (64-100)	1.20 (0.82 to 1.76)
Missing	9/11				
Weather condition [h]					
Dry	785/1028	76 (72-81)	447/483	93 (89-96)	1.21* (1.13 to 1.30)
Wet	98/146	67 (52-86)	117/131	89 (84-95)	1.33* (1.03 to 1.72)
Temperature [i]					
High	271/379	72 (64-79)	138/162	85 (79-92)	1.19* (1.05 to 1.35)
Moderate	450/607	74 (67-82)	405/430	94 (91-97)	1.27* (1.15 to 1.40)
Low	162/188	86 (82-91)	21/22	95 (85-100)	1.11 (0.99 to 1.24)

a- Prevalence ratio of helmet use 2006 versus 2000
b- Missing was not listed if there was no missing
c- Other smaller communities included Airdrie, Cochrane, Fort Saskatchewan, Leduc, Okotoks, Sherwood Park, and Spruce Grove
d- Riding with at least one adult or child companion
e- Based on census data and proportion of male and female <18 years of age in the same dissemination area [quintile 2000: (0-0.11, 0.12-0.19, 0.20-0.24, 0.25-0.28, 0.29-1.00); for 2006: (0-0.10, 0.11-0.17, 0.18-0.20, 0.21-0.25, 0.26-1.00)]
f- Based on census data on median income level for each dissemination area in Alberta for the year of observation [quintile 2000: ($0.0-$42644, $42645-$54016, $54017-$65275, $65276-$82701, $82702-$1000000); for 2006: ($0.0-$56947, $56948-$71124, $71125- $88420, $88421-$111020, $111021-$1000000)]
g- Based on census data on incidence of low income economic family percentage (%) in each dissemination area (0/0.1%=1, 0.2/10.0%=2, 10.1/20.0%=3, 20.1/30.0%=4, 30.1/100%=5)
h- Any rain ≥1 mm was considered wet otherwise defined as dry based on Environments Canada National Climate Archive Data
i- Low<10, Moderate=10-20, and High>20 degrees Celsius
* Statistically significant; (‡) % greater than 100 for upper limit was cut off to 100

Table 3-2 Prevalence of helmet use and prevalence ratio 2006 versus 2000 for adolescents (13-17) in Alberta, Canada

Variable	2000		2006		PR (95% CI) cluster adjusted [a]
	n/N	% (95% CI)	n/N	% (95% CI)	
Overall	190/635	30 (25-36)	292/461	63 (55-73)	2.12* (1.71 to 2.62)
Gender					
Male	128/452	28 (23-35)	229/377	61 (53-70)	2.14* (1.70 to 2.70)
Female	62/181	34 (27-43)	62/83	75 (63-89)	2.18* (1.64 to 2.89)
Missing [b]	0/2		1/1		
City					
Calgary	99/256	39 (31-49)	112/198	57 (48-67)	1.46* (1.11 to 1.94)
Edmonton	68/304	22 (17-29)	125/187	67 (53-85)	3.00* (2.28 to 3.93)
Other [c]	23/75	31 (19-50)	55/76	72 (57-91)	2.36* (1.39 to 4.01)
Location					
Residential	17/90	19 (12-29)	61/111	55 (41-73)	2.87* (1.74 to 4.75)
School	118/308	38 (31-48)	141/202	70 (57-85)	1.82* (1.36 to 2.43)
Campus	1/7	14 (02-99)	5/8	63 (28-100)‡	5.63* (1.40 to 22.5)
Park	11/46	24 (14-41)	15/27	56 (42-74)	2.32* (1.30 to 4.17)
Cycling path	19/83	23 (15-35)	20/30	67 (49-90)	2.81* (1.69 to 4.67)
Commuter route	24/101	24 (16-36)	50/83	60 (49-74)	2.68* (1.72 to 4.18)
Companion helmet use [d]					
Alone	132/493	27 (22-33)	243/384	63 (55-73)	2.36* (1.89 to 2.96)
Riding with ≥ 1 at least one helmeted	53/67	79 (69-90)	44/48	92 (85-99)	1.16 (0.99 to 1.35)
Riding with ≥ 1 none of them helmeted	3/66	05 (01-19)	3/21	14 (05-43)	3.14 (0.53 to 18.6)
Missing	2/9		2/8		
Neighborhood age proportion <18 [e]					
1st quintile	19/68	28 (18-44)	14/29	48 (32-72)	1.73 (0.97 to 3.08)
2nd quintile	38/120	32 (22-45)	21/39	54 (40-72)	1.70* (1.09 to 2.65)
3rd quintile	49/165	30 (20-44)	78/124	63 (47-84)	2.12* (1.30 to 3.46)
4th quintile	52/147	35 (25-49)	36/71	51 (39-66)	1.43 (0.94 to 2.19)
5th quintile	31/124	25 (16-38)	143/198	72 (61-85)	2.89* (1.86 to 4.50)
Missing	1/11				
Income [f]					
1st quintile	49/159	31 (20-47)	42/82	51 (36-72)	1.66 (0.96 to 2.88)
2nd quintile	34/133	26 (17-39)	31/72	43 (29-64)	1.68 (0.94 to 3.03)
3rd quintile	38/121	31 (23-43)	65/90	72 (58-89)	2.30* (1.57 to 3.36)
4th quintile	36/113	32 (20-52)	95/131	73 (57-92)	2.28* (1.33 to 3.89)
5th quintile	31/96	32 (25-41)	56/83	67 (58-79)	2.09* (1.57 to 2.78)
Missing	2/13		3/3		
Low income family in neighborhood (%) [g]					
0 to 0.1	104/350	30 (24-37)	95/127	75 (64-87)	2.52* (1.92 to 3.30)
0.2 to 10.0	14/46	30 (18-53)	131/203	65 (51-81)	2.12* (1.37 to 3.28)
10.1 to 20.0	37/105	35 (21-60)	30/65	46 (32-67)	1.31 (0.69 to 2.47)
20.1 to 30.0	16/54	30 (17-53)	26/52	50 (31-81)	1.69 (0.80 to 3.55)
30.1 to 100	18/69	26 (15-46)	10/14	71 (51-99)	2.74* (1.35 to 5.56)
Missing	1/11				
Weather condition [h]					
Dry	157/493	32 (26-39)	213/356	60 (52-69)	1.88* (1.48 to 2.39)
Wet	33/142	23 (16-34)	79/105	75 (60-95)	3.24* (2.42 to 4.33)
Temperature [i]					
High	79/292	27 (21-34)	86/156	55 (44-69)	2.04* (1.48 to 2.80)
Moderate	87/286	30 (23-40)	185/280	66 (56-78)	2.17* (1.62 to 2.92)
Low	24/57	42 (23-77)	21/25	84 (56-100)	2.00* (1.02 to 3.89)

a- Prevalence ratio of helmet use 2006 versus 2000
b- Missing was not listed if there was no missing
c- Other smaller communities included Airdrie, Cochrane, Fort Saskatchewan, Leduc, Okotoks, Sherwood Park, and Spruce Grove
d- Riding with at least one adult or child companion
e- Based on census data and proportion of male and female <18 years of age in the same dissemination area [quintile 2000: (0-0.11, 0.12-0.19, 0.20-0.24, 0.25-0.28, 0.29-1.00); for 2006: (0-0.10, 0.11-0.17, 0.18-0.20, 0.21-0.25, 0.26-1.00)]
f- Based on census data on median income level for each dissemination area in Alberta for the year of observation [quintile 2000: ($0.0-$42644, $42645-$54016, $54017-$65275, $65276-$82701, $82702-$1000000); for 2006: ($0.0-$56947, $56948-$71124, $71125- $88420, $88421-$111020, $111021-$1000000)]
g- Based on census data on incidence of low income economic family percentage (%) in each dissemination area (0/0.1%=1, 0.2/10.0%=2, 10.1/20.0%=3, 20.1/30.0%=4, 30.1/100%=5)
h- Any rain ≥1 mm was considered wet otherwise as dry based on Environments Canada National Climate Archive Data
i- Low<10, Moderate=10-20, and High>20 degrees Celsius
* Statistically significant; (‡) % greater than 100 for upper limit was cut off to 100

Table 3-3 Prevalence of helmet use and prevalence ratio 2006 versus 2000 for adults (18+) in Alberta, Canada

Variable	2000		2006		PR (95% CI) cluster adjusted [a]
	n/N	% (95% CI)	n/N	% (95% CI)	
Overall	1074/2077	52 (49-55)	744/1348	55 (50-61)	1.07 (0.96 to 1.19)
Gender					
Male	696/1473	47 (44-51)	526/1015	52 (46-58)	1.10 (0.96 to 1.25)
Female	357/572	62 (58-67)	216/329	66 (60-72)	1.05 (0.94 to 1.18)
Missing [b]	21/32		2/4		
City					
Calgary	603/1104	55 (51-59)	385/608	63 (58-69)	1.16* (1.03 to 1.31)
Edmonton	432/900	48 (43-54)	321/673	48 (41-56)	0.99 (0.82 to 1.19)
Other [c]	39/73	53 (45-63)	38/67	57 (46-70)	1.06 (0.82 to 1.38)
Location					
Residential	163/362	45 (38-53)	119/239	50 (39-63)	1.11 (0.84 to 1.47)
School	70/147	48 (38-60)	81/147	55 (41-75)	1.12 (0.76 to 1.66)
Campus	69/178	39 (32-47)	81/183	44 (37-53)	1.14 (0.90 to 1.45)
Park	341/577	59 (53-65)	157/236	67 (59-74)	1.13 (0.98 to 1.30)
Cycling path	230/396	58 (52-65)	87/124	70 (63-78)	1.20* (1.02 to 1.40)
Commuter route	201/417	48 (41-56)	219/419	52 (43-63)	1.09 (0.85 to 1.39)
Companion helmet use [d]					
Alone	910/1792	51 (48-54)	665/1220	55 (50-60)	1.07 (0.96 to 1.20)
Riding with ≥ 1 at least one helmeted	146/179	82 (74-90)	76/92	83 (74-92)	1.01 (0.88 to 1.16)
Riding with ≥ 1 none of them helmeted	9/97	09 (05-17)	3/36	08 (03-26)	0.90 (0.25 to 3.26)
Missing	9/9		0/0		
Neighborhood age proportion <18 [e]					
1st quintile	312/666	47 (42-52)	180/381	47 (40-56)	1.01 (0.84 to 1.22)
2nd quintile	238/447	53 (47-60)	162/246	66 (59-74)	1.23* (1.05 to 1.45)
3rd quintile	203/360	56 (48-66)	130/264	49 (39-63)	0.87 (0.66 to 1.16)
4th quintile	157/292	54 (45-64)	125/223	56 (44-71)	1.04 (0.78 to 1.39)
5th quintile	142/282	50 (43-59)	146/232	63 (54-73)	1.25* (1.01 to 1.55)
Missing	22/30				
Income [f]					
1st quintile	176/431	41 (36-47)	109/286	38 (28-53)	0.93 (0.67 to 1.30)
2nd quintile	203/436	47 (40-54)	139/259	54 (44-65)	1.15 (0.91 to 1.45)
3rd quintile	171/320	53 (46-62)	157/245	64 (56-73)	1.20 (0.99 to 1.46)
4th quintile	242/392	62 (55-70)	137/218	63 (53-74)	1.02 (0.83 to 1.25)
5th quintile	251/447	56 (50-63)	164/260	63 (56-71)	1.12 (0.96 to 1.32)
Missing	31/51		38/80		
Low income family in neighborhood (%) [g]					
0 to 0.1	734/1354	54 (50-58)	182/306	59 (51-69)	1.10 (0.93 to 1.29)
0.2 to 10.0	25/49	51 (34-77)	251/422	59 (53-67)	1.17 (0.77 to 1.76)
10.1 to 20.0	165/328	50 (43-59)	200/364	55 (45-67)	1.09 (0.85 to 1.40)
20.1 to 30.0	32/90	36 (25-50)	77/137	56 (44-71)	1.58* (1.06 to 2.37)
30.1 to 100	96/226	42 (35-51)	33/117	28 (18-44)	0.66 (0.42 to 1.05)
Missing	22/30		1/2		
Weather condition [h]					
Dry	931/1751	53 (50-57)	624/1154	54 (49-60)	1.02 (0.90 to 1.15)
Wet	143/326	44 (38-50)	120/194	62 (52-73)	1.41* (1.16 to 1.72)
Temperature [i]					
High	653/1242	53 (49-57)	363/706	51 (44-60)	0.98 (0.83 to 1.15)
Moderate	409/800	51 (46-57)	377/635	59 (53-66)	1.16 (0.99 to 1.35)
Low	12/35	34 (19-61)	4/7	57 (23-100)‡	1.67 (0.64 to 4.32)

a- Prevalence ratio of helmet use 2006 versus 2000
b- Missing was not listed if there was no missing
c- Other smaller communities included Airdrie, Cochrane, Fort Saskatchewan, Leduc, Okotoks, Sherwood Park, and Spruce Grove
d- Riding with at least one adult or child companion
e- Based on census data and proportion of male and female <18 years of age in the same dissemination area [quintile 2000: (0-0.11, 0.12-0.19, 0.20-0.24, 0.25-0.28, 0.29-1.00); for 2006: (0-0.10, 0.11-0.17, 0.18-0.20, 0.21-0.25, 0.26-1.00)]
f- Based on census data on median income level for each dissemination area in Alberta for the year of observation [quintile 2000: ($0.0-$42644, $42645-$54016, $54017-$65275, $65276-$82701, $82702-$1000000); for 2006: ($0.0-$56947, $56948-$71124, $71125- $88420, $88421-$111020, $111021-$1000000)]
g- Based on census data on incidence of low income economic family percentage (%) in each dissemination area (0/0.1%=1, 0.2/10.0%=2, 10.1/20.0%=3, 20.1/30.0%=4, 30.1/100%=5)
h- Any rain ≥1 mm was considered wet otherwise defined as dry based on Environments Canada National Climate Archive Data i- Low<10, Moderate=10-20, and High>20 degrees Celsius
* Statistically significant (‡) % greater than 100 for upper limit was cut off to 100

Table 3-4 Adjusted prevalence ratio 2006 versus 2000 of bicycle helmet use in Alberta, Canada

Variable	Cluster adjusted (95% CI)		
	Children (<13)	Adolescents (13-18)	Adults (18+)
Year effect	1.29* (1.20 to 1.39)	2.12* (1.75 to 2.56)	1.14* (1.02 to 1.27)
Gender			
Male	1.00	1.00	1.00
Female	1.06* (1.02 to 1.10)	1.12 (0.98 to 1.28)	1.25* (1.16 to 1.34)
City			
Calgary	1.00	1.00	1.00
Edmonton	0.81* (0.75 to 0.88)	0.91 (0.74 to 1.13)	0.90* (0.81 to 0.99)
Other [a]	0.90* (0.83 to 0.96)	1.00 (0.80 to 1.26)	0.94 (0.80 to 1.11)
Location			
Residential	1.00	1.00	1.00
School	1.08 (0.99 to 1.18)	1.42* (1.11 to 1.82)	1.11 (0.90 to 1.36)
Campus	0.84 (0.53 to 1.34)	0.63 (0.18 to 2.23)	1.00 (0.78 to 1.29)
Park	1.08 (0.97 to 1.21)	1.02 (0.72 to 1.44)	1.25* (1.09 to 1.44)
Cycling path	1.09 (0.92 to 1.30)	1.21 (0.88 to 1.68)	1.20* (1.03 to 1.40)
Commuter route	0.87 (0.74 to 1.02)	1.19 (0.92 to 1.53)	0.99 (0.85 to 1.17)
Companion helmet use			
Alone	1.00	1.00	1.00
Riding with ≥ 1 at least one helmeted [b]	1.17* (1.11 to 1.23)	2.00* (1.61 to 2.49)	1.41* (1.28 to 1.54)
Riding with ≥ 1 none of them helmeted [b]	0.64* (0.52 to 0.80)	0.20* (0.09 to 0.47)	0.15* (0.09 to 0.26)
Neighborhood age proportion <18 [c]			
1st quintile	1.00	1.00	1.00
2nd quintile	1.07 (0.93 to 1.22)	0.98 (0.65 to 1.48)	1.10 (0.97 to 1.25)
3rd quintile	1.07 (0.94 to 1.22)	0.94 (0.63 to 1.40)	1.06 (0.92 to 1.23)
4th quintile	1.02 (0.88 to 1.19)	1.01 (0.68 to 1.51)	1.02 (0.87 to 1.19)
5th quintile	1.03 (0.90 to 1.18)	0.92 (0.63 to 1.35)	1.09 (0.92 to 1.29)
Income [d]			
1st quintile	1.00	1.00	1.00
2nd quintile	0.90 (0.81 to 1.01)	0.96 (0.67 to 1.38)	1.16 (0.94 to 1.43)
3rd quintile	0.99 (0.89 to 1.10)	1.25 (0.88 to 1.78)	1.31* (1.07 to 1.60)
4th quintile	1.01 (0.91 to 1.12)	1.29 (0.91 to 1.82)	1.25* (1.02 to 1.54)
5th quintile	1.02 (0.91 to 1.13)	1.37 (0.94 to 1.99)	1.20 (0.97 to 1.48)
Low income [e]			
0 to 0.1	1.00	1.00	1.00
0.2 to 10.0	0.98 (0.90 to 1.06)	0.93 (0.75 to 1.15)	0.98 (0.84 to 1.14)
10.1 to 20.0	1.02 (0.92 to 1.12)	1.06 (0.79 to 1.42)	0.95 (0.83 to 1.09)
20.1 to 30.0	0.93 (0.81 to 1.07)	1.10 (0.72 to 1.68)	0.94 (0.77 to 1.15)
30.1 to 100	0.93 (0.76 to 1.13)	1.16 (0.73 to 1.84)	0.94 (0.70 to 1.27)
Weather condition [f]			
Dry	1.00	1.00	1.00
Wet	0.96 (0.87 to 1.06)	1.05 (0.86 to 1.30)	0.97 (0.84 to 1.12)
Temperature [g]			
High	1.00	1.00	1.00
Moderate	1.07 (0.98 to 1.16)	1.31 (0.94 to 1.83)	0.69 (0.42 to 1.13)
Low	1.06 (0.99 to 1.15)	1.03 (0.85 to 1.25)	1.04 (0.94 to 1.15)

a- Other smaller communities included Airdrie, Cochrane, Fort. Saskatchewan, Leduc, Okotoks, Sherwood Park, Spruce Grove
b- Riding with at least one adult or child companion
c- Based on census data and proportion of male and female <18 years of age in the same dissemination area [quintile 2000: (0-0.11, 0.12-0.19, 0.20-0.24, 0.25-0.28, 0.29-1.00); for 2006: (0-0.10, 0.11-0.17, 0.18-0.20, 0.21-0.25, 0.26-1.00)]
d- Based on census data on median income level for each dissemination area in Alberta for the year of observation [quintile 2000: ($0.0-$42644, $42645-$54016, $54017-$65275, $65276-$82701, $82702-$1000000); for 2006: ($0.0-$56947, $56948-$71124, $71125- $88420, $88421-$111020, $111021-$1000000)]
e- Based on census data on incidence of low income economic family percentage (%) in each dissemination area (0/0.1%=1, 0.2/10.0%=2, 10.1/20.0%=3, 20.1/30.0%=4, 30.1/100%=5)
f- Any rain ≥1 mm was considered wet otherwise defined as dry based on Environments Canada National Climate Archive Data
g- Low<10, Moderate=10-20, and High>20 degrees Celsius
*statistically significant

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4 CHAPTER 4

BICYCLE HELMET USE AFTER THE INTRODUCTION OF ALL AGES HELMET LEGISLATION IN AN URBAN COMMUNITY IN ALBERTA, CANADA (1)

Abstract

Background: Bicycle trauma is a common cause of recreational death and disability and helmets have been shown to reduce fatal and non-fatal head and face injuries. This study evaluated the effect of mandatory bicycle helmet legislation for all-ages in St. Albert, Alberta.

Methods: We observed bicyclists from June to September of 2006 in St. Albert; a community subject to both provincial (<18 years old) and municipal (all ages) helmet legislation and compared our results with observations taken in 2000 when no legislation existed. Helmet wearing and rider characteristics were recorded by trained observers. Poisson regression analysis was used to obtain helmet prevalence (HP) and prevalence ratio (PR) estimates.

Results: HP increased from 45% to 92% (PR=2.03; 95% CI: 1.72 to 2.39) post-legislation. Controlling for other covariates, children were 53% (PR=1. 53; 95% CI: 1.34 to 1.74) and adolescents greater than 6 times (PR=6.57; 95% CI: 1.39 to 31.0) more likely to wear helmets; however, adults (PR=1.26; 95% CI: 0.96 to 1.66) did not show a statistically significant change post-legislation. Restricting the analysis to high socio-economic status areas, adult helmet prevalence increased in St. Albert from 58% to 73% post-legislation compared with a 52% to 57% change across the Province; this effect was not statistically significant.

Conclusions: Helmet legislation in St. Albert was associated with a significant increase in helmet use among child and adolescent cyclists. A larger increase in HP was observed for adults in St. Albert than in other areas of the province; however, this difference was not statistically significant, which may reflect the small sample size or insufficient time passage after by-law enactment.

4.1 Introduction

4.1.1 Background

Bicycle riding is a popular recreational and transportation activity in Canada (2); however, injuries do occur and may result in emergency department (ED) visits, hospitalizations (3-6) and even deaths (7, 8). Approximately 20% of bicyclist ED visits result from head injuries; (9) though the proportion can rise to over 75% for those fatally injured (8). Evidence from two systematic reviews suggests helmets reduce the risk of head, brain and severe brain injury between 58% and 88% among bicyclists of all ages (10, 11).

4.1.2 Interventional studies

Given the effectiveness of helmets in preventing head injuries, efforts to increase helmet use while bicycling have been undertaken in many countries. A systematic review has shown that promotional activities such as education, media campaigns, and community incentives may increase short-term use (12). Some jurisdictions have implemented mandatory helmet use legislation; some for all ages (13-16) and some for cyclists under 18 years of age (17). Two systematic reviews indicated that bicycle helmet legislation can increase helmet use from 5% to 54% (18) as well as decrease head injury rates (19); however, due to variations in the target age group and compliance, there is a need for more research in this area.

A comprehensive roadside survey in two major cites (Edmonton and Calgary) and eight smaller communities in Alberta in 2000 demonstrated a helmet use rate of 55% among all age groups (20). On May 1st 2002, Alberta passed a provincial law requiring all bicyclists less than 18 years of age to wear helmets (21). Two years after provincial legislation, an observational survey repeated in Edmonton, revealed that helmet use among bicyclists <18 increased from 28% to 83% with little associated change for helmet use for cyclists over 18 (18+) (22). In February 2006, the City Council of St. Albert (a suburban community northwest of Edmonton with a population of 57,000, reported by Statistics Canada 2006) passed a traffic by-law amending the Provincial helmet legislation to include all age groups effective from July 1st 2006 (personal communication with John Younie, Manager, Major Projects and Park Planning, City of St. Albert May 1st 2009).

4.1.3 Aim

To evaluate the effect of this legislation change, we conducted a follow-up observational survey in the summer of 2006.

4.2 Methods

4.2.1 Study population

Pre- and post-legislation observational surveys were conducted in St. Albert as part of a larger province-wide survey two years before (in 2000) and four years after provincial helmet legislation (in 2006). All observations were made between June and September in 2000 and 2006.

4.2.2 Helmet use data

A total of five trained observers collected information on cyclists at selected sites among five strata of residential areas, schools, parks, commuter routes, and designated cycling paths. A list of schools and parks were obtained from municipal web sites. For residential areas, commuter routes and designated cycling paths we used standard road maps divided by alphanumeric zones. From the lists we randomly selected observation sites. As the number of sites in the provincial survey was based on the population of each area, 11 sites from a total of 136 were selected for the observations in St. Albert (20). In 2006, the original sites in 2000 were re-surveyed and seven additional sites from all new and existing potential sites (n=138) were randomly selected. Our observations among re-visited sites were at the same days and times as in 2000. Other methods for collecting demographics and environmental conditions were detailed in another provincial study and are provided upon request (23). Data were collected on age, sex, helmet use, location, and companionship for each bicyclist. Reliability of the data was examined in a parallel study in Alberta (23).

Contact was made with Edmonton and Calgary Police Services as well as the Royal Canadian Mounted Police (RCMP) to estimate police enforcement of the helmet law by means of documented ticket citations during the study period.

4.2.3 Analysis

Data were analyzed using Stata/SE version 10 (24). We compared the prevalence of helmet use between 2000 and 2006 by important factors including: age, sex, location type, weather conditions (dry, wet), and temperature (low: <10˚C; moderate: 10-20˚C; high: ≥ 20˚C). Weather and temperature data were obtained from an archive on the Environment Canada web site (25).

Given that our outcome was a count variable (number of bicyclists who wore a helmet), we used Poisson regression analysis with cluster adjustment for site, for univariate and multiple regression analysis with the robust (sandwich or Huber-White) estimator to correct the standard error of the estimates(26). We report HP (%, with 95% confidence intervals [CI]) and prevalence ratios (PRs, 95% CI) (27, 28) comparing the post- to the pre-legislation period (28).

Examining the means and variances of our main outcome (helmet use) in all three age groups demonstrated that data were not over- but under-dispersed; consequently, Poisson was preferred over negative binomial regression modeling. If variances are smaller than the means it would imply less variability in helmet use than estimated with the Poisson distribution leading to wider CI and more conservative estimates (i.e., less likely to be statistically significant) (28). As age was previously shown to be an effect modifier for the relationship between bicycle helmet legislation and HP (22), in the multiple Poisson regression analysis, we incorporated the interaction of year (2000, 2006) with age (children <13; adolescents 13-17; adults 18+) allowing the effect of year of survey to vary depending on age group.

To compare adult helmet use in St. Albert (with universal helmet legislation) versus the rest of Alberta (with a helmet law for those under 18), we selected that part of the Alberta population with a high SES (i.e., 3rd, 4th, and 5th quintile of neighborhood median income level) and compared adult HP with the corresponding HP in St. Albert.

4.3 Results

4.3.1 Sample characteristics

The sites of observation for St. Albert are shown in Table 4-1. Of the 11 sites in 2000, one had zero observations, and from the 18 sites in 2006, two had zero observations; these sites were not part of the analysis. Inter-observer reliability in capturing cyclist characteristics was examined in a parallel study in Alberta and showed that disagreements between two observers at the same site were less than 6% in recording bicyclists' characteristics (23).

4.3.2 Univariate results

Overall HP increased from 45% to 92% (PR =2.03; 95% CI: 1.72 to 2.39) post-legislation. Sub-group analysis showed that HP among children increased from 63% to 100% (PR=1.59; 95% CI: 1.38 to 1.82). Adolescent HP increased from 10% to 76% (PR=8.00; 95% CI: 1.60 to 39.9), and adult HP increased from 58% to 73% (PR=1.26; 95% CI: 0.93 to 1.70) (Table 4-2). HP increased in males and females, at schools and on cycling paths and regardless of companion helmet use (Table 4-2).

In Calgary and Edmonton, 188 tickets were issued between 2003-2008, targeting only children and adolescents (personal communication with Allison Bouthillier, Edmonton Police Services and Allison Miller, Calgary Police Services). In St. Albert, 130 tickets were issued during 2006-2008, targeting cyclists of all ages (personal communication with Corporal Don Murray, St. Albert RCMP).

4.3.3 Multiple Poisson regression results

From the full model with all covariates and the interaction of age with year, HP among children (PR=1.53; 95% CI: 1.34 to 1.74) increased 53% from 2000 to 2006 (Table 4-3). Adolescents (PR=6.57; 95% CI: 1.39 to 31.0) demonstrated a 6-fold increase in HP from 2000 to 2006. Adults did not show a statistically significant increase in HP over time after adjustment for covariates (PR=1.26; 95% CI: 0.96 to 1.66). In 2000, HP among adolescents (PR=0.20; 95% CI: 0.04 to 0.87) was 80% lower than adults; however, children (PR=1.14; 95% CI: 0.85 to 1.49) did not show a statistically significant difference compared with adults. In 2006, HP among children

(PR=1.38; 95% CI: 1.17 to 1.63) was 38% higher than adults, but adolescent helmet use was similar to adults (PR=1.02; 95% CI: 0.76 to 1.38) (Table 4-3). Controlling other covariates, HP among females was 12% greater compared with males (PR=1.12; 95% CI: 1.02 to 1.22) (Table 4-3). Locations did not show a significant relation to HP. Those riding with anyone who had a helmet (child, adolescent or adult) demonstrated 17% greater HP than those riding alone (PR=1.17; 95% CI: 1.02 to 1.33). After adjustment for other covariates, weather conditions and temperature had little effect on helmet use (Table 4-3).

In St. Albert, HP for adults increased from 58.1% (95% CI: 46.3 to 72.8) in 2000 to 73.1% (95% CI: 63.6 to 84.0) in 2006; while in other high SES areas of Alberta (see methods), HP changed from 51.7% (95% CI: 48.3 to 55.2) in 2000 to 56.8% (95% CI: 51.8 to 62.2) in 2006 (Figure 1). The results of a sensitivity analysis comparing the HP post- to pre-legislation ratio among adults in St. Albert in 2006 by excluding the month of June (before the city-by-law) demonstrated little practical or statistical change (Including June HP=1.26; 95% CI: 0.72, 2.20 vs Excluding June HP=1.24; 95% CI: 0.69, 2.22; P-value=0.47).

4.4 Discussion

4.4.1 Findings

This study evaluated bicycle helmet use four years after the introduction of provincial bicycle helmet legislation targeting those under age 18 in St. Albert, Alberta, a municipality that elected to adopt a universal helmet use by-law in 2006. Overall, the results suggest that helmet use increased 53% among children, more than six-fold among adolescents with no statistically significant change among adults (Table 4-3). There was no statistically significant difference between helmet use among children and adults pre-legislation in 2000; however, after legislation it is estimated that child helmet use was 39% greater than adults.

The results from the provincial survey showed that HP increased post-legislation by 29% among children, 112% among adolescents and 14% among adults (23). HP trends in St. Albert demonstrate a greater, though not statistically significant increase from pre- to post-legislation compared with a much more modest increase at other Alberta sites (Figure 1). One explanation for this trend in St. Albert for adults may be the limited time post-legislation for people to adhere to the new city-by-law; nevertheless, the rising adult HP in this community is encouraging.

Evaluation of British Columbia's universal helmet legislation showed that HP among all age groups increased between 18% and 28% four years after legislation from 1995 to 1999 (14). HP in Nova Scotia, a province that implemented all ages bicycle helmet legislation in 1997, increased substantially from 1995/96 to 1998/99 among all age groups (children: 49% to 84%; adolescents: 29% to 70%; adults: 36% to 86%) (13). In our study HP increased from 63% to 100%, 10% to 76%, and 58% to 73% among children, adolescents and adults, respectively. We controlled for other covariates in a multiple regression analysis demonstrating HP improved significantly among children and adolescents, but not among adults (Table 4-3).

An examination of four cycles of Canadian Community Health Surveys between 2001 and 2007 has shown that helmet use was much higher in a province with universal helmet legislation (youth=77.5%, adults=71.4%) than a province with helmet legislation targeting only those under 18 (youth=46.7%, adults=38.9%) (29).

In 1990, Victoria, Australia became the first jurisdiction in the world to introduce compulsory bicycle helmet use for all age groups following 10 years of promotional helmet use activities that started in 1980. HP estimates the year before legislation for metropolitan primary school students, secondary school students, and adults were 76.8%, 18.4%, and 47%, respectively. One year after legislation, HP increased for all age groups to 92.2%, 44.2%, and 92%, respectively (30). This shows that implementing all-age helmet legislation can increase helmet use in children, adolescents and adults.

Two studies in Ontario demonstrated that HP among higher income areas was greater at baseline than in lower income areas. These areas were observed to have a smaller percentage increase after implementing helmet legislation (17, 31). Given that the sites observed in St. Albert were generally of high SES, we would then suggest that the increase in adult HP from 58% to 73% was a promising finding.

4.4.2 Limitations

Our study is not without limitations. Our observers did not stop cyclists to obtain demographic information; however, they used their best estimate for age category, sex and other variables, a strategy which has been used in many other similar investigations (13, 14, 17). This approach may result in some misclassification; however, we would consider that these errors were likely not systematically related to helmet use or year of the study. Although the number of observations in this study was small and not evenly distributed among different age groups, the results are practically and statistically significant for children and adolescents.

A post-hoc power calculation indicates that we had only 29% power to detect a 15% change in HP among adults based on the total number of adults observed pre- to post-legislation. Therefore, two elements might have played an important role in lower than expected HP among adults in St. Albert. First, the short interval between helmet legislation and evaluation may have been insufficient for the intervention to take full effect. Second, the limited number of observations before and after implementation of the by-law (i.e., the interplay of sample size and magnitude of effect) may have limited our ability to measure this effect.

Finally, it appears neither Alberta, nor St. Albert, had any promotional and limited enforcement activities in place for bicycle helmet use before or after the laws was implemented. Whatever enforcement occurred was concentrated in the first year (80% in 2006) in St. Albert and in the second and third year (18% in 2003; 37% in 2004) in Calgary and Edmonton. Therefore, the low HP may be attributable to a general reluctance of adults to change behaviours, low perceived risk of consequences, low perceived risk of head injury, or a combination of these factors.

4.4.3 Strength

This study has several strengths. For data collection, we directly observed persons engaged in bicycling rather than relying on self-reports through telephone or questionnaire surveys that may be subject to response bias (29). We used pre-legislation observations as a control period in the same population with consistent observation methods to observe bicyclist characteristics, including helmet use. To address the methodological issues identified by other authors in the evaluation of helmet legislation (32), we repeated observations at the same locations, day of week and time of the day as in the pre-legislation study and assessed the effect of legislation four years after implementation of the law. We incorporated interaction terms between age and study year in our multiple regression analysis to allow separate legislation effects for children, adolescents, and adults and adjusted for sex, location of observation, companionship, weather conditions, and temperature. We also controlled for the potential non-independence of bicycle helmet use at particular data collection sites (i.e., clustered data) in the statistical analysis.

4.5 Conclusion

Provincial (targeting those <18) and municipal (targeting adults) helmet legislation in St. Albert increased helmet use significantly among children and adolescents. The increase in helmet use among adults in St. Albert was greater than among adults in other areas of the province, though this effect was not statistically significant. The small sample size, insufficient time between legislation and our survey, poor enforcement or lack of influence of the legislation on adult may have influenced the results seen in HP among St. Albert adults. Future research targeting a larger sample size is required to determine the impact of universal helmet legislation on helmet use in all age groups, but in particular among adults subject to the municipal by-law.

Table 4-1 Number of sites and cyclists observed in the two studies in St. Albert, Alberta Canada

Location	**2000**		**2006**	
	Site	**Observations**	**Site**	**Observations**
School	3	49	4	136
Park	2	11	4	16
Residential	2	2	5	12
Cycling path	2	63	3	51
Commuter route	2	17	2	10
Total	11	142	18	225

Table 4-2 Prevalence of helmet use and prevalence ratio 2006 versus 2000 in St. Albert, Alberta Canada

Variable	2000		2006		Prevalence ratio (95% CI), cluster adjusted [a]
	n/N	% (95% CI)	n/N	% (95% CI)	
Overall	64/142	45 (40-51)	206/225	92 (86-98)	2.03* (1.72 to 2.39)
Age					
<13	39/62	63 (55-73)	152/152	100 (NA)	1.59* (1.38 to 1.82)
13-17	4/42	10 (2-44)	16/21	76 (59-99)	8.00* (1.60 to 39.9)
18+	18/31	58 (46-73)	38/52	73 (64-84)	1.26 (0.93 to 1.70)
Missing data [c]	3/7		0/0		
Gender					
Male	41/98	42 (36-48)	139/155	90 (84-96)	2.14* (1.80 to 2.55)
Female	21/41	51 (40-65)	67/70	96 (91-100) [b]	1.87* (1.41 to 2.47)
Missing data	2/3		0/0		
Location					
Park/residential/commuter route	17/30	57 (45-72)	30/38	79 (62-100)	1.39 (0.91 to 2.13)
School	21/49	43 (42-44)	132/136	97 (94-100)	2.26* (2.19 to 2.34)
Cycling path	26/63	41 (35-48)	44/51	86 (81-92)	2.09* (1.78 to 2.46)
Companion helmet use [d]					
Alone	48/107	45 (38-54)	152/171	89 (81-98)	1.98* (1.61 to 2.43)
Riding with anyone helmeted [d]	12/17	71 (53-94)	54/54	100 (NA)	1.42* (1.07 to 1.87)
Riding with anyone non-helmeted [d]	3/15	20 (8-52)	0/0	NA	NA
Missing	1/3		0/0	NA	NA
Weather condition [e]					
Dry	64/142	45 (40-51)	153/171	89 (83-96)	1.99* (1.66 to 2.37)
Wet	0/0	NA	53/54	98 (93-100)	NA
Temperature [f]					
High	41/93	44 (37-53)	103/115	90 (82-98)	2.03* (1.62 to 2.56)
Moderate	20/42	48 (38-60)	83/89	93 (83-100)	1.96* (1.47 to 2.61)
Low	3/7	43 (17-100)	20/21	95 (86-100)	2.22 (0.92 to 5.34)

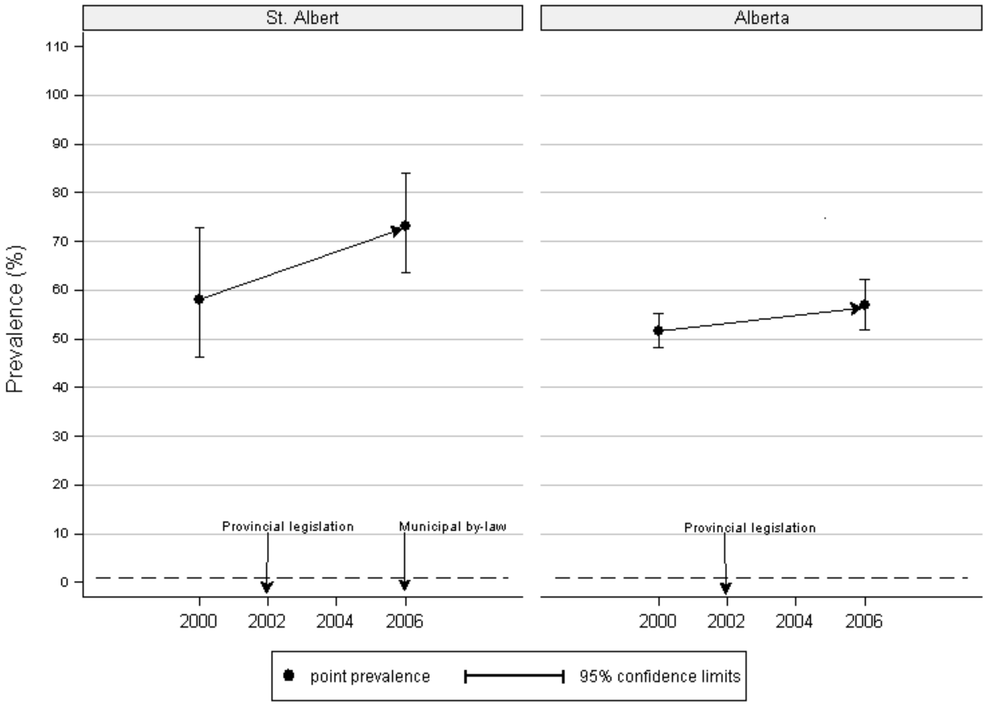
* Statistically significant; (NA) not applicable
a- Prevalence ratio of helmet use 2006 versus 2000; clusters were sites of observation
b- % greater than 100 for upper limit was cut off to 100
c- Missing was not listed if there was no missing data
d- Riding with at least one adult or child companion
e- Any rain ≥1 mm was considered wet otherwise defined as dry based on Environments Canada National Climate Archive Data
f- Low<10, Moderate=10-20, and High≥20 degrees Celsius

Table 4-3 Adjusted prevalence ratio of helmet use 2006 versus 2000 in St. Albert, Alberta Canada

Variable		Prevalence ratio (95% CI), cluster adjusted
Age	year	
<13	2000	1.0 (ref)
	2006	1.53* (1.34 to 1.74)
13-17	2000	1.0 (ref)
	2006	6.57* (1.39 to 31.0)
18+	2000	1.0 (ref)
	2006	1.26 (0.96 to 1.66)
Year	Age	
2000	<13	1.14 (0.89 to 1.45)
	13-17	0.20* (0.04 to 0. 87)
	18+	1.0 (ref)
2006	<13	1.38* (1.17 to 1.63)
	13-17	1.02 (0.76 to 1.36)
	18+	1.0 (ref)
Gender		
Male		1.0
Female		1.12* (1.02 to 1.22)
Location		
Park/residential/commuter route		1.00
School		0.93 (0.84 to 1.04)
Cycling path		0.96 (0.87 to 1.06)
Companion helmet use		
Alone		1.00
Riding with anyone helmeted [a]		1.17* (1.02 to 1.33)
Riding with anyone non-helmeted [a]		0.60 (0.28 to 1.28)
Temperature [b]		
High		1.00
Moderate		1.07 (0.99 to 1.14)
Low		1.09 (0.97 to 1.22)

* Statistically significant
a- Riding with at least one adult or child companion
b- Low<10, Moderate=10-20, and High≥20 Celsius degree

Figure 4-1 Trends in bicycle helmet prevalence for adults (18+ years) in the municipality of St. Albert associated with implementation of all ages bicycle helmet legislation compared with other areas of the province of Alberta with bicycle helmet legislation targeting only those under 18.



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5 CHAPTER 5

BICYCLING RATES TWO YEARS BEFORE AND FOUR YEARS AFTER HELMET LEGISLATION IN ALBERTA, CANADA

Abstract

Background: Bicycle helmet legislation has generated debate regarding corresponding bicycling participation. Although safe bicycling is the main objective of legislation, decreased bicycling activity is undesirable. This study evaluated the association between bicycle helmet legislation and bicycling rates in urban and non-urban areas of Alberta.

Methods: In two similar studies six years apart (2000 and 2006), bicyclists were observed in randomly selected sites in Calgary, Edmonton and smaller communities from June to September. Trained observers recorded bicyclists passing by in a defined time period and classified them according to estimated age group (<13, 13-17, 18+). Negative binomial regression analysis was used to estimate the rate of bicycling per hour of observation along with adjusted and unadjusted rate ratios with 95% confidence intervals (CI) comparing the post- (2006) to pre-legislation (2000) periods. Multiple imputations method was used for missing data analysis.

Results: After stratification for age group and location and controlling for neighborhood age proportion <18, city, weather conditions, and temperature, bicycling to/from school decreased in children (RR=0.33; 95% CI: 0.24, 0.46) and in adolescents (RR=0.49; 95% CI: 0.31, 0.77); however, bicycling increased in adults (RR=1.83; 95% CI: 1.16, 2.88) post-legislation. Bicycling by children also increased in campus areas (RR=4.37; 95% CI: 1.08, 17.6) post-legislation. On commuter routes, bicycling decreased in children (RR=0.58; 95% CI: 0.40, 0.84) and adolescents (RR=0.65; 95% CI: 0.43, 0.99); however, it increased (RR=1.48; 95% CI: 1.09, 2.00) in adults post-legislation. No significant changes in other locations were observed. Wet and dry conditions did not influence the rate of bicycling in any age groups.

Conclusions: Since bicycling rates decreased in only two of the five groups of observation sites (schools and commuter routes) among the legislated target age group (<18) post-legislation and simultaneous increases

in cycling were observed in other locations, the results of our study refute claims that helmet legislation has a negative effect on cycling exposure.

5.1 Introduction

5.1.1 Background

In a Cochrane systematic review, bicycle helmets were reported to provide a 63% to 88% reduction in the risk of head, brain and severe brain injury for bicyclists of all ages (1). Results of another systematic review revealed that helmets reduce the risk of head and brain injury between 58% and 73% and facial injuries by 47% (2). Community promotion programs such as education in schools, media campaigns, and purchasing incentives have been used to increase bicycle helmet use (3-6, 7). Such interventions have been shown to effectively increase helmet use among children and adolescents up to 12 months after intervention (8). Bicycle helmet legislation has also been effective in increasing helmet use (9). Many jurisdictions have now implemented helmet legislation for all ages (10) or bicyclists under 18 years of age (11).

Although increasing helmet use and reducing head/brain injuries are the main objectives of helmet legislation, a corresponding decrease in bicycling activity would be undesirable. Since the introduction of helmet legislation, there has been limited research investigating the effect of helmet legislation on bicycling activity. In New South Wales, bicycling among all age groups decreased 44% after helmet legislation in 1992 (12). In repeated surveys in Victoria, Australia from 1987-88 to 1992, it was shown that after enacting helmet legislation in 1990, the number of bicyclists decreased by 24% in children, 46% in adolescents and 29% in adults in the first year after the helmet law came into effect. One year later, however, there was an increase in bicycling by 20%, 6% and 34% in children, adolescents, and adults, respectively (13).

In a Canadian study, the average bicycling per hour for children 5-14 years old was higher a year after the helmet legislation targeting children <18 came into effect (11). Although improving bicycling safety is the main objective behind bicycle helmet legislation, decreased bicycling activity may counteract efforts to promote physical activity, a key component of healthy living (14).

A comprehensive study was conducted in 2000 to evaluate helmet use in Alberta (15). Based on amendments to the Highway Traffic Bicycle

Safety Helmet Amendment Act, all bicyclists under age 18 in Alberta were required to wear approved helmets commencing on May 1st, 2002. As part of the legislation, a fine was implemented for not wearing an approved helmet ($69) (16). In 2006, the same study was repeated to investigate helmet use in Alberta four years after legislation (17). Although the results of the two surveys revealed that helmet legislation had increased helmet use among children and adolescents (17), it is not known if this legislation was associated with a decrease in bicycling activity.

5.1.2 Aim

The aim of this study was to examine the rates of bicycling pre- to post-legislation among target in comparison to non-target age groups in Alberta.

5.2 Methods

5.2.1 Study population

Using similar methods, observational studies were conducted pre- (2000) and post- (2006) legislation. The studies were conducted in Calgary and Edmonton, Alberta's two largest cities with populations of 1,079,310 and 1,034,945, respectively (18). In addition, observations were conducted in eight surrounding communities within 50 KM of either city center and with a population exceeding 9500 (Airdrie, Cochrane, Fort Saskatchewan, Leduc, Okotoks, Sherwood Park, Spruce Grove, and St. Albert) (15). St. Albert was excluded from the analysis because it introduced a new municipal by-law in 2006 mandating bicyclists of ***all ages*** wear helmets and this local legislation was different from the rest of the province (19).

5.2.2 Observation sites

Observation sites were randomly selected from six location strata (schools, universities/colleges, parks, commuter routes, designated cycling paths, and residential areas) from potential sites in 2000. Observation days were scheduled for each observer and time of observation was one hour at schools, parks, and campuses and two hours at roadways, cycling paths and residential areas. Observations at school sites were performed during weekdays in the morning and afternoon based on student arrival and departure times. Observation at parks and residential areas was conducted during the week and on weekends. Observation start times at non-school sites were 7:00, 9:00, 11:00, 13:00, 17:00, or 19:00. These sites, except one school, were re-visited on the same day and at the same time in 2006. All observations were made between June and September in 2000 and 2006. In the event of inclement weather, observations were delayed to the same day one week later. KIDSAFE connection staff had training sessions for data collectors in both 2000 and 2006 (KIDSAFE connection is the child and teen injury prevention program affiliated with Stollery Children's Hospital, Edmonton, Alberta, Canada) (20).

Weather conditions and temperature for the observation times/locations were obtained from archived data tables of the Environment Canada website (21). Average temperature for each observation time and weather conditions (wet=any rain≥1 mm; dry=no rain or rain<1 mm) were extracted.

Demographics of the population were obtained at the dissemination area (DA) level from Statistics Canada (SC) (22). DAs are small areas made up of 400 to 700 persons that cover the entire country of Canada and are the smallest geographical unit for which census data are available (23).

As the proportion of those under the age of 18 may increase the number of bicyclists in neighborhoods, we used census data to calculate the proportion of potential bicyclists <18 years old in each DA related to sites in 2000 and 2006. Using the quintiles of this proportion distribution in our sample frame, we attempted to control for younger versus older populations in the multiple regression analysis.

5.2.3 Analysis

We compared the rate of bicycling per hour among 270 revisited sites in 2006 with those same sites in 2000. Taking into account the effect measure modification of the year of observation on bicycling exposure, we reported estimates of bicycling rates for three age categories of <13, 13-17, and 18+ separately (24, 25). In each age category, subgroup analyses were performed for site-specific characteristics of location divided into urban (Calgary and Edmonton) and non-urban areas (cities and towns with less than 100,000 population), strata (school, campus, park, cycling path, commuter route, and residential areas), weather conditions (wet=any rain≥1 mm and dry=no rain or rain<1 mm), and temperature (low <10, moderate 10-20, and high >20˚Celsius). In calculation of bicycling rate, the numerator was aggregated frequency of cyclists in each category and denominator was aggregated observation time for that subgroup (observation time are the same for three age categories).

Negative binomial regression was used in univariate and multiple regression analysis adjusted for clustering by sites (26). In univariate analyses, unadjusted bicycling rate per hour of observation and ratio of the rates 2006 to 2000 was calculated. A separate model for each age category was constructed and the adjusted bicycling rate ratio controlling for covariates of quintile of neighborhood age proportion less than 18 years old, location, weather conditions, and temperature was reported. Interaction terms for year/strata were incorporated in separate models. Multiple imputation methods were used to account for missing values (27) and analysis were repeated using the imputed file and compared to the complete case analysis.

As our data were overdispersed,(deviance/df=7.9; alpha=1.72 (95% CI: 1.57, 1.88) using simple Poisson regression could be misleading (28). Alternative approaches were considered including a modified Poisson regression by estimating a factor for correcting the regression model's inferential statistics (28), using quasi-Poisson (29) or negative binomial regression analysis (28, 29). The quasi-Poisson method estimates the variance as a linear function of the mean while the variance of a negative binomial regression (NBR) is quadratic function of the mean (29). The later (NBR) is more appropriate for estimating probability distribution of an individual count data (28). As our data were individual count data we chose NBR as a method of choice for regression analysis. Data were analyzed by Stata/IC version 11 (30).

5.3 Results

5.3.1 Sample characteristics

Bicyclists were observed in 270 sites (Calgary 136, Edmonton 104, others 30) in 2000 and 269 in 2006 (one school closed in Edmonton). We observed 7314 bicyclists in the two surveys (4002 in 2000, 3312 in 2006). In 2000 there were 1175 children, 635 adolescents, and 2077 adults (age group was missing for 115 bicyclists). In 2006, there were 494 children, 440 adolescents, and 2375 adults (age group was missing for 3 bicyclists). Total observation time in 2000 was 330.3 hours (Metropolitan 300.0 and urban/suburban 30.3) and in 2006 was 313.2 hours (Metropolitan 284.7 and urban/suburban 28.5). The frequency of observed bicyclists ranged from 1 to 143 at each site for both surveys. Inter-observer reliability in capturing bicyclist characteristics was examined in a parallel study in Alberta and showed that disagreements between two observers at the same selected sites did not exceed 6% in recording bicyclists' characteristics (17).

5.3.2 Unadjusted observed bicycling rates

The overall bicycling rate decreased in children by 56% (RR=0.44; 95% CI: 0.36, 0.55) (Table 5-1). In urban areas, bicycling decreased in children by 59% (RR=0.41; 95% CI: 0.33, 0.52) but not in non-urban areas. Bicycling by children decreased to/from school (PR=0.32; 95% CI: 0.24, 0.44), on commuter routes (PR=0.59; 95% CI: 0.37, 0.92), and in residential areas (PR=0.63; 95% CI: 0.41, 0.98); however, the rate increased in campus areas (RR=4.80; 95% CI: 1.10, 20.9). Children bicycling in all weather conditions and in different temperatures also decreased (Table 5-1).

The overall bicycling rate decreased in adolescents by 27% (RR=0.73; 95% CI: 0.57, 0.94) (Table 5-2). Bicycling declined similarly in urban (RR=0.77; 95% CI: 0.60, 0.99) and non-urban areas (RR=0.43; 95% CI: 0.18 to 1.01), although the effect was statistically significant only for urban areas. No change in bicycling rates was observed in different locations for adolescents post-legislation. Adolescent bicycling decreased only in dry weather conditions (RR=0.69; 95% CI: 0.54, 0.89) and on days with low temperatures (RR=0.09; 95% CI: 0.02, 0.38) (Table 5-2).

The bicycling rate increased in adults by 21% (RR=1.21; 95% CI: 1.03, 1.41) (Table 5-3). Adult bicycling in urban areas increased by 23% (PR=1.23; 95% CI: 1.05, 1.44) and decreased in non-urban areas by 42% (RR=0.58; 95% CI: 0.35, 0.97). Bicycling by adults to/from school (RR=1.87; 95% CI: 1.17, 2.99) and in residential areas (RR=1.37; 95% CI: 1.06, 1.78) increased post-legislation; however, no statistically significant change was observed in other locations. Adult bicycling increased in dry weather (RR=1.23; 95% CI: 1.04, 1.46) and on high temperature days (RR=1.29; 95% CI: 1.05, 1.58) (Table 5-3).

5.3.3 Adjusted bicycling rates

Using negative binomial regression, after stratification for age group and location (i.e., school, campus, park, residential, path, roadway) and controlling for quintile of population <18 years of age in the DAs related to sites, city (i.e., urban vs. non-urban area), weather conditions, and temperature, bicycling to/from school decreased in children by 67% (RR=0.33; 95% CI: 0.24, 0.46) and in adolescents by 51% (RR=0.49; 95% CI: 0.31, 0.77); however, the bicycling rate increased in adults by 83% (RR=1.83; 95% CI: 1.16, 2.88) post-legislation. Bicycling rates in children increased near campus areas (RR=4.37; 95% CI: 1.08, 17.6) post-legislation. On commuter routes, bicycling decreased in children (RR=0.58; 95% CI: 0.40, 0.84) and adolescents (RR=0.65; 95% CI: 0.43, 0.99); however, the rate increased in adults (RR=1.48; 95% CI: 1.09, 2.00) post-legislation. There were no other statistically significant changes in bicycling rates in other locations post-legislation.

In both 2000 and 2006, the rate of bicycling by children to/from school and in parks was greater than residential areas; children bicycling near campuses in 2000 were less than residential areas (Table 5-4). In 2000, bicycling by adolescents to/from school, on cycling paths and on commuter routes was higher than residential areas; however, in 2006 the rate of bicycling to/from school was higher than residential areas (see Table 5-4). The rates of adult bicycling in both 2000 and 2006 near campuses, in parks, on cycling paths and on commuter routes were greater than residential areas; however, in 2000 this rate was smaller in school areas compared with residential areas (Table 5-4).

After adjustment for strata, location, weather condition, and temperature, the rates for children and adult cycling were lower in those areas with fewer children and adolescents under the age of 18 (Table 5-4). There was no evidence of a difference in bicycling rates in adolescents according to the proportion of children and adolescents under age 18 in the area.

After controlling for strata, quintile of neighborhood age proportion <18, weather condition, and temperature, the rate of children bicycling in urban areas decreased (RR=0.69; 95% CI: 0.48, 0.99) in comparison to non-urban areas; however, corresponding adult bicycling increased (RR=2.22;

95% CI: 1.50, 3.29) (Table 5-4). Wet or dry weather condition was not related to bicycling in any age group (Table 5-4). The rate of cycling among adolescents and adults was lower on days with low and moderate temperatures.

5.3.4 Missing data analysis

There were missing data for approximate age of bicyclists in our data including 115 (2.9%) in 2000 and three (0.09%) in 2006. In the negative binomial regression analysis using the dataset with imputed missing values, adjusted bicycling rate in children demonstrated some significant changes. Bicycling rate became insignificant (RR=1.99; 95% CI: 0.68, 5.82) on campuses and declined in residential areas (RR=0.64; 95% CI: 0.41, 0.99). No other changes were observed for other rates after imputation.

5.4 Discussion

5.4.1 Findings

This study compared the bicycling rate between two study periods (2000 and 2006) where comprehensive sampling of a total of 270 sites in two urban and seven non-urban communities in Alberta, Canada was performed. In univariate analyses, we observed a 56% decline in bicycling in children and 27% in adolescents (Table 5-2). In the cluster-adjusted multiple regression analysis controlling for quintile of <18 age group, location, weather condition and temperature and by taking into account location/year effect measure modification in each age-specific model, the decline in bicycling was only related to cycling to/from schools and cycling on commuter routes (Table 5-4). Moreover, in the multiple regression analysis, bicycling activity increased among adults and was attributed to significant increases in cycling to/from schools and on commuter routes. Children cycling in campus areas increased post-legislation by more than 4 fold. Unless otherwise indicated, we did not observe any other significant changes in cycling at other locations for any age group (Table 5-4).

Although many studies have shown that helmet legislation is necessary and can increase helmet use (8, 9), a possible negative effect of legislation on the rate of bicycling has been an issue of debate among researchers and members of the health promotion community (14, 31, 32). A series of observational surveys on bicycle usage and helmet wearing in metropolitan Melbourne (VIC ROADS) were conducted between 1987 and 1992. The results of observation from 64 sites demonstrated decease in bicycling among children, adolescents, and adults by 24%, 46%, and 29%, respectively in the first year after a helmet law (introduced on July 1st 1990 targeting all bicyclists) in Melbourne, Australia. One year later, however, the authors observed an increase in bicycling by 20% among children, 6% among adolescents and 34% in adults (13). Moreover, because the authors did not control for weather conditions, they conducted a sensitivity analysis, the results of which suggested that weather may have contributed to the observed decline in bicycling in children and teenagers (13). Therefore, they were cautious drawing conclusions from their results and suggested the helmet law only decreased bicycling in teenagers.

There were also consecutive observational surveys on bicycling and bicycle helmet use in New South Wales, Australia from 1991 to 1993 (33, 34). In New South Wales, bicycle helmet use became mandatory from January 1st 1991 for people aged >15 and extended to all ages in July 1st in the same year. In the first year after law in 1991 and across 123 observational sites, bicycling decreased by 36% in children (<18) and 14% in adults (34). Bicycling in the second year (in 1993) decreased by10% in children, but increased 12% in adults compared with the preceding year (33). Due to some limitations related to the surveys the authors explicitly mentioned that these results should not be used to estimate total exposure or ridership in New South Wales post-legislation. They highlighted the following items as limitations: selected towns for observation in rural areas were not homogeneous in terms of population, layout, and activities; non-governmental schools were not included in the surveys; schools had different attitudes towards bike riding (bike riding banned by some school officials throughout the surveys in metropolitan areas; concurrent social events such as Easter holidays; the influence of weather conditions on cyclist activities; delayed or cancelled observations and/or variation of actual observation time from school to school in some surveys (33).

Re-evaluating the preceding two observational surveys from Melbourne and New South Wales, Robinson believed that legislation was accompanied by a decrease in bicycling which in turn counteracts the promotion of an active life style (12). The author further discussed that the reduction in bicycling after helmet legislation may increase health care costs, arguing that bicycling, even without a helmet, is beneficial. Conversely, while we also observed a decrease in cycling in children and adolescents at two of six location types (schools and commuter routes), we did not see such declines at other locations. Moreover, cycling rates increased among adults (Table 5-4).

Considering the results of the Australian studies and this study, one should be cautious to draw a causal relationship between declines in bicycling rates, general public health and corresponding costs until more robust studies specifically designed for this purpose are conducted. Before rushing to a decision and perhaps interventions, it would be helpful to see some of the criteria (e.g., temporal association, strength and consistency of association, and dose-response relationship) of causal relationship between bicycle helmet law and/or decrease in bicycling as well as some specific indicator of general public health (35).

Moreover, surveying 1240 teenagers (13-17) from 14 secondary schools in south east Melbourne, Finch demonstrated that the major factors leading teenagers not to wear helmet were appearance (23%) and comfort (33%). Of the total sample (1240), only 15% (186) considered law/police force or fear of a fine or ticket as a reason for not wearing a helmet. Over half the sample (n=670; 54%) considered safety and 31% (384) their parents obligation as the main reasons to wear helmet (36).

Furthermore, in a study in Ontario among children 5-14, bicycling increased significantly in the first year after helmet legislation from 4.32 cyclists per hour in 1995 to 6.84 in 1996 (11). Then cycling decreased to 4.57 cyclists per hour in 1997 and rapidly rose to 10.07 cyclists per hour in 1999, four years after helmet legislation (11). In the same study, the authors reported that after the first year of helmet legislation, the rate of cycling to school did not change significantly, cycling at parks increased; and cycling decreased at major intersections (11). Conversely, during surveys in 1992 and 1993 in New South Wales, Australia, bicycling to schools (both primary and high school) declined in metropolitan Sydney after implementation of helmet law (in 1991); similar results were not seen in rural areas (33). Overall decreases after two years in metropolitan areas were -33% in primary schools and -31% in high schools; these rates in rural areas were +18% and -1%, respectively.

Four cycles of Canadian Community Health Surveys between 2001 and 2007 have demonstrated that helmet legislation targeting all age groups did not introduce a significant change in ridership among both youth (12-18 years of age) and adults (18+) in Prince Edward Island. This study has also shown that trend of bicycling in Alberta from before (2001) to after (2003, 2005, and 2007) legislation was independent of that intervention (37).

A study demonstrated that enforcement can increase helmet use particularly if accompanied by incentives and free helmets (38); however, no study has examined the relationship between helmet law enforcement by police and the rate of bicycling. Limited data obtained from police services in Calgary and Edmonton indicate that the total number of tickets issued to bicyclists has been low (64 in Calgary and 89 in Edmonton; 153 in total) during the study period (2003-2006). This is an average of 19 tickets per city per year in a combined population of over 2,000,000.

5.4.2 Limitations

This study was a pre/post community-based experimental study and continuation of a larger helmet prevalence study in Alberta. As in other similar non-experimental studies, internal validity issues must be taken into account when interpreting the study results. In such studies, two important time-dependent factors of history and maturation may explain some of the estimated effects for the intervention. History refers to the events occurring concurrently with the intervention (co-intervention) that may be affecting the observed outcome. Maturation refers to the phenomenon of behaviour change over time (e.g., increased safety in general) that can distort the intervention effects (39). Nevertheless, we have not observed province-wide programs targeting helmet use among bicyclists or potentially influencing bicycling exposure during the study period. Although there might have been some local activities in schools or communities, in general Alberta did not implement promotional programs such as: comprehensive educational program, community incentives (e.g., free helmets), rigorous province-wide legal enforcement for helmet use, or extensive media campaign. Maturation of societal safety awareness is quite possible; however, because the study period was brief (2000-2006) it is unlikely that it played an important role in changing prevalence of helmet use or exposure to cycling.

In our study, there might have been some degree of under-estimation in terms of number of bicyclists. One reason is that if a group of more than 3 bicyclists approached an observer, observers only captured information on one selected cyclist. This rule was applied in both 2000 and 2006, therefore should not differentially influence the rate ratios. Determining the age group of the bicyclists was based on appearance and body size, which may have led to some degree of misclassification. While this is an acceptable method which has been used in other studies (40-43), any misclassification would be non-systematic and similar between the 2000 and 2006 observation periods. Moreover, our inter-rater reliability study for common observations between two observers demonstrated that age group discrepancies between observers did not exceed 6%. We also did not control for other factors such as enforcement, extent of bicycle-friendly environment, and frequency of bicycling by riders (40, 44). Finally, the cycling patterns in a community may be related to other unmeasured factors such as in- and out-migration within a community, traffic patterns, educational campaigns, current and past construction activity, although they are unlikely to be influential factors in Alberta as indicated by a nation-wide Canadian health survey in 2010 (37).

5.4.3 Strengths

This study has several strengths over previous reports. First, this is one of the largest studies to evaluate the association between bicycle helmet legislation and bicycling exposure. Second, these results were based on actual observations of bicyclist rather self-report surveys. Third, to make our observations comparable between pre- and post-legislation, we repeated observations at the same locations, day of week and time of the day and used a relatively long follow-up period of four years. We revisited all 2000 sites (n=269) in 2006 except one school that had closed. In our study there was consistency among observers in recording bicyclist information (discrepancies did not exceed 6%). Fourth, all bicycling rates (with observation time as denominator) and rate ratios for the two surveys are presented separately by age group and stratified for locations. Fifth, we adjusted for covariates (weather conditions, temperature, quintile of <18 age group in each DA) using negative binomial regression with cluster adjustment for site of observation.

Finally, observation time (hour) was accounted for in our multiple regression analysis and multiple imputation methods were employed for missing data.

5.5 Conclusion

Since bicycling rates decreased in only two of the five groups of observation sites (schools and commuter routes) among the legislated target age group (<18) post-legislation and simultaneous increases in cycling were observed in other locations, the results of our study refute claims that helmet legislation has a negative effect on cycling exposure. Additional controlled and long term studies covering all age groups with concurrent examination of socio-economic status of bicyclists, level of enforcement, and other replacement activities would provide a more detailed understanding of the relationship between bicycle helmet laws and bicycling activity.

Table 5-1 Bicycling rate (per hour) and rate ratio of 2006 versus 2000 for children (<13) in site-specific variables in Alberta, Canada

Variable	2000			2006			RR (95% CI)[a]
	N [a]	OT [a]	R [a]	N	OT	R	
Total	1175	330.3	3.56	494	313.2	1.58	0.44* (0.36 to 0.55)
Location							
Urban [b]	1039	300.0	3.46	409	284.7	1.44	0.41* (0.33 to 0.52)
Non-ban[c]	136	30.3	4.49	85	28.5	2.99	0.66 (0.38 to 1.18)
Strata							
School	854	71.0	12.0	246	63.3	3.89	0.32* (0.24 to 0.44)
Campus	2	12.0	0.17	8	10.0	0.80	4.80* (1.10 to 20.9)
Park	69	40.0	1.72	75	36.0	2.09	1.21 (0.62 to 2.37)
Cycling path	54	43.6	1.24	48	44.7	1.07	0.87 (0.54 to 1.38)
Commuter route	88	61.7	1.43	53	63.4	0.84	0.59* (0.37 to 0.92)
Residential	108	102.0	1.06	64	95.8	0.67	0.63* (0.41 to 0.98)
Weather condition [d]							
Wet	147	68.1	2.16	57	60.8	0.94	0.43* (0.26 to 0.73)
Dry	1028	262.2	3.92	437	252.3	1.73	0.44* (0.35 to 0.56)
Temperature [e]							
Low	188	20.7	9.09	23	19.3	1.19	0.13* (0.08 to 0.22)
Moderate	608	162.6	3.74	246	151.8	1.62	0.43* (0.31 to 0.60)
High	379	147.0	2.58	225	142.1	1.58	0.61* (0.45 to 0.83)

a- N= total number of cyclists observed; OT= Observation time in hours; R= actual rate per hour of observation; RR= actual rate ratio 2006 versus 2000
b- Urban areas including Edmonton and Calgary
c- Non-urban areas including: Airdrie, Cochrane, Fort Saskatchewan, Leduc, Okotoks, Sherwood Park, Spruce Grove,
d- Based on Environments Canada National Climate Archive Data
e- Low<10, Moderate=10-20, and High>20 degrees Celsius
* Statistically significant

Table 5-2 Bicycling rate (per hour) and rate ratio of 2006 versus 2000 for adolescents (13-17) in site-specific variables in Alberta, Canada

Variable	2000			2006			RR (95% CI)[a]
	N [a]	OT [a]	R [a]	N	OT	R	
Total	635	330.3	1.92	440	313.2	1.41	0.73* (0.57 to 0.94)
Location							
Urban [b]	560	300.0	1.87	410	284.7	1.44	0.77* (0.60 to 0.99)
Non-ban[c]	75	30.3	2.48	30	28.5	1.05	0.43 (0.18 to 1.01)
Strata							
School	306	71.0	4.31	151	63.3	2.38	0.55 (0.31 to 1.00)
Campus	9	12.0	0.75	8	10.0	0.80	1.10 (0.59 to 1.93)
Park	46	40.0	1.15	38	36.0	1.06	0.92 (0.54 to 1.56)
Cycling path	83	43.6	1.90	73	44.7	1.63	0.86 (0.59 to 1.25)
Commuter route	101	61.7	1.64	69	63.4	1.09	0.67 (0.43 to 1.04)
Residential	90	102.0	0.88	101	95.8	1.05	1.19 (0.79 to 1.80)
Weather condition [d]							
Wet	142	68.1	2.08	111	60.8	1.82	0.88 (0.46 to 1.68)
Dry	493	262.2	1.88	329	252.3	1.30	0.69* (0.54 to 0.89)
Temperature [e]							
Low	57	20.7	2.76	5	19.3	0.26	0.09* (0.02 to 0.38)
Moderate	286	162.6	1.76	207	151.8	1.36	0.78 (0.51 to 1.18)
High	292	147.0	1.99	228	142.1	1.60	0.81 (0.61 to 1.08)

a- N= total number of cyclists observed; OT= Observation time in hours; R= actual rate per hour of observation; RR= actual rate ratio 2006 versus 2000

b- Urban areas including Edmonton and Calgary

c- Non-urban areas including: Airdrie, Cochrane, Fort Saskatchewan, Leduc, Okotoks, Sherwood Park, Spruce Grove,

d- Based on Environments Canada National Climate Archive Data

e- Low<10, Moderate=10-20, and High>20 degrees Celsius

* Statistically significant

Table 5-3 Bicycling rate (per hour) and rate ratio of 2006 versus 2000 for adults (18+) in site-specific variables in Alberta, Canada

Variable	**2000**			**2006**			**RR (95% CI)[a]**
	N [a]	**OT [a]**	**R [a]**	**N**	**OT**	**R**	
Total	2077	330.3	6.29	2375	313.2	7.58	1.21* (1.03 to 1.41)
Location							
Urban [b]	2004	300.0	6.68	2335	284.7	8.20	1.23* (1.05 to 1.44)
Non-ban[c]	73	30.3	2.41	40	28.5	1.41	0.58* (0.35 to 0.97)
Strata							
School	124	71.0	1.75	207	63.3	3.27	1.87* (1.17 to 2.99)
Campus	201	12.0	16.8	248	10.0	24.8	1.48 (0.90 to 2.45)
Park	577	40.0	14.4	524	36.0	14.6	1.01 (0.63 to 1.63)
Cycling path	396	43.6	9.08	425	44.7	9.50	1.05 (0.77 to 1.41)
Commuter route	417	61.7	6.76	505	63.4	7.97	1.18 (0.88 to 1.58)
Residential	362	102.0	3.55	466	95.8	4.86	1.37* (1.06 to 1.78)
Weather condition [d]							
Wet	327	68.1	4.80	300	60.8	4.93	1.03 (0.63 to 1.68)
Dry	1750	262.2	6.67	2075	252.3	8.22	1.23* (1.04 to 1.46)
Temperature [e]							
Low	35	20.7	1.69	40	19.3	2.07	1.22 (0.64 to 2.34)
Moderate	801	162.6	4.93	790	151.8	5.21	1.06 (0.82 to 1.36)
High	1241	147.0	8.44	1545	142.1	10.9	1.29* (1.05 to 1.58)

a- N= total number of cyclists observed; OT= Observation time in hours; R= actual rate per hour of observation; RR= actual rate ratio 2006 versus 2000
b- Urban areas including Edmonton and Calgary
c- Non-urban areas including: Airdrie, Cochrane, Fort Saskatchewan, Leduc, Okotoks, Sherwood Park, Spruce Grove,
d- Based on Environments Canada National Climate Archive Data
e- Low<10, Moderate=10-20, and High>20 degrees Celsius
* Statistically significant

Table 5-4 Adjusted rate ratio of bicycling by age group, 2006 to 2000 in Alberta, Canada

Variable		Rate ratio, cluster adjusted (95% CI)		
		Children (<13)	**Adolescents (13-18)**	**Adults (18+)**
Location				
School	2006	0.33* (0.24, 0.46)	0.49* (0.31, 0.77)	1.83* (1.16, 2.88)
	2000	1.0[a]	1.0	1.0
Campus	2006	4.37* (1.08, 17.6)	0.93 (0.53, 1.63)	1.28 (0.87, 1.87)
	2000	1.0	1.0	1.0
Park	2006	1.07 (0.61, 1.87)	1.18 (0.67, 2.09)	0.85 (0.52, 1.39)
	2000	1.0	1.0	1.0
Cycling path	2006	0.82 (0.47, 1.45)	0.84 (0.59, 1.21)	0.80 (0.53, 1.21)
	2000	1.0	1.0	1.0
Commuter route	2006	0.58* (0.40, 0.84)	0.65* (0.43, 0.99)	1.48* (1.09, 2.00)
	2000	1.0	1.0	1.0
Residential	2006	0.65 (0.41, 1.01)	1.15 (0.74, 1.77)	1.24 (0.95, 1.61)
	2000	1.0	1.0	1.0
Year				
2000	School	11.4* (8.00, 16.3)	5.97* (3.73, 9.57)	0.60* (0.37, 0.98)
	Campus	0.22* (0.06, 0.87)	1.00 (0.45, 2.24)	3.27* (2.10, 5.09)
	Park	1.91* (1.20, 3.06)	1.41 (0.87, 2.30)	3.77* (2.46, 5.77)
	Cycling path	1.25 (0.74, 2.09)	1.89* (1.19, 3.02)	2.95* (1.95, 4.47)
	Commuter route	1.26 (0.78, 2.04)	1.86* (1.23, 2.81)	1.49* (1.09, 2.05)
	Residential	1.0	1.0	1.0
2006	School	5.80* (3.67, 9.18)	2.56* (1.41, 4.64)	0.89 (0.56, 1.42)
	Campus	1.50 (0.63, 3.56)	0.81 (0.36, 1.81)	3.38* (1.82, 6.25)
	Park	3.17* (1.76, 5.69)	1.46 (0.74, 2.87)	2.60* (1.56, 4.33)
	Cycling path	1.59 (0.96, 2.64)	1.39 (0.87, 2.23)	1.90* (1.21, 3.00)
	Commuter route	1.13 (0.69, 1.83)	1.06 (0.69, 1.62)	1.78* (1.15, 2.76)
	Residential	1.0	1.0	1.0
Neighborhood age proportion <18[b]				
1st quintile		1.53 (0.99, 2.38)	1.24 (0.83, 1.86)	0.68 (0.45, 1.04)
2nd quintile		1.45 (0.97, 2.16)	1.21 (0.81, 1.81)	0.46* (0.31, 0.68)
3rd quintile		1.73* (1.13, 2.64)	1.22 (0.81, 1.83)	0.44* (0.30, 0.63)
4th quintile		2.16* (1.42, 3.31)	1.51 (0.94, 2.44)	0.32* (0.21, 0.48)
5th quintile		1.0	1.0	1.0
Location [c]				
Urban		0.69* (0.48, 0.99)	1.01 (0.64, 1.57)	2.22* (1.50, 3.29)
Non-urban		1.0	1.0	1.0
Weather condition [d]				
Wet		0.77 (0.57, 1.03)	1.51 (0.97, 2.36)	1.01 (0.72, 1.41)
Dry		1.0	1.0	1.0
Temperature [e]				
Low		0.81 (0.57, 1.17)	0.37* (0.20, 0.70)	0.32* (0.17, 0.57)
Moderate		0.88 (0.68, 1.13)	0.64* (0.49, 0.84)	0.72* (0.55, 0.94)
High		1.0	1.0	1.0

a- 1.0 is showing reference group in that particular comparison
b- Based on census data and proportion of male and female <18 years of age in the same dissemination area [quintile 2000: (0-0.11, 0.12-0.19, 0.20-0.24, 0.25-0.28, 0.29-1.00); for 2006: (0-0.10, 0.11-0.17, 0.18-0.20, 0.21-0.25, 0.26-1.00)]
c- Urban areas included two big cites of Calgary and Edmonton; non-urban areas are those cities and towns with less than 100,000 populations
d- Any rain ≥1 mm was considered wet otherwise defined as dry based on Environments Canada National Climate Archive Data
e- Low<10, Moderate=10-20, and High>20 degrees Celsius

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6 CHAPTER 6

EMERGENCY DEPARTMENT CODING OF BICYCLE AND PEDESTRIAN INJURIES DURING THE TRANSITION FROM ICD-9 TO ICD-10 (1)

Abstract

Background: The international classification of diseases version 10 (ICD-10) uses alphanumeric expanded codes and external cause of injury codes (E-Codes). We conducted a study to examine the reliability and validity of emergency department (ED) coders in applying E-codes in ICD-9 and 10.

Methods: Bicycle and pedestrian injuries were identified from the ED Information System from one period before and two periods after transition from ICD-9 to -10 coding. Overall, 180 randomly selected bicycle and pedestrian injury charts were reviewed as the reference standard (RS). Original E-codes assigned by ED coders (ICD-9 in 2001 and ICD-10 in 2004 and 2007) were compared with charts (validity) and also to ICD-9 and -10 codes assigned from RS chart review, to each case by an independent (IND) coder (reliability). Sensitivity, specificity, simple and chance-corrected agreements (Kappa statistics; κ) were calculated.

Results: Sensitivity of E-coding bicycle injuries by the IND coder in comparison with the RS ranged from 95.1 (95% CI: 86.3, 99.0) to 100% (95% CI: 94.0, 100.0) for both ICD-9 and -10. Sensitivity of ED coders in E-coding bicycle injuries ranged from 90.2 (95% CI: 79.8, 96.3) to 96.7% (95% CI: 88.5, 99.6). The sensitivity estimates for the IND coder ranged from 25.0 (95% CI: 14.7, 37.9) to 45.0% (95% CI: 32.1, 58.4) for pedestrian injuries for both ICD-9 and -10.

Conclusions: Bicycle injuries are coded in a reliable and valid manner; however, pedestrian injuries are often mis-coded as falls. These results have important implications for injury surveillance research.

6.1 Introduction

6.1.1 Background

Edmonton is one of the two largest cities in Alberta with a population of 1,034,945 (city=730,372; other metropolitan areas=304,573) (reported by Statistics Canada 2006). Four periods of a biannual Canadian community health survey (2001-2007) demonstrated that the prevalence of recreational bicycle use in Alberta among youth (12-17 years of age) ranged from 58-65% and the mean number of times adolescents bicycled in the past 3 months ranged from 16-30%. The prevalence of recreational bicycling for adults (18+) were 24-28% and mean number of times adults bicycled were 17-19 in the past three months (2). In the same study the prevalence of commuting bicycle use among youth in Alberta ranged from 31-35% and among adults ranged from 6-7% (2).

A nation-wide Canadian study demonstrated that 2% of all hospitalizations were due to bicycle-related injuries during ten-year period (1994- 2004) (3). A five-year study (1991-1995) in British Columbia also demonstrated that 4% of all children (1-19 years of age) ED visits were resulting from bicycle-related injuries (4).

In order to conduct surveillance studies, we need to code patients' diseases and circumstances of the event leading to admission to EDs or hospitals. Inpatient coding has been established in hospitals for use in disease and mortality surveillance, epidemiologic studies, billing and financial planning, and policy analyses (5 , 6).

The International Classification of Diseases versions 9 (ICD-9) and 10 (ICD-10) have been used to code diseases and other health problems recorded on many types of health and vital records including death certificates, hospitalization and emergency department (ED) data. The ICD-10 classification is the latest in a series which has its origins in the 1850s (7). ICD-10 was endorsed by the forty-third World Health Organization (WHO) assembly in May 1990 and began implementation in WHO member states in 1994 (8). The differences between the ICD-9 and ICD-10 are substantial, not only in disease classification, but also in coding rules. As the ICD-9 system has been used by many hospitals and clinics for years and is still used in many US centers, this transition introduced some challenges for long-term and comparative studies (9).

ICD-9 diagnosis codes consist of 3-digit numeric characters (001-999) with two decimals representing illnesses and conditions; alpha-numeric E codes (E000-E999), describing external causes of injuries, poisonings, and adverse effects; and V codes (01-V89) describing factors influencing health status and contact with health services. ICD-10 uses 3-digit alphanumeric codes (A00-Z99) with two decimals (8, 10). There are many other changes in ICD-10 that have been described in detail elsewhere (11). Canada implemented ICD-10 for the classification of cause of death beginning in 2000 (9). In an agreement with WHO, Canada adopted an enhanced version of ICD-10-CA by keeping the main structure of ICD-10, yet including more sub-group definitions using a third decimal and introducing the first Canadian classification of intervention (12).

E-codes have been widely used in surveillance system for mortality in traffic-related injuries (13) and morbidity of bicyclists, pedestrian, and sport and recreational related injuries (14-16); however, coding issues might have led to errors in the interpretation of research findings (17). Appropriate coding by ICD-9 and ICD-10 has always been an important issue for health surveillance and health services research. There have been many studies that have evaluated the validity and/or reliability of ICD-9 coding for external causes of injuries (from now on called E-coding for both ICD-9 and ICD-10) (6, 18-22) or that focused on principal diagnosis (23). Other studies evaluated the validity/reliability of ICD-10 for E-coding (24, 25) or only principal diagnosis in ICD-10 (26).

6.1.2 Transition from ICD-9 to ICD-10

For those countries that implemented ICD-10, the transition from ICD-9 to ICD-10 may have had an impact on the trends of causes of injuries. Bridge coding studies, to date, have evaluated the impact of a coding change by focusing on principal causes of mortality and not external cause of injury (9, 11, 27-31). One study examined the usefulness of ICD-10-CM in capturing public health diseases (reportable diseases, leading cause of death and morbidity/mortality related to terrorism) and reported agreement levels of coders when coding such diseases in ICD-9-CM and ICD-10-CM. They found

ICD-10-CM was more specific and fully captured more diseases than ICD-9-CM; however, coders were more consistent in coding ICD-9-CM than ICD-10-CM (32).

A long-term surveillance study in Alberta, Canada has shown that transition from ICD-9-CM to ICD-10- CA appeared to cause a decrease in the number of motor-vehicle-related deaths/hospital admissions with a smaller impact on motor-vehicle ED visits (33). Similar studies have demonstrated that transition from ICD-9 to ICD-10 can affect ranking of causes of death (30) possibly resulting in a decrease in diseases such as pneumonia or an increase in cerebrovascular diseases (31).

In Alberta, ICD-10-CA codes were implemented on January 1st 2000 for deaths and April 1st 2002 for morbidity data (hospitalization and ED records) (33). Concurrently, the Alberta Government implemented a law mandating bicyclists <18 years of age to wear helmets, effective May 1st 2002 (34). Given the timing of the bicycle helmet legislation and the coding change, it was essential to investigate if the coding transition may have influenced the overall incidence of cycling-related injuries independent of the legislation.

6.1.3 Aim

The aim of this study was to evaluate the reliability and validity of ED coders in applying ICD-9-CM and ICD-10-CA external cause of injury codes for bicyclists. In our study we used pedestrian injuries to establish how coding changes affected injury trends in another vulnerable road user group not affected by bicycle helmet legislation.

6.2 Methods

6.2.1 Case selection

We identified all cycling- and pedestrian-related injuries from the Hospital Administration System Solutions (HASS) Emergency Department Information System (EDIS) software.(35) This system captures data on all patients presenting to the ED including patient demographics, illness and injury severity, times of arrival and care, injury descriptions, symptoms, consultations, and triage/vital signs assessment. Using the patient's complete paper chart, medical record nosologists (henceforth referred to as ED coders) assign ICD-9-CM before or ICD-10-CA, after April 1st 2002, after reviewing physician-assigned diagnoses at the time of ED discharge (home or hospital). EDIS review and case selection was performed for the four busiest cycling months of the year (May through August) in three separate years (2001 = pre-transition to ICD-10; 2004 and 2007 = post-transition to ICD-10).

6.2.2 Definitions

On the basis of ICD-9 and ICD-10 E-code descriptions (7), bicycle and pedestrian injuries were defined (see Appendix 1) and used by investigators to identify all cases from the EDIS database. The key words from these definitions were used for searching cases of bicycle and pedestrian injuries admitted to the EDs. Key words for bicycle injuries included: bike, biking, cycle, bicycle, bicycling, bike injuries, cycle injuries, bicycle injuries, biking, and tricycle. Key words for pedestrian injuries included: pedestrian, walking, jogging, car-ped, side walk, curb, cross walk, hit by (bicycle, motorcycle, car, or bus), ran over, parking lot. A variety of misspellings of bicycle (e.g., bik, bicycl) and pedestrian terms (e.g., wlk, jogin) were also used to make sure we have not missed any cases due to typing mistakes.

6.2.3 Data collection

After retrieving all relevant cases, two separate pools of bicycle and pedestrian injuries was prepared from adjudication with senior nursing staff (making sure they were valid bicycle and pedestrian injuries), research assistants randomly selected and reviewed 180 bicyclist and 180 pedestrian presentations (360 in total) from three hospital EDs in Edmonton (University of Alberta Hospital, Stollery Children's Hospital and North East Community Health Center). Our sample included 60 injured cyclists and 60 injured pedestrians in each year.

A specific data extraction form was designed to capture necessary information from patients' paper charts. Using the extracted information, an independent expert coder (IND coder) was employed to assign both ICD-9-CM and ICD-10-CA codes. The IND coder was not aware of any previous coding associated with a bicyclist or pedestrian injury, nor the study hypothesis. After providing both ICD-9-CM and ICD-10-CA codes for each case, we merged these data with administrative data from the ambulatory care classification system (ACCS), a central electronic database for diagnosis, procedure, health care utilization and follow-up of emergency department patients in Alberta, *Canada* which originally produced by ED coders. Therefore, each case had an ICD-9-CM (before April 1st, 2002) or an ICD-10-CA code (after April 1st, 2002) assigned by ED coders as usual practice forming part of the electronic administrative health record, with ICD-9-CM *and* ICD-10-CA codes assigned by the IND coder.

6.2.4 Analysis

Data were analyzed using Stata IC version 11 (36). The data included information from chart review of selected bicyclists and pedestrians from EDIS, ICD-9-CM (before April 1st, 2002) or ICD-10-CA (after April 1st, 2002) codes available from the ACCS by ED coders at the time of discharge, and ICD-9-CM/ICD-10-CA codes assigned by our IND coder. Examining validity, we calculated sensitivity, with 95% confidence intervals (CIs), as the proportion of all cycling injuries we identified through our chart review (reference standard) that were similarly coded as bicycle injuries by the ED and IND coders. Similar sensitivity estimates and 95% CIs were produced for ED (ACCS data) and IND coders for pedestrians.

Simple percent agreement between the two coders was calculated. Since simple percent agreement does not account for agreement by chance, we used Cohen's Kappa statistic [κ], a measure of chance-corrected proportional agreement. (37). Kappa agreement was defined *a priori* as almost perfect (0.81-1.0), substantial (0.61 - 0.8), moderate (0.41 - 0.60), fair (0.21 – 0.40), slight (0.0 – 0.20) or poor (< 0.0) (38).

We constructed separate 2 x 2 tables for ICD-9-CM and ICD-10-CA by year. We calculated percent agreement and Kappa for coding between the ED coders and the IND coder. For sensitivity and agreement analysis pedestrians were used as negative cases for bicyclists and vice-versa.

6.2.5 Post-hoc analysis

After we finished our analyses and on the basis of our reference standard medical chart reviews, many of the pedestrian injuries were not E-coded accurately; therefore, we decided to perform a post-hoc investigation for those mis-classified E-codes among pedestrian injuries.

6.2.6 Sample size

We based our sample size on sensitivity, or the proportion of all EDIS identified cycling injuries in Edmonton transferred to ACCS. Our focus was on estimation (confidence intervals) rather than statistical testing. For a confidence interval width of 15% (+/-7.5%), assuming a worst case of 50% sensitivity, we would require 171 subjects. Therefore, with 180 subjects, the 95% CI around the estimate of sensitivity was expected to be less than 10%.

6.2.7 Ethics

We obtained ethical approval from the University of Alberta Health Research Ethics Board. Patients were not contacted during this study.

6.3 Results

6.3.1 Validity of E-coding by ED and IND coder

Sensitivity of E-coding bicycle injuries by ED coders in comparison to the RS ranged from 90.2% (95% CI: 79.8, 96.3) in 2007 to 96.7% (95% CI: 88.5, 99.6) in both 2001 and 2004 (Table 1 upper section). Sensitivity of E-coding bicycle injuries by the IND coder in comparison to the RS ranged from 95.1% (95% CI: 86.3, 99.0) in 2007 to 100% (95% CI: 94.0, 100) in 2001 (Table 1 bicycle injuries).

Sensitivity of E-coding pedestrian injuries by ED coders in comparison to the RS ranged from 25.0 (95% CI: 14.7, 37.9) in 2004 to 38.3% (95% CI: 26.1, 51.8) in 2001.The sensitivity estimates for the IND coder in coding pedestrian injuries compared with the RS ranged from 30.0% (95% CI: 18.8, 43.2) in 2004 to 43.3% (95% CI: 30.6, 56.8) in 2001 (Table 1 pedestrian injuries).

Specificities for bicycle injuries were from 98.3 to 100% and for pedestrian injuries all were 100% (not presented in the Table 1).

6.3.2 Validity of E-codes in ICD-10 and ICD-9

The results of the validity analysis showed that sensitivity of E-coding bicycle injuries by the IND coder using ICD-10 for the pre-transition year of 2001 was 98.3% (95% CI: 91.1, 100); sensitivity for ICD-9 for post-transition was 98.3% (95% CI: 91.1, 100) in 2004 and 96.7% (95% CI: 88.7, 99.6) in

2007 (Table 1 shaded rows upper section). Sensitivity of E-coding for pedestrian injuries by the IND coder using ICD-10 for the pre-transition year (2001) was 45% (95% CI: 32.1, 58.4) and re-testing of ICD-9 for post-transition were 25.0% (95% CI: 14.7, 37.9) in 2004 and 37.3% (95% CI: 25.0, 59.0) in 2007 (Table 1 shaded rows lower section).

6.3.3 Reliability of E-coding between ED and IND coders

Examining chance-corrected agreement (Kappa) and applying Landis (38) ranking of Kappa, agreement between ED coders and the IND coder for bicycle injuries were almost perfect ranged between 0.88 and 0.97 (κ_{pooled} = 0.94; 95% CI: 0.91, 0.98). Similarly, almost perfect agreement was seen in the comparison of ED coders to the IND coder for pedestrian injuries ranged between 0.90 and 0.92 (κ_{pooled}= 0.92; 95% CI: 0.87, 0.98) (Table 2).

6.3.4 Post-hoc results for pedestrian E-coding

Approximately 3.4% of pedestrian injuries that we identified and confirmed through EDIS and chart review were not assigned an external cause of injury by the ED coder. ED coders also misclassified between 57% (ICD-9-CM) and 66% (ICD-10-CA) of pedestrian injuries. Of 57% misclassified pedestrian injuries in ICD-9-CM, 67% were miscoded as falls, 17% as unspecified, 3% as unspecified vehicle collision, and 8% had no E-code. Of 67% misclassified pedestrian in ICD-10-CA, 70% were miscoded as falls, 23% overexertion, 1% bitten dog, 1% striking stationary object, and 5% had no E-code (not shown in Figure 1). Missing or misclassified bicycling injuries did not exceed 4% (Figure 1).

For the IND coder (who independently coded all bike and pedestrian injuries by ICD-9-CM and ICD-10-CA) there were no missing E-codes for pedestrian injuries; however, approximately 63% of the records were misclassified. Of these, 58% were misclassified as falls for both ICD-9-CM and ICD-10-CA codes. The IND coder had 1.1% missing codes (in ICD-10 CA) for bicycle injuries and 2.2 and 1.7% misclassification for ICD-9-CM and ICD-10-CA respectively (Figure 2).

6.4 Discussion

6.4.1 Findings

This study evaluated the reliability of ED coders in E-coding bicycle injuries in three Canadian EDs. We also studied the validity of ICD-9-CM and ICD-10-CA in E-coding bicycle injuries, using pedestrian E-coding as a comparison group. The results of our study revealed that sensitivity of E-coding bicycle injuries was consistently high before and after transition from ICD-9-CM to ICD-10-CA for IND/ED coders using medical charts as reference standard. Reviewing documented information, the IND coder was able to assign relevant E-codes for bicycle injuries close to perfect match. The limited differences between ED coders and the IND coder have demonstrated the high quality of bicycle injury coding, and supports conclusions drawn from bicycle studies using hospital and ED administrative databases.

The difference between ICD-9 and ICD-10 for external cause of injuries among pedestrian and bicyclists is mostly related to the method of defining each code. In ICD-9 the letter "E" at the beginning of codes is an indication of external cause of injury followed by three digits that specify both external cause of injury and the circumstances of the injury (e.g. E801=railway involving collision with other object); decimals will specify if the injured person is a pedestrian or bicyclist. In ICD-10 the letter "V" and the first digit will specify the external cause of injury and the injured person (V0 for pedestrian and V1 for bicyclist) and the second digit will specify the external cause of injury (e.g. 5= pedestrian injured in collision with railway or railway vehicle). The decimal in ICD-10 is used for specifying circumstances of the injury event (e.g. traffic or non-traffic related) (8, 10). We have shown in validity analysis by the IND coder that ICD-10 is a valid classification for E-coding all bicycle and pedestrian injuries so as ICD-9.

Five studies in the United States (6, 18, 20-22) and one in New Zealand (19) reported reliability of ICD-9-CM E-coding for injured patients. Exact code agreements between an IND coder and hospital nosologists were reported to be from 55.6 to 82%. One study in Australia (24) and one in New Zealand (25) reported 67.6 and 71% correct E-coding in ICD-10, respectively. A systematic review (including 5 studies) also demonstrated that the range of accurate E-coding in hospital records was between 65% (exact code agreement) and 85% (agreement for broader groups of codes) (39).

Our study found different results for E-coding of a comparison population of pedestrian injuries. Despite the reliability of pedestrian E-coding between the IND and ED coders (Table 2), both demonstrated many cases (over 50%) with incorrect E-codes (Table 1 lower section). The differences between all coders and the reference standard (medical charts) demonstrate the poor quality of pedestrian injury coding, and call into question conclusions drawn from any hospital and ED administrative databases examining pedestrian injuries.

Studying the accuracy of E-coding for work-related and non-work-related injuries in Massachusetts ED data, Hunt et al. demonstrated that machinery injuries were misclassified in many cases (65%) to other external cause of injuries such as cut/pierce, struck by/against, falls, overexertion, and missing (18). In the same study it was revealed that there was misclassification for coded as not-specified (54%), not-elsewhere classified (31%), other specified (19%), natural/environmental (17%), fall (11%), fire/burn (11%), poisoning (9%), struck by/against (9%), cut/pierce (3%), transportation (1%), overexertion (1%). Overall, all causes were misclassified 14% of the times to other groups of injuries (18).

In another study, the % error in the 5th digit location for E-coding was between 2% (for Homicide/assault) and 15% (for medical injury) (6). Another source of inconsistency between original and independent auditor codes appeared to be due to missing E-codes making up between 14% (22) and 20% (21) of injury cases. We investigated the many missing E-codes for pedestrian injuries and found that only 3.3% (pre-transition to ICD-10) and 3.4% (post-transition to ICD-10) of the time ED coders forgot to E-code for pedestrian injuries; however, between 57% and 66.3% of pedestrian injuries were misclassified, mostly as falls. The IND coder had also miscoded a substantial proportion of pedestrian injuries as falls.

As suggested by other studies (6, 18-20, 22, 25), we also realize that E-coding for pedestrian injuries needs to be emphasized in the nosologist training programs to reduce the number of misclassified cases. As fall was the main source of misclassification, we would suggest that a detailed search for location of the falls must be considered an important piece of information for pedestrian E-coding. It is quite likely that other mechanisms of injury would be subject to the same level of misclassification as our pedestrian injuries (e.g., “struck by or against, falls in non-pedestrian settings) and further work in this area is required. Sensitivity of coding for bicycle injuries was high for both ED and IND coders and, due to misclassification, was lower for coding of pedestrian injuries. ED coders and our IND coder demonstrated a high degree of agreement regardless of coding for bicycle or pedestrian injuries (Table 2).

6.4.2 Limitations

Our study was not without limitations. Since we only conducted our study in three hospital EDs in Edmonton, our results may not be generalizable to other locations. In our study, the reference standard was developed through chart review by research staff and confirmed by clinical nurses. The decisions were made long after the discharge occurred and could not be validated further; however, we believe that we selected an unbiased group of both cyclists and pedestrians for coder review. Although it seems very unlikely, we may have missed some patients in the EDIS if ED staff failed to use appropriate key words to identify bicycle or pedestrian injuries; however, missing cases do not affect the validity and reliability of our study. Since in our analysis we have only used pedestrians as the comparison group for bicyclists it may be argued that we would over-estimate levels of agreement because of the limited range of other non-cyclist choices. However, we suspect our choice of pedestrians as a comparator group will have led to a conservative estimate in that it would be hard to distinguish this group from cyclists. If we had chosen less similar mechanisms (e.g., farm injuries or motor vehicle injuries) as our comparison group, it is quite likely that the agreement would have been higher. Another limitation of our study is that we did not look at validity and reliability of E-codes by outcome status of bicyclists (e.g., head vs non-head injuries) and also we did not measure comparability ratio of two classification systems for such outcomes.

6.4.3 Strengths

We selected cases from one year coded by ICD-9-CM (2001) and two years coded by ICD-10-CA. Unlike other coding studies, we focused only on one external cause of injury (bicycle) and we examined a similarly vulnerable road user group (pedestrian). This is very helpful to make sure that using administrative data to study all bike-related injuries is reliable. Concurrently, validity of IDC-9-CM and ICD-10-CA was evaluated for E-coding of these two types of traffic-related injuries. Finding more than 50% misclassified E-codes for pedestrian injuries initiated a post-hoc investigation showing that pedestrian injuries were often miscoded as falls. In our analysis we emphasized Kappa rather than simple percent agreement to test reliability and validity. This is also the first study in Canada evaluating the reliability of coders and the validity of the ICD-9-CM and ICD-10-CA systems for bicycle and pedestrian injuries. We selected our cases from the months of summer that included more cases of bicycle or pedestrian injuries and used a random selection method from a pool of bicycle and pedestrian injuries.

6.5 Conclusion

This study shows that ED coders are reliable in E-coding bicycle injuries using ICD-9-CM and 10 systems. ICD-10-CA and ICD-9-CM are valid classification tools in capturing bicycle injuries presenting to the ED. Pedestrian injuries, however, may be miscoded as falls and this needs to be considered when examining ICD coded administrative data on these vulnerable road users. These results have important implications for injury surveillance research.

Table 6-1 Sensitivity of ED and IND coder in comparison to reference standard (medical charts) in coding external cause of bicycle and pedestrian injuries in the three EDs in Edmonton to Alberta Canada

Activity	**Reference standard (Medical charts)**				**Sensitivity [b]**	
Bicycle injuries	a [a]	b	c	d	%	95% CI
ED coder 2001 (ICD-9)	58	0	2	60	96.7	(88.5 to 99.6)
ED coder 2004 (ICD-10)	58	0	2	60	96.7	(88.5 to 99.6)
ED coder 2007 (ICD-10)	55	0	6	59	90.2	(79.8 to 96.3)
Overall	*171*	*0*	*10*	*179*	*94.5*	*(90.1 to 97.3)*
IND coder 2001 (ICD-9)	60	0	0	60	100.0	(94.0 to 100)
IND coder 2001 (ICD-10) [c]	59	0	1	60	98.3	(91.1 to 100)
IND coder 2004 (ICD-10)	59	1	1	59	98.3	(91.1 to 100)
IND coder 2004 (ICD-9) [c]	59	1	1	59	98.3	(91.1 to 100)
IND coder 2007 (ICD-10)	58	0	3	59	95.1	(86.3 to 99.0)
IND coder 2007 (ICD-9) [c]	59	0	2	59	96.7	(88.7 to 99.6)
Overall	*180*	*1*	*1*	*178*	*99.4*	*(97.0 to 100)*
Pedestrian injuries						
ED coder 2001 (ICD-9)	23	0	37	60	38.3	(26.1 to 51.8)
ED coder 2004 (ICD-10)	15	0	45	60	25.0	(14.7 to 37.9)
ED coder 2007 (ICD-10)	21	0	38	61	35.6	(23.6 to 49.1)
Overall	*59*	*0*	*120*	*181*	*33.0*	*(26.1 to 40.4)*
IND coder 2001 (ICD-9)	26	0	34	60	43.3	(30.6 to 56.8)
IND coder 2001 (ICD-10) [c]	27	0	33	60	45.0	(32.1 to 58.4)
IND coder 2004 (ICD-10)	18	0	42	60	30.0	(18.8 to 43.2)
IND coder 2004 (ICD-9) [c]	15	0	45	60	25.0	(14.7 to 37.9)
IND coder 2007 (ICD-10)	22	0	37	61	37.3	(25.0 to 50.9)
IND coder 2007 (ICD-9) [c]	22	0	37	61	37.3	(25.0 to 50.9)
Overall	*67*	*0*	*112*	*181*	*37.4*	*(30.3 to 45.0)*

ED: emergency department; IND: independent
a- a: chart (+) coder (+) or true positive; b: chart (-) coder (+) or false positive; c: chart (+) coder (-) or false negative; d: chart (-) coder (-) or true negative
b- Sensitivity=a/(a+c)
c- Double coding

Table 6-2 Simple and chance-corrected agreements between ED and IND coders (head to head) in coding external cause of bicycle and pedestrian injuries in the three EDs in Edmonton, Alberta Canada

Activity	**IND coder**				**Agree ment b**	**Kappa statistics [c]**	
Bicycle injuries	a a	b	c	d	%	Point estimate	95% CI
ED coder 2001 (ICD-9)	58	0	2	60	98.3	0.97	(0.92, 1.00)
ED coder 2004 (ICD-10)	57	1	3	59	96.7	0.93	(0.87, 0.99)
ED coder 2007 (ICD-10)	53	2	5	60	94.2	0.88	(0.80, 0.97)
Total and pooled Kappa	171	0	10	179	97.2	0.94	(0.91, 0.98)
Pedestrian injuries							
ED coder 2001 (ICD-9)	23	0	3	94	97.5	0.92	(0.84, 1.00)
ED coder 2004 (ICD-10)	15	0	3	102	97.5	0.90	(0.78, 1.00)
ED coder 2007 (ICD-10)	21	0	1	98	99.2	0.97	(0.92, 1.00)
Total and pooled Kappa	59	0	8	293	97.8	0.92	(0.87, 0.98)

ED: emergency department; IND: independent
a- a: chart (+) coder (+) or true positive; b: chart (-) coder (+) or false positive; c: chart (+) coder (-) or false negative; d: chart (-) coder (-) or true negative
b- Agreement= (a+d)/(a+b+c+d)
c- kappa statistics=(probability of agreement) –(probability of by-chance agreement)/1 - (probability of by-chance agreement)

Figure 6-1 Frequency of missed/misclassified E-codes by ED coders for bicycle (bike) and pedestrian (ped) injuries in three EDs in Edmonton, Alberta Canada

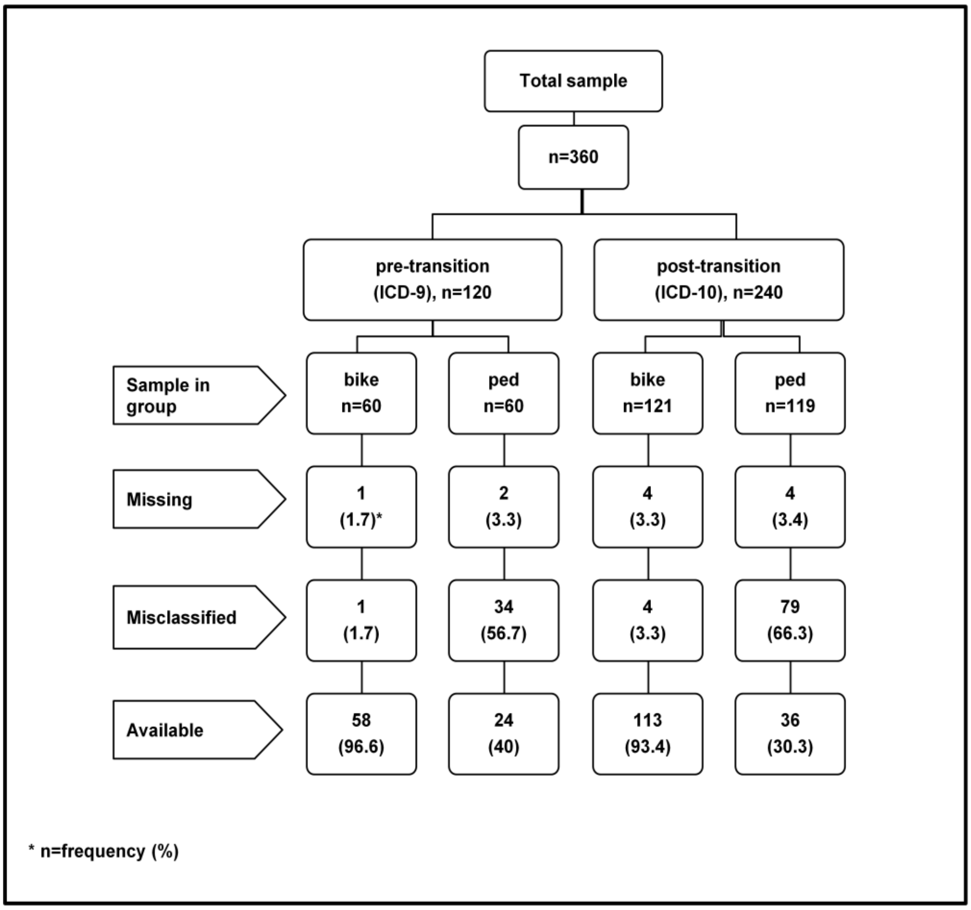
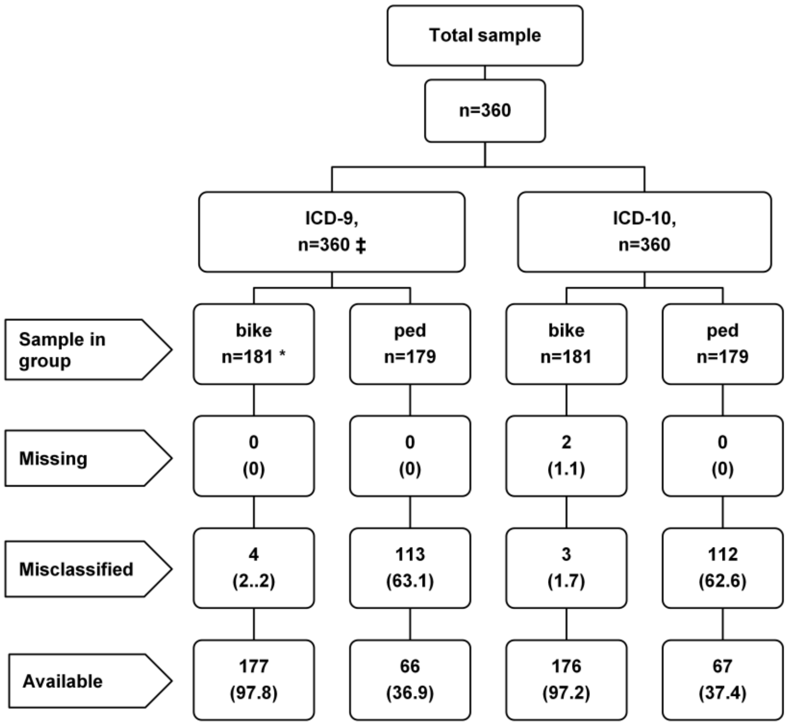


Figure 6-2 Frequency of missed/misclassified E-codes by IND coder for bicycle (bike) and pedestrian (ped) injuries in three EDs in Edmonton, Alberta Canada



‡ Independent coder coded all bike or ped cases with both ICD-9 and ICD-10 either pre-transition or post-transition
* n=frequency (%)

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7 CHAPTER 7

TREND IN HEAD INJURIES ASSOCIATED WITH MANDATORY BICYCLE HELMET LEGISLATION TARGETING CHILDREN AND ADOLESCENTS

Abstract

Background: Bicycling related head injuries (HIs) can be severe. Helmet use has been shown to be effective in reducing head injury risk. We conducted this study to investigate any change in HIs after helmet legislation in Alberta in 2002.

Methods: Using ICD9-CM and ICD10-CA coding, data were collected from over 100 hospitals and emergency departments (EDs) in Alberta Canada for the six fiscal years (April 1999 - March 2007). Data from Statistics Canada were used for population rates. Trends in HI rates were compared between bicyclists and pedestrians in three age groups (children: <13, adolescents: 13-17, and adults: 18+). The HI Proportion (P) and proportion ratio (PR) comparing post (2003-06)- to pre (1999-2001)-legislation were examined. Multiple Poisson regression analyses were used to assess main and interaction effects of year, activity, and age groups on HI.

Results: During seven years (excluding the run-in fiscal year of April 2002-March 2003) there were 42895 ED visits and 2838 hospitalizations for bicyclists; during the same period there were 9479 ED visits and 2123 hospitalizations for pedestrians. ED bicycle HI declined by 20% (PR = 0.80; 95% CI: 0.77, 0.84) in children and 11% (PR=0.89; 95% CI: 0.82, 0.97) in adolescents; however, no change was observed for adults (PR=0.98; 95% CI: 0.92, 1.04). Bicycle HI related hospitalizations decreased by 39% (PR = 0.61; 95% CI: 0.47, 0.79), in children, 43% (PR = 0.57; 95% CI: 0.43, 0.75) in adolescents and 27% (PR = 0.73; 95% CI: 0.61, 0.87) in adults. There were no observed changes in the proportion of pedestrian HIs resulting in ED presentations or hospitalizations over the same period.

Conclusion: Among cyclists, the target age groups (<18) experienced a significant decline in the proportion of HI ED visits after helmet legislation;

the proportion of bicyclist HI hospitalizations declined for all age groups. Decreasing HI among the target group was larger than expected in both ED visits and hospitalization based on trends in pedestrian and adult cyclist injury data.

7.1 Introduction

7.1.1 Background

During the period from 1994-95 to 2003-04, bicycle-related injuries resulted in 2% of hospitalizations in Canada, of which 24% were head injuries (HI) (1). Head injuries are among the most serious injuries among bicyclists comprising one-third of emergency department (ED) visits, two-thirds of hospital admissions, and three-quarters of deaths (2). Because bicycling is popular as a means of recreation and transportation, studies have shown that children and adolescents (3-9), adults (1, 10-12), ***and*** older adults (13) are at risk of serious injuries from bicycling.

HIs are consistently one of the most common and serious bicycling injuries (6, 7, 9, 10, 14-21). It has been theorized that bicycling related traumatic brain injury creates a greater financial burden on society than non-traumatic brain injury (3, 11) and some argue helmets are a cost effective intervention (22, 23). The evidence is clear that bicycle helmet use prevents head, brain and facial injuries (24, 25) and this evidence has advanced the call for mandatory helmet legislation in Canada and elsewhere (26, 27).

Since surveillance systems for capturing non-fatal head injuries in bicyclists are largely imperfect, it is difficult to determine the true effectiveness of bicycle legislation on injury rates. Moreover, due to the insufficient numbers of bicycle injuries in any single community, the lag between occurrence and reporting, and potential for incorrectly coding cases (28) impedes the evaluation of local and regional initiatives. It has been suggested that the measurement of helmet use by cyclists is the most appropriate proxy indicator of preventable bicycle-related HIs. Despite these barriers, some studies have investigated the relationship between legislation and HI, and have identified a substantial decrease in bicycle-related mortality (29, 30) and head injuries (31-36) in communities where bicycle helmet legislation was implemented. Other studies have demonstrated declining trends in bicycle HIs following helmet promotion campaigns (37-39) and in areas where helmet use has increased over time (16, 34, 40).

7.1.2 Intervention

Legislation mandating helmet use for all cyclists less than 18 years of age in Alberta, Canada was implemented effective May 1st, 2002 (41). Helmet use before and after legislation has been assessed through direct observation after two (42) and four (43) years of legislation. These two studies demonstrated an increase in helmet use among the targeted population less than 18 years old, with less impressive increases for adults not covered by legislation.

7.1.3 Aim

This study was designed to investigate the rate of ED visits and hospitalizations for HIs among bicyclists after helmet legislation in Alberta. It has been suggested that the pattern of pedestrian traffic injuries could be used to assess trends in the road safety environment independent of bicycle helmet use and legislation (44). In order to examine general traffic safety, we compared bicyclist injury trends with those of pedestrians over the same period in age groups targeted (<18 years old) and not targeted (18 years and older) by bicycle helmet legislation.

7.2 Methods

7.2.1 Data sets

Data on hospitalizations (Discharge Abstract Database – DAD) and ED visits (Ambulatory Care Classification System - ACCS) were obtained from Alberta Health and Wellness (AHW) for all injuries sustained by bicyclists and pedestrians from April 1st, 1999 to March 31st, 2007 (8 chronological years).

ACCS is an ambulatory care database maintained by AHW (45). This database records all ED visits for over 100 hospitals across Alberta. Prior to 2002, diseases were coded in ACCS based on the international classification of diseases (ICD) Version 9 (ICD-9-CM); ICD-10-CA coding was implemented in January 2000 for vital statistics data (deaths) and April 2002 for morbidity data (both hospitalization and ED records) (46). All AHW data are coded by trained medical records nosologists, and make use of the emergency record, imaging results, nursing notes and consultation notes available from each encounter (47).

The DAD is a hospital admission database maintained by AHW for the Canadian Institute of Health Information (CIHI) at all hospitals where admissions occur. The data are coded by trained medical records nosologists, and make use of the medical record including ED and in-patient records, nursing and physician progress notes, imaging and laboratory results, and consultations available during the admission (48).

7.2.2 Bicyclist and pedestrian definition

We included all bicycle injuries regardless of whether they involved a motor-vehicle, using the CIHI definition of head injuries (1, 49) or where non-traffic related injuries occurred in areas such as parks, residential areas or designated cycling paths. This definition has been used by other Canadian researchers (32). Therefore, all pedal cyclists with external injury codes (E-codes) including E800-807 with .3 extensions, E810-E825 with .6 extensions (excluding E817 and E824), and 826- E829 with .1 extensions were captured from the data set in the period before transition to ICD 10-CA. After April 1st, 2002, pedal cyclists were captured using ICD10-CA codes including V10.0-V10.5, V10.9; V11.0-V11.5, V11.9; V12.0-V12.5, V12.9, V13.0-V13.5, V13.9, V14.0-V14.5, v14.9, V15.0-V15.5, V15.9, V16.0-V16.5, v16.9, V17.0-V17.5, V17.9, V18.0-V18.5, V18.9, V19.0-V19.6, V19.8, and V19.9. It has been shown that ICD-9 (50) and ICD-10 (51, 52) coding systems are reliable sources for external cause of injury and also for reportable public health diseases (53).

ICD9-CM pedestrian codes before April 1st, 2002 included E-codes E800-E807 with .2 extensions, E810-E825 with .7 extensions and E826-E829 with .0 extensions. ICD10-CA pedestrian codes for the period after April 1st, 2002 included V01-V06, V09 with extensions .0, .1, and .9, V09.2 and V09.3.

We excluded re-admissions for treatment of the same injury (54), defined as a repeat encounter for a bicycling or pedestrian injury within one month of the initial visit. For ICD9-CM, before April 1st, 2002, both ACCS and DAD provided E-codes separately in three diagnosis code fields. After April 1st, 2002 using ICD-10-CA, of all aforementioned data that ACCS captures, up to nine diagnosis code fields were available for each ED visit and up to 15 diagnosis code fields were available in DAD for each hospitalization. Of these nine and 15 diagnosis codes, some could be used for external cause of disease codes if applicable.

7.2.3 Injury definitions

In this study, HI was defined as an injury either to the scalp, skull, brain, brain stem or face (55). Injury to the head included superficial laceration, abrasions, bruises on the scalp, skull fractures, concussions, cerebral contusions and lacerations, and all intracranial hemorrhages (e.g., subarachnoid, subdural, epidural, and intra-cerebral). Non-specific diagnoses of closed head injuries were also included as HI in these analyses. Any injury above the neck was included as a HI (56, 57). We included all facial injuries (upper and lower) as HI; although helmets are not supposed to protect the lower face; considering them as facial injuries is a conservative method for assessing the protective effect of legislation on HI (i.e., increasing probability of HI per injured bicyclist post-legislation). In those cases where a bicyclist or pedestrian suffered both head and/or facial injuries and an accompanying injury (e.g., fractured femur, dislocated shoulder, abdominal trauma), they were coded as having a head or facial injury.

ICD9-CM codes for the defined head injuries included 800-805, 850-860, 870-875, 900-901, 920-922, 959.0-959.1. ICD9-CM codes for other injuries included 800-940 and 950-960, excluding head injuries. ICD10-CA codes for defined head injuries included S00-S09 and for other injuries included S00-S99 and T00-T149, excluding head injuries.

7.2.4 Analysis

SPSS version 14 (58) was used for linking data and identifying cases in the administrative data set and STATA/IC version 11.1 (59) was used for analyses. The primary study outcome was the trend in HIs among bicyclists compared with other injuries (non-head). The same injuries among pedestrians were used as a control group for traffic safety trends independent of the legislation. Changes over time in the cumulative incidence of HIs and non-head injuries based on ED visits and hospitalizations, are reported. Injury data denominators were estimated from the Alberta population from 1999 to 2006 based on Canadian Census data (60). Since census data are only available every five years, we used predicted population for the years between census years as the best estimate available (60) which is being produced though a specifically designed method of estimation available from Statistics Canada (61).

We reported annual cumulative incidence of head and non-head injuries (new cases in a year per 100,000 population), for the three years (1999-2001) before and four years (2003-2006) after bicycle helmet legislation stratified by activity (bicycling vs. pedestrians) and age groups.

The proportion of HIs (defined as HI divided by HI + Non-HI) and proportion ratio (PR) post- to pre-legislation (with 95% confidence limits) were estimated. We reported subgroup analysis for variables of activity (bicycling/pedestrians) , age group (<13, 13-17, 18+) (3, 5, 16, 29, 35), sex (3, 5, 6, 16, 17), and urban/non-urban (Calgary and Edmonton as urban and other smaller communities as non-urban areas) factors (62). It has been shown in some studies that child bicyclists in high socio-economic status (SES) areas were more likely to wear helmet (63); however, two former studies did not find any significant association between SES and bicycle head injury (32, 62). Since our data from AHW did not contain individual measures of SES, we did not attempt to use census-based SES in our sample population. Moreover, in another study examining bicycle helmet use in Alberta, neighbourhood average annual income (<50,000, 50,000-59,000, and 60,000+) based on Statistics Canada census data did not influence prevalence of helmet use among bicyclists (42).

The analyses were conducted for both bicyclists and pedestrians excluding the fiscal year of April 2002- March 2003 (year of transition to helmet legislation for those <18 years old).

We used Poisson regression analysis for both uni- and multivariate analyses. Using multiple Poisson regression analysis, we estimated the proportion of HIs post- to pre-legislation with covariates of sex and location (urban/non-urban area) in the model (64). 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 (42). The goal of the study was to investigate trends in the proportion of head injuries among pedestrians to account for the general road safety environment independent of the bicycle helmet legislation. Separate analyses were conducted for ED visits and hospitalizations. Model goodness of fit was assessed by using deviance statistics and models were checked for overdispersion (59, 65).

7.2.5 Post-hoc analysis

Assuming that any change in the proportion of HIs could have been translated to health care utilization (66, 67), we conducted a post-hoc analysis of HI among cyclists and pedestrians by age after controlling for sex and location. In this method, any change in the proportion of HI was considered as change in the presentation of injured bicyclists or pedestrians to EDs or hospitals and the corresponding health care utilization. If the effect estimate of bicycle and pedestrian HI was statistically significant, subtraction of that from 100% has been used as change in the health care utilization and if effect estimate was not significant it was reported as no difference (ND).

7.3 Results

During the seven years of study (excluding the run-in year of 2002) there were 42895 ED visits and 2838 hospitalizations for bicyclists; during the same period there were 9479 ED visits and 2123 hospitalizations for pedestrians (Table 7-1 and 7-2). Of those, bicyclist HIs were recorded for 9633 ED visits (22%) and 702 hospitalizations (33%). Pedestrian ED visits and hospitalizations due to HIs were 2032 (21%) and 849 (40%) respectively, (see frequency of head injuries by age and year in 7-1 and 7-2).

7.3.1 Cumulative incidence rate per 100,000 population of head and non-head injuries presenting to the ED

The average annual cumulative incidence of HIs for child bicyclists presenting to Alberta EDs decreased from 136.8 per 100,000 in the pre-legislation period to 106.5 per 100,000 in the post-legislation period (change(Δ) = -30.4; 95% CI: -37.5, -23.2). This incidence did not change significantly for adolescents and adults (Table 7-1). The incidence of HI for child pedestrians decreased from 16.2 per 100,000 pre-legislation to 8.7 per 100,000 in post-legislation period (Δ = -7.5; 95% CI: -6.1, -5.2). The incidence for adults decreased from 8.4 to 7.5 per 100,000 (Δ = -0.9; 95% CI: -1.8, -0.08); however, no significant change was observed in the rate of HI for adolescents (Table 7-1).

The average annual cumulative incidence of other injuries (non-head) in bicyclists presenting to Alberta EDs increased in children from 310.4 per 100,000 pre-legislation to 325.0 per 100,000 post-legislation (Δ = 14.5; 95% CI: 3.1, 26.0) and increased in adolescents from 390.2 to 464.0 (Δ = 73.8; 95% CI: 53.5, 94.0). At the same time, the rate of non-HI in pedestrians decreased pre- to post-legislation in children from 33.3 to 21.2 per 100,000 (Δ = -12.1; 95% CI: -15.5, -8.7) and in adolescents from 81.0 to 71.3 per 100,000 (Δ = -9.7; 95% CI: -18.4, -1.0); however, no change was observed for adult pedestrians (See Table 7-1).

7.3.2 Cumulative incidence rate per 100,000 population of head and non-head injuries requiring hospitalization

The HI admission rate for bicyclists decreased from 6.7 to 3.5 per 100,000 children between the pre- and post-legislation period (Δ = -3.2; 95% CI: -4.7, -1.7). The HI admission rate for bicyclists decreased from 10.9 to 7.1 per 100,000 adolescents (Δ = -3.9; 95% CI: -6.9, -0.8) and from 2.5 to 2.1 per 100,000 adults (Δ = -0.5; 95% CI: -0.9, -0.2) between the pre- and post-legislation period (Table 7-2). Correspondingly, pedestrian HIs for children, adolescents and adults decreased between 1.0 (adults) and 2.7 (adolescents) per 100,000 population (Table 7-2).

The rate of admission for other (non-head) injuries in bicyclists increased from 16 to 23.4 per 100,000 adolescents (Δ = 7.4; 95% CI: 3.1, 11.7) and from 6.7 to 8.2 per 100,000 adults (Δ = 1.5; 95% CI: 0.7, 2.4); however, no change was observed for children (Table 7-2). The rate of non-HI in pedestrians decreased for children from 5.1 to 3.4 per 100,000 (Δ = -1.8; 95% CI: -3.1, -0.4) and from 6.8 to 5.2 per 100,000 (Δ = -1.3; 95% CI: -2.1, -0.5) among adults; however, no change was observed for adolescents (Table 7-2).

7.3.3 Proportion of head injuries among ED visits

The proportion of HIs (in percent) among bicyclists decreased significantly following the introduction of legislation for children (PR = 0.80; 95% CI: 0.76, 0.85) and adolescents (PR = 0.89; 95% CI: 0.81, 0.98); however, no change was observed for adults. The proportion of HIs among both male (PR = 0.86; 95% CI: 0.82, 0.90) and female (PR = 0.88; 95% CI: 0.81, 0.95) bicyclists decreased significantly following the introduction of legislation. Declines were also seen in urban (PR = 0.92; 95% CI: 0.87, 0.97), and non-urban (PR = 0.79; 95% CI: 0.74, 0.84) areas (Table 7-3).

There was no change in the proportion of HIs in children, adolescent, and adult pedestrians from the pre- to post-legislation periods. The proportion of ED pedestrian HIs decreased only for males (PR = 0.86; 95% CI: 0.77, 0.96). Correspondingly, the proportion of head injuries among pedestrians decreased significantly in urban (PR = 0.90; 95% CI: 0.81, 0.99) areas only (Table 7-3).

7.3.4 Proportion of head injuries among hospitalizations

The proportion of HIs among hospitalized bicyclists decreased significantly for children (PR = 0.60; 95% CI: 0.45, 0.81), adolescents (PR = 0.57; 95% CI: 0.41, 0.80), and adults (PR = 0.73; 95% CI: 0.59, 0.89) post-legislation. The proportion of bicycling HIs among those hospitalized decreased significantly post-legislation for both males (PR = 0.68; 95% CI: 0.58, 0.80) and females (PR = 0.58; 95% CI: 0.41, 0.81). Similarly, both urban (PR = 0.64; 95% CI: 0.53, 0.76) and non-urban (PR = 0.69; 95% CI: 0.54, 0.87) areas had a significant decrease in the proportion of HIs among hospitalized bicyclists (Table 7-4).

No significant changes were observed for pedestrian head injuries requiring hospitalization in any age group, sex or location (Table 7-4).

7.3.5 Adjusted Proportion ratio of head injuries for ED visits

Controlling for sex and location, the proportion of HIs in EDs declined by 20% post-legislation (APR = 0.80; 95% CI: 0.77, 0.84) for children and 11% (APR=0.89; 95% CI: 0.82, 0.97) for adolescents; no change was observed for adult bicyclists. None of the models revealed age-related changes in the prevalence of head injuries for pedestrians following legislation (Table 7-5).

7.3.6 Adjusted proportion ratio of head injuries among hospitalizations

The proportion of head injuries among bicyclists who were hospitalized decreased significantly post-legislation for children (APR = 0.61; 95% CI: 0.47, 0.79), adolescents (APR = 0.57; 95% CI: 0.43, 0.75), and adults (APR = 0.73; 95% CI: 0.61, 0.87) after adjustment for sex and location. None of the corresponding pedestrian age groups experienced changes in the proportion of head injuries following legislation (Table 7-6).

7.3.7 Health care utilization

In the post-hoc analysis, health care utilization for bicyclist HIs decreased in child bicyclists by 20% and adolescent bicyclists by 11% based on presentations to EDs. However, no statistically significant change was observed among corresponding pedestrian age groups (Table 7-7).

Moreover, hospitalizations decreased by 39%, 43%, and 27% in bicyclists <13, 13-17, and adults, respectively; however, no statistically significant change was observed among pedestrians (Table 7-7).

7.4 Discussion

7.4.1 Findings

This was a comprehensive long-term study of bicycle-related head injuries before and after the introduction of bicycle helmet legislation targeting cyclists <18 in Alberta, Canada. All bicycle injuries were captured from the provincial agency responsible for recording, monitoring and reporting ED visit and hospitalization data. Moreover, all relevant injured and hospitalized bicyclists and pedestrians were compared using pre-defined external cause of injury ICD-9-CM and IDC-10-CA codes from April 1999 (3 years pre) to March 2007 (4 years post), excluding the year 2002, which was the first year of helmet legislation. Head injuries in children, adolescents, and adults injured as bicyclists or pedestrians are reported pre- and post-legislation for ED presentations and hospitalizations. Finally, other (non-head) injuries for bicyclists and pedestrians were compared pre- to post-legislation.

Overall, these results produce different trends for bicyclist and pedestrian head and other injuries presenting to EDs and hospitals. The cumulative incidence of HI for child bicyclists who presented to EDs decreased post-legislation by 30 per 100,000 while those for pedestrians decreased by 7 per 100,000. While non-head injuries increased in child (14 per 100,000) and adolescent (74 per 100,000) bicyclists who visited EDs, this rate decreased for child (-12 per 100,000) and adolescent (-10 per 100,000) pedestrians. Fairly consistent decreases in head and non-head injuries among child pedestrians may have been an indication of a safer environment for pedestrians in the years post-legislation. Decline in bicycle head injuries might have been a reflection of helmet legislation and its effectiveness in increasing helmet use by child and adolescent bicyclists but this was accompanied by an increase in non-head injuries (43).

Two explanations may account for these findings; one is an increase in bicycling exposure and the second is risk compensation theory (68). Examining data from the Canadian Community Health Survey, Dennis et al reported that prevalence of recreational bicycling among youth (12-17) in Alberta increased between 2001 and 2003 (69). Therefore, increasing exposure would increase the absolute number of injuries for a given rate of bicycle injury. Second, proponents of risk compensation theory claim that bicyclists who wear a helmet might take more risk in their activity because they feel safer (68). Increasing helmet use among youth <18 in Alberta (43) associated with lower HI but higher non-head bicyclists injuries provides support for the risk compensation theory. Since the percentage of helmet use for admitted cyclists is unknown, it is unclear whether this finding is the result of risk compensation. Nevertheless, opponents of this theory have demonstrated that many bicyclists who wear helmets were either adopting helmet legislation (70) or have inherently lower risk taking behaviours than non-users (71). They also reported a positive association between non-helmet helmet use and taking more risk (70) or committing violation of traffic laws (71).

Considering the very important consequence of head injuries in terms of human life loss and financial burden to society, even if we accept that risk compensation were occurring, the costs associated with head injuries place a greater financial burden on society than the costs associated with other injuries (3, 11).

Multiple regression analyses demonstrated that the adjusted proportion of HI among bicyclists presenting to the EDs declined by 20% in children and by 11% in adolescents. Conversely, the adjusted prevalence of HIs in adult bicyclists and all ages of pedestrians remained unchanged over time. For bicyclists who were hospitalized, the adjusted prevalence of HI in the targeted (e.g., 39% in children; 43% in adolescents) and non-targeted (e.g., 27% in adults) groups decreased significantly; however, none of the pedestrian age groups experienced a decline in HI. Comparing the adjusted prevalence of HI between age groups revealed that child bicyclists and pedestrians who visited EDs have always had higher rates of HI than adults either pre- or post-legislation. The prevalence of HI for children decreased 28% for bicyclists and 11% for pedestrians post-legislation. The corresponding adjusted prevalence of HI for adolescent bicyclists decreased compared with adults post-legislation, but did not reach a statistical significance (1.04 to 0.95); however, no change was observed for adolescent pedestrians.

Two studies in 12 provinces in Canada and in California, USA evaluated the relationship between bicycle helmet legislation and head injuries in children (31, 32). The Canadian study (1994-1998) showed that the HI rate among hospitalized children 5-19 declined by 45% in the four provinces with bicycle helmet legislation; however this change was significantly different from the 27% reduction observed in eight other provinces without such legislation. Other injuries between the two sets of provinces did not show a significant difference over time (32). A study on hospital discharge data (1991 to 2000) in California demonstrated that bicycle helmet legislation targeting those <18 years of age was associated with a reduction of 18.2% in the ratio of traumatic brain injuries; however the rate of other head, face and neck injuries were not significantly changed (31). We similarly observed a 39% (95%CI: -21 to -53%) decline in HIs for hospitalized children <13 and a 43% (95% CI: -25 to -57%) decline among hospitalized adolescents 13-17; however, no such changes were observed for child and adolescent pedestrians requiring hospitalization for HI.

These results indicate a decrease in HIs among bicyclists who presented to the EDs, with a corresponding increase in non-head injuries. Some have suggested that the decrease in bicycle head injuries reflect a downward trend in HIs among other road users (e.g., pedestrians) rather than the effectiveness of bicycle helmet legislation (36, 72, 73). The results from this study demonstrated that non-head injuries for bicyclists have increased during post-legislation period.

In our multiple regression analysis controlling for sex and location, we failed to observe decreases in pedestrian head injuries over the study period. Conversely, the proportion of bicyclist HIs resulting in both ED visits (<13 by

20% and 13-18 by 11%) and hospital admissions (<13 by 39% and 13-18 by 43%) decreased. No significant changes were seen in bicycle related head injuries resulting in ED visits among adults; however, hospitalizations decreased by 27%. Therefore, these results support the argument for a decrease in the proportion of head injuries presenting to the ED or requiring hospitalization among bicyclists. Since helmet laws did not involve pedestrians, their injury results remained relatively unchanged over the same study period. Combined with observational data that documents increased use of helmets following legislation in Alberta (43), this would support the conclusion that HIs among bicyclists have been reduced by increased helmet wearing, and not general traffic safety measures.

From other studies, it has been reported that even a non-compulsory increase in helmet use (temporal effect) among children (0-15 years old) in Sweden was accompanied by a 46% reduction in the cumulative incidence of HIs as a result of collisions with motor vehicles compared with adults (16-50 years old) based on a 10 year study (16). Other researchers also demonstrated that bicycle helmet information campaigns could decrease HIs from 29 to 11% among children 5-12 years of age (39). A New Zealand study demonstrated that HIs for hospitalized bicyclists decreased with increasing helmet use; for every 5% increase in the helmet wearing rate the corresponding HIs involving bicyclists due to motor vehicle crashes decreased by 10.2%, 5.3%, and 3.2% for children (5-12), adolescents (13-18), and adults, respectively (35).

7.4.2 Limitations

This study was a pre and post non-experimental study where bicycle helmet legislation was a community level intervention between the two time periods. As in other community-based interventional experiments, this study is susceptible to influences that may bias the effect estimates. History and maturation in the periods of pre- to post-intervention can concurrently affect the outcome independent of the intervention introducing a spurious lower or higher effect estimates(74). These two factors, which reflect the changes over time, refer to co-interventions and society developments that decrease head injuries among bicyclists independent of helmet legislation. Although we have not observed any comprehensive province-wide educational programs in schools or communities for safe bicycling or helmet use, there might have been some local or limited safety promotion for bicyclists in schools, clinics, or bicycling clubs. From other possible co-interventions we can highlight:

1. Law enforcement activities for safe driving including progressive use of speed camera or escalating police observations in major highways in or out of cities;
2. Improving emergency medical services availability in terms of time of arrival at the scene and/or medical and first aid preliminary assistance;
3. Improving ED services or availability of urgent medical surgery or hospital beds;
4. Improving safety in roads such as decreasing blind spots for drivers, increasing designated cycling paths in the cities, implementing graduate driver licensing, more visible roads at nights, and more use of visible or reflective clothing among cyclists, and safer cycling.

Of the preceding list of safety developments, we have not observed considerable change from the period of before to after legislation in Alberta, hence we believe these factors are unlikely responsible for trend in bicycle head injuries post-legislation in Alberta.

There are limitations associated with this study that require discussion. Alberta changed coding systems from ICD-9-CM to ICD-10-CA in April 1st 2002 and adjustment for this transition was not possible due to an absence of studies reporting comparability ratios of ICD-10/ICD-9 for head injuries. Therefore, we assumed that these two coding systems captured HIs similarly. Supporting this assumption, a bridge coding study among three EDs in Alberta has shown that ED records are a reliable source for capturing external cause of injuries for bicyclists using both coding systems (75). Moreover, the change in coding system was partially addressed through examination of concurrent pedestrian injuries.

We did not separate severe and mild head injuries because it is very difficult to perform a consistent and comparable selection of codes from ICD-9 as the pre- and IDC-10 as the post-legislation coding system in Alberta. Based on the assumption that hospitalization in bicyclists and pedestrians could be an indication of severe head or other injuries, we believe we were able to address this to some extent by analyzing hospital data concurrent to ED data. Regarding our rate denominators, because census data are only available every five years, we had to use a predicted population for the years between census years; however, these are the best estimates available.

7.4.3 Strengths

This study has considerable strengths. First, we examined province-wide data for both ED visits and hospitalizations for bicyclist HIs. Second, evaluating bicycle-related HIs in the targeted ages (< 18), we have benefited from including adult bicyclists and pedestrian injuries as traffic-related injury control groups. Third, by using population data we were able to compare the rate of injuries in four subgroups of head versus other injuries and bicyclists versus pedestrians. Fourth, we separated our analysis for children (<13) and adolescents (13-17) to take into account variable helmet use adherence (43, 76). Fifth, we performed our multiple regression analysis allowing interaction effects of year, age, and activity. In this way, we controlled for temporal safety improvement (by incorporating pedestrian injuries) and other covariates such as sex and geographical areas. Sixth, by examining long term trends from 1999 to 2006 we could present all descriptive analyses by calendar year as well as pooling pre- and post-legislation results. Finally, we did not use data for the year 2002, since we believed there was insufficient transition time from the implementing of bicycle helmet legislation to influence behaviours.

7.5 Conclusion

After bicycle helmet legislation targeting those under the age of 18, the proportion of bicyclist ED visits and hospitalizations due to HIs declined among the target age groups to a greater extent than expected based on trends in pedestrian injuries subject to similar non-helmet legislation road safety trends (e.g. using traffic cameras to control speed on the roads, control of drivers' blood alcohol level, implementation of graduated driver licensing, city construction development for safer roads, and public education programs for safe commuting). Based on our findings, we encourage all-ages helmet legislation to reduce the toll of head injuries on ***all*** cyclists, their families, and the health care system.

Table 7-1 Frequency and cumulative incidence of head injuries (per 100,000) in emergency department visits in Alberta, Canada from April 1999 to March 2007 [a]

	1999		2000		2001		Pre[a]	2003		2004		2005		2006		Post [c]	Diff. [d]	(95% CI) [d]
Bicyclists	**F [b]**	**I [b]**	**F**	**I**	**F**	**I**	**I**	**F**	**I**	**F**	**I**	**F**	**I**	**F**	**I**	**I**		
head injury																		
Children	766	141.3	749	138.7	702	130.5	*136.8*	620	115.5	607	113	566	104.3	516	93.4	*106.5*	-30.4*	(-37.5 to -23.2)
Adolescents	223	101.2	230	103	237	105.1	*103.1*	235	100.6	251	106.6	294	123.3	232	96	*106.6*	3.5	(-6.6 to 1.4)
Adults	442	20.3	484	21.7	503	21.9	*21.3*	503	20.8	533	21.6	498	19.6	482	18.3	*20.1*	-1.3	(-2.7 to 1.6)
Total	1431	48.6	1463	48.9	1358	44.4	*47.3*	1358	42.7	1391	42.9	1358	40.9	1230	36	*40.5*	-6.7*	(-8.5 to -5.0)
Non-head injury																		
Children	1670	308.1	1761	326.1	1598	297	*310.4*	1944	362	1742	324.4	1789	329.7	1573	284.8	*325.0*	14.5*	(3.1 to 26.0)
Adolescents	852	386.8	843	377.4	916	406.3	*390.2*	1089	466.1	1167	495.8	1122	470.5	1026	424.6	*464.0*	73.8*	(53.5 to 94.0)
Adults	1763	80.9	1914	85.8	1863	81.2	*82.6*	2075	86	2107	85.4	2088	82.2	1980	75.4	*82.1*	-0.5	(-3.3 to 2.3)
Total	4285	145.6	4518	150.9	4377	143.1	*146.5*	5108	160.5	5016	154.8	4999	150.5	4579	133.8	*149.6*	3.1	(-1.5 to 6.4)
Pedestrians																		
head injury																		
Children	88	16.2	92	17	83	15.4	*16.2*	48	8.9	45	8.4	46	8.5	50	9.1	*8.7*	-7.5*	(-6.1 to -5.2)
Adolescents	33	15	41	18.4	44	19.5	*17.6*	31	13.3	33	14	35	14.7	49	20.3	*15.6*	-2.0	(-6.1 to 2.0)
Adults	189	8.7	193	8.7	182	7.9	*8.4*	163	6.8	177	7.2	207	8.1	202	7.7	*7.5*	-0.9*	(-1.8 to -0.08)
Total	310	10.5	326	10.9	309	10.1	*10.5*	242	7.6	256	7.9	288	8.7	301	8.8	*8.3*	-2.3*	(-3.1 to -1.4)
Non-head injury																		
Children	175	32.3	177	32.8	187	34.8	*33.3*	131	24.4	109	20.3	113	20.8	106	19.2	*21.2*	-12.1*	(-15.5 to -8.7)
Adolescents	146	66.3	198	88.7	198	87.8	*81*	152	65.1	167	71	192	80.5	166	68.7	*71.3*	-9.7*	(-18.4 to -1.0)
Adults	704	32.3	667	29.9	667	29.1	*30.4*	674	27.9	654	26.5	806	31.7	833	31.7	*29.5*	-0.9	(-2.6 to 0.8)
Total	1025	34.8	1052	35.1	1052	34.4	*34.8*	957	30.1	930	28.7	1111	33.4	1105	32.3	*31.2*	-3.6*	(-5.2 to -2.1)

a- Data for the year 2002 (transition time) excluded due to implementing helmet legislation in Alberta
b- F= frequency of injury; I= incidence (cumulative) of injury per 100,000 population
c- Average cumulative incidence rate for pre- and post-legislation period per 100,000
d- Difference between rate of overall head injuries post-legislation and those in pre-legislation period per 100,000 population
* Statistically significant

Table 7-2 Frequency and cumulative incidence of head injuries (per 100,000) in hospitalized bicyclists and pedestrians in Alberta, Canada from April 1999 to March 2007 [a]

	1999		**2000**		**2001**		**Pre [a]**	**2003**		**2004**		**2005**		**2006**		**Post [c]**	**Diff. [d]**	**(95% CI) [d]**
Bicyclists	**F [b]**	**I [b]**	**F**	**I**	**F**	**I**	**I**	**F**	**I**	**F**	**I**	**F**	**I**	**F**	**I**	**I**		
head injury																		
Children	35	6.5	41	7.6	33	6.1	*6.7*	24	4.5	24	4.5	18	3.3	10	1.8	*3.5*	-3.2*	(-4.7 to -1.7)
Adolescents	24	10.9	27	12.1	22	9.8	*10.9*	22	9.4	18	7.6	16	6.7	11	4.6	*7.1*	-3.9*	(-6.9 to -0.8)
Adults	51	2.3	68	3	51	2.2	*2.5*	37	1.5	72	2.9	45	1.8	53	2	*2.1*	-0.5*	(-0.9 to -0.2)
Total	110	3.7	136	4.5	106	3.5	*3.9*	83	2.6	114	3.5	79	2.4	74	2.2	*2.7*	-1.3*	(-1.8 to -0.8)
Non-head injury																		
Children	68	12.5	78	14.4	68	12.6	*13.2*	80	14.9	69	12.8	85	15.7	63	11.4	*13.7*	0.5	(-1.9 to 2.8)
Adolescents	33	15	38	17	36	16	*16*	63	27	58	24.6	51	21.4	50	20.7	*23.4*	7.4*	(3.1 to 11.7)
Adults	117	5.4	158	7.1	175	7.6	*6.7*	193	8	213	8.6	191	7.5	229	8.7	*8.2*	1.5*	(0.7 to 2.4)
Total	218	7.4	274	9.2	279	9.1	*8.6*	336	10.6	340	10.5	327	9.8	342	10	*10.2*	1.6*	(0.8 to 2.5)
Pedestrians																		
head injury																		
Children	21	3.9	23	4.3	17	3.2	*3.8*	11	2	14	2.6	11	2	16	2.9	*2.4*	-1.4*	(-2.5 to -0.2)
Adolescents	16	7.3	15	6.7	19	8.4	*7.5*	11	4.7	9	3.8	7	2.9	18	7.4	*4.7*	-2.7*	(-5.2 to -0.2)
Adults	102	4.7	108	4.8	88	3.8	*4.4*	75	3.1	94	3.8	84	3.3	90	3.4	*3.4*	-1.0*	(-1.7 to -0.4)
Total	139	4.7	146	4.9	124	4.1	*4.5*	97	3	117	3.6	102	3.1	124	3.6	*3.3*	-1.2*	(-1.8 to -0.6)
Non-head injury																		
Children	25	4.6	32	5.9	26	4.8	*5.1*	19	3.5	19	3.5	20	3.7	15	2.7	*3.4*	-1.8*	(-3.1 to -0.4)
Adolescents	14	6.4	13	5.8	19	8.4	*6.9*	10	4.3	11	4.7	16	6.7	17	7	*5.7*	-1.2	(-3.7 to 1.3)
Adults	157	7.2	154	6.9	146	6.4	*6.8*	102	4.2	131	5.3	160	6.3	161	6.1	*5.5*	-1.3*	(-2.1 to -0.5)
Total	196	6.7	199	6.6	191	6.2	*6.5*	131	4.1	161	5.0	196	5.9	193	5.6	*5.2*	-1.3*	(-2.0 to -0.7)

a- Data for the year 2002 (transition time) excluded due to implementing helmet legislation in Alberta
b- F= frequency of injury; I= incidence (cumulative) of injury per 100,000 population
c- Average cumulative incidence rate for pre- and post-legislation period per 100,000
d- Difference between rate of overall head injuries post-legislation and those in pre-legislation period per 100,000 population
* Statistically significant

Table 7-3 Proportion (P) and Proportion ratio (PR) post- to pre-legislation in bicyclists and pedestrians presenting to emergency departments in Alberta, Canada

	Pre-legislation		Post-legislation		PR (95% CI) [c]
	n/N [a]	P % (95% CI) [b]	n/N [a]	P % (95% CI) [b]	
Bicyclists	4296/17598	24.4 (23.7-25.2)	5337/25297	21.1 (20.5-21.7)	0.86* (0.83 to 0.90)
Age group					
<13	2217/7290	30.4 (29.2-31.7)	2309/9438	24.5 (23.5-25.5)	0.80* (0.76 to 0.85)
13-17	690/3317	20.8 (19.3-22.4)	1012/5461	18.5 (17.4-19.7)	0.89* (0.81 to 0.98)
18+	1389/6991	19.9 (18.9-20.9)	2016/10398	19.4 (18.6-20.3)	0.98 (0.91 to 1.04)
Sex					
Male	3243/12956	25.0 (24.2-25.9)	4110/19122	21.5 (20.8-22.2)	0.86* (0.82 to 0.90)
Female	1053/4642	22.7 (21.4-24.1)	1227/6175	19.9 (18.8-21.0)	0.88* (0.81 to 0.95)
Location [d]					
Urban	2519/10469	24.1 (23.1-25.0)	3289/14883	22.1 (21.4-22.9)	0.92* (0.87 to 0.97)
Non-urban	1777/7129	24.9 (23.8-26.1)	2048/10414	19.7 (18.8-20.5)	0.79* (0.74 to 0.84)
Pedestrians	945/4152	22.8 (21.4-24.3)	1087/5327	20.4 (19.2-21.7)	0.90* (0.82 to 0.98)
Age group					
<13	263/820	32.1 (28.4-36.2)	189/667	28.3 (24.6-32.7)	0.88 (0.73 to 1.07)
13-17	118/636	18.6 (15.5-22.2)	148/842	17.6 (15.0-20.6)	0.95 (0.74 to 1.21)
18+	564/2696	20.9 (19.3-22.7)	749/3817	19.6 (18.3-21.1)	0.94 (0.84 to 1.05)
Sex					
Male	576/2426	23.7 (21.9-25.8)	647/3166	20.4 (18.9-22.1)	0.86* (0.77 to 0.96)
Female	369/1726	21.4 (19.3-23.7)	440/2161	20.4 (18.5-22.4)	0.95 (0.83 to 1.09)
Location [d]					
Urban	599/2440	24.5 (22.7-26.6)	747/3389	22.0 (20.5-23.7)	0.90* (0.81 to 0.99)
Non-urban	346/1712	20.2 (18.2-22.5)	339/1937	17.5 (15.7-19.5)	0.87 (0.75 to 1.01)

a- n=# of head injuries; N=# of all injuries (head and non-head combined including unspecified injuries)
b- Proportion= proportion of head injuries as a percentage of all injuries with 95% confidence interval
c- Proportion ratio= ratio of proportion of post- to pre-legislation period
d- Urban areas included Edmonton and Calgary; non-urban areas are those cities and towns with less than 100,000 population
* Statistically significant

Table 7-4 Proportion (P) and Proportion ratio (PR) of head injuries post- to pre-legislation in bicyclists and pedestrians hospitalized in Alberta Canada

	Pre-legislation		Post-legislation		PR (95% CI) [c]
	n/N [a]	**P % (95% CI) [b]**	**n/N [a]**	**P % (95% CI) [b]**	
Bicyclists	352/1129 [d]	31.2 (28.1-34.6)	350/170	20.5 (18.4-22.7)	0.66* (0.57 to 0.76)
Age group					
<13	109/327	33.3 (27.6-40.2)	76/377	20.2 (16.1-25.2)	0.60* (0.45 to 0.81)
13-17	73/181	40.3 (32.1-50.7)	67/290	23.1 (18.2-29.4)	0.57* (0.41 to 0.80)
18+	170/621	27.4 (23.6-31.8)	207/104	19.9 (17.3-22.8)	0.73* (0.59 to 0.89)
Sex					
Male	282/869	32.5 (28.9-36.5)	287/130	22.0 (19.6-24.7)	0.68* (0.58 to 0.80)
Female	70/260	26.9 (21.3-34.0)	63/404	15.6 (12.2-20.0)	0.58* (0.41 to 0.81)
Location [d]					
Urban	215/712	30.2 (26.4-34.5)	218/112	19.4 (17.0-22.1)	0.64* (0.53 to 0.76)
Non-urban	137/417	32.9 (27.8-38.8)	132/585	22.6 (19.0-26.8)	0.69* (0.54 to 0.87)
Pedestrians	409/996	41.2 (37.3-45.2)	440/112	39.0 (35.6-42.9)	0.95 (0.83 to 1.09)
Age group					
<13	61/144	42.4 (33.0-54.4)	52/125	41.6 (31.7-45.6)	0.98 (0.68 to 1.42)
13-17	50/96	52.1 (39.5-68.7)	45/99	45.4 (33.9-60.9)	0.87 (0.58 to 1.31)
18+	298/756	39.4 (35.2-44.2)	343/903	38.0 (34.2-42.2)	0.96 (0.83 to 1.13)
Sex					
Male	255/605	42.1 (37.3-47.7)	258/682	37.8 (33.5-42.7)	0.90 (0.75 to 1.07)
Female	154/391	39.4 (33.6-46.1)	182/445	40.9 (35.4-47.3)	1.04 (0.84 to 1.29)
Location [d]					
Urban	286/658	43.5 (38.7-48.8)	309/751	41.1 (36.8-46.0)	0.95 (0.81 to 1.11)
Non-urban	123/338	36.4 (30.5-43.4)	131/376	34.8 (29.4-41.3)	0.96 (0.75 to 1.22)

a- n=# of head injuries; N=# of all injuries (head and non-head combined including unspecified injuries)
b- Proportion= proportion of head injuries as a percentage of all injuries with 95% confidence interval
c- Proportion ratio= ratio of proportion of post- to pre-legislation period
d- Urban areas included Edmonton and Calgary; non-urban areas are those cities and towns with less than 100,000 population
* Statistically significant

Table 7-5 Adjusted proportion ratio (APR) post- to pre-legislation among bicyclists and pedestrians presenting to emergency departments in Alberta, Canada

Variable	Activity	Time period [a]	APR	(95% CI)
Age				
<13	bicyclists	post.	0.80*	(0.77 to 0.84)
		pre.	1.0 (ref) [b]	
	pedestrians	post.	0.87	(0.75 to 1.02)
		pre.	1.0 (ref)	
13-17	bicyclists	post.	0.89*	(0.82 to 0.97)
		pre.	1.0 (ref)	
	pedestrians	post.	0.95	(0.76 to 1.18)
		pre.	1.0 (ref)	
18+	bicyclists	post.	0.98	(0.92 to 1.04)
		pre.	1.0 (ref)	
	pedestrians	post.	0.94	(0.85 to 1.03)
		Pre.	1.0 (ref)	
Time period		**Age**		
Post-legislation [a]	bicyclists	<13	1.29*	(1.22 to 1.36)
		13-17	0.95	(0.89 to 1.02)
		18+	1.0 (ref)	
	pedestrians	<13	1.45*	(1.27 to 1.66)
		13-17	0.90	(0.77 to 1.06)
		18+	1.0 (ref)	
Pre-legislation [a]	bicyclists	<13	1.57*	(1.48 to 1.67)
		13-17	1.04	(0.96 to 1.13)
		18+	1.0 (ref)	
	pedestrians	<13	1.56*	(1.38 to 1.76)
		13-17	0.89	(0.75 to 1.07)
		18+	1.0 (ref)	
Location [c]				
Urban			1.12*	(1.08 to 1.15)
Non-urban			1.00 (ref)	
Sex				
Male			1.13*	(1.09 to 1.17)
Female			1.0 (ref)	

a- Pre= pre-legislation period (3 fiscal years of April 1999- March 2002); post= post-legislation period (4 fiscal years of April 2003-March 2007)
b- (ref)= Reference group
c- Urban included two largest cities of Calgary and Edmonton; Non-urban areas are those cities and towns with less than 100,000 populations
* Statistically significant

Table 7-6 Adjusted proportion ratio (APR) post- to pre-legislation among bicyclists hospitalized in Alberta, Canada

Variable	Activity	Time period [a]	APR	(95% CI)
Age				
<13	bicyclists	Post.	0.61*	(0.47 to 0.79)
		Pre.	1.0 (ref) [b]	
	pedestrians	Post.	0.98	(0.74 to 1.31)
		Pre.	1.0 (ref)	
13-17	bicyclists	Post.	0.57*	(0.43 to 0.75)
		Pre.	1.0 (ref)	
	pedestrians	Post.	0.87	(0.65 to 1.17)
		Pre.	1.0 (ref)	
18+	bicyclists	Post.	0.73*	(0.61 to 0.87)
		Pre.	1.0 (ref)	
	pedestrians	Post.	0.97	(0.86 to 1.09)
		Pre.	1.0 (ref)	
Time period [a]		Age		
Post-legislation	bicyclists	<13	1.03	(0.82 to 1.31)
		13-17	1.15	(0.90 to 1.47)
		18+	1.0 (ref)	
	pedestrians	<13	1.09	(0.87 to 1.37)
		13-17	1.20	(0.95 to 1.51)
		18+	1.0 (ref)	
Pre-legislation	bicyclists	<13	1.24*	(1.01 to 1.51)
		13-17	1.48*	(1.19 to 1.84)
		18+	1.0 (ref)	
	pedestrians	<13	1.07	(0.87 to 1.33)
		13-17	1.33*	(1.08 to 1.64)
		18+	1.0 (ref)	
Location [c]				
Urban			1.06	(0.97 to 1.16)
Non-urban			1.0 (ref)	
Sex				
Male			1.09	(0.99 to 1.19)
Female			1.0 (ref)	

a- Pre= pre-legislation period (3 fiscal years of April 1999- March 2002); post= post-legislation period (4 fiscal years of April 2003-March 2007)
b- (ref)= Reference group
c- Urban included two largest cities of Calgary and Edmonton; Non-urban areas are those cities and towns with less than 100,000 populations
* Statistically significant

Table 7-7 Summary estimated of health services utilizations for head injuries in Alberta, Canada following mandatory bicycle helmet legislation in 2002

Type of injury grouped by age	ED Visits	Hospitalizations
Bicycle head injuries		
Children	↓ 20%	↓ 39%
Adolescents	↓ 11%	↓ 43%
Adults	*ND*	↓ 27%
Pedestrian head injuries		
Children	ND	ND
Adolescents	ND	ND
Adults	ND	ND

ED=emergency department;
ND=no statistically significant difference

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8 CHAPTER 8

GENERAL DISCUSSION AND CONCLUSION

8.1 Overview

Five distinct studies have been presented in this program of research in bicycle injury prevention. The first and second studies investigated bicycle helmet use in Alberta (excluding St. Albert) and St. Albert before and after legislation implemented in 2002 mandating all cyclists less than 18 to wear a helmet. The third study examined the trend of bicycling activity before and after legislation in Alberta (excluding St. Albert). The fourth study assessed the accuracy and validity of bicycle injuries captured using ICD-9 and ICD-10 codes from patients presenting to typical EDs in Alberta. This study also examined the reliability of ED coders to code appropriate external causes of injury for bicyclists using ICD-9 and ICD-10 before and after transition (ICD-10 was implemented for all ED and hospitalization cases on April 1st 2002). The final study evaluated the rate of head and other injuries and trends in the proportion of head injuries among bicyclists pre- to post-legislation in Alberta. The following discussion summarizes the results of these studies and provides future directions for this program of research.

The methodology of 4 out of 5 of our studies in this research program was pre and post non-experimental design. In chapter 3 and 4, we examined bicycle helmet use before and after legislation through direct observation of cyclists in Alberta and St. Albert. In chapter 5 we assessed bicycling rate pre- and post-legislation. In chapter 7 we compared bicycle head injuries in the period before and after helmet legislation. Bicycle helmet legislation was a community level intervention but the outcomes (helmet use, bicycling, and bicycle injuries) were evaluated at individual level. This specification of such study design is an advantage to ecological studies that both intervention and outcome are assessed at the community level. These studies seem to have more external validity (generalizability) because they examine the actual response of the individual to the community intervention such as legislation (1). However, they are susceptible to distorted estimates due to internal validity issues. History and maturation in the periods of pre- to post-intervention have been discussed as time-dependent factors which can independently change the outcome (1). As explained in previous chapters, these two factors which change over time, refer to co-interventions (history) and other social development, for instance safer environment due to more knowledge or changing norms of the societies towards safety, at the same time of study intervention.

For bicycle helmet use and bicycling rate studies (chapters 3, 4, and 5) history and maturation could affect the results through:

1. Extensive community educational programs (e.g., schools) that may have promoted helmet use and cycling safety;
2. Helmet use popularity resulting from distributing free helmet or discount vouchers;
3. Extensive law enforcement by police for helmet use among bicyclists;
4. Continual media advertisement for the benefits of bicycle helmet use.

Although we recognize these activities are capable of changing helmet prevalence independent of legislation, we believe their influences would be comparatively small and we have not observed such concurrent community programs in Alberta during the period of our studies. We think it is unlikely that the results of our helmet prevalence and bicycling exposure studies have been affected by history and maturation factors, although there might be minor effects resulting from local and limited programs in some communities.

For bicycle head injuries pre- to post-legislation, history and maturation factors could affect our results through:

1. Comprehensive province-wide educational programs in schools or communities for safe bicycling or helmet use;
2. Law enforcement activities for safe driving including progressive use of speed camera or escalating police observations in major highways in or out of the cities;
3. Improving emergency medical services availability (e.g., minimizing time of arrival at the scene of injury and/or improving primary medical services at the scene);

4. Improving ED services or availability of urgent medical surgery or hospital beds;
5. Improving safety in roads such as decreasing blind spots for drivers, increasing designated cycling paths in the cities, implementing graduate driver licensing, more visible roads at nights, and more use of visible or reflective clothing among cyclists, and safer cycling.

Of the preceding list we have not observed appreciable changes from the period before to after legislation in Alberta, although limited improvement resulting from these activities can no be ruled out. Therefore, we believe these factors are unlikely to change our results of trend of bicycle head injury study, given we had two control groups of adults who were not affected by legislation and also pedestrian as closest vulnerable road users to bicyclists in our analysis.

8.2 Bicycle helmet use

It has been shown repeatedly in national and international studies that bicycle helmet use is generally low without legislation and that helmet legislation is effective in increasing helmet use in the target age groups (2-12). Some of these studies demonstrated that this intervention is an effective complementary method to other promotional activities in place prior to implementing helmet legislation. We conducted a systematic review incorporating 12 studies that evaluated helmet use after helmet legislation (4) in different jurisdictions across four countries. This review demonstrated that helmet use rose 5 to 54% post-legislation in target age groups. A Cochrane systematic review focusing on helmet use and head injuries among children post-legislation has shown that bicycle helmet legislation was accompanied by increasing helmet use and decreasing head injuries (2).

In our pre- and post-legislation observational survey, we report that helmet use increased more among adolescents and children as target age groups; however, there was no increase outside the target group (e.g., adults 18 and older). The failure of legislation to influence helmet use among adults is an indication that greater helmet use among youth less than 18 is related to helmet legislation rather than other societal and/or trends over time. It is also likely that the lack of change in adult helmet use patterns rules out alternative explanations for increasing helmet use among children and adolescents such as associated educational interventions, and modeling behaviour of adults on the target population (13).

In a separate study in the municipality of St. Albert, where an expanded by-law requiring adult bicyclists to wear helmets was passed in 2006, we demonstrated that helmet use increased in youth; however, the increased helmet use among adults did not reach statistical significance. The short interval between by-law implementation and our observational study in 2006 as well as the limited number of observations before and after the by-law came into effect (interplay of sample size and magnitude of effect) might have been important factors for the insignificant change in adult helmet use in St. Albert (14).

Implications of findings

Evidence from pre- to post-legislation bicycle helmet use studies suggests that legislating helmet use, even without enforcement, is associated with the adoption of this safety behaviour among cyclists. Both younger age groups (<18) and adults (18+) appear to respond if targeted by legislation; however, studies in areas with age-restricted helmet laws (<18) demonstrated that target age groups respond to legislation but not necessarily non-targeted age groups. Increases in adult helmet use in St. Albert, Alberta following by-law expansion to all age groups is an example of this effectiveness.

Implications for research

It would be important to repeat the St. Albert observations in a larger sample to increase precision and also to determine if additional time since bylaw implementation has produced a valid and sustained effect. In addition, future studies assessing the relationship between legislation and helmet use should consider the following issues in roadside surveys:

1. *Avoiding selection bias*: determining locations *a priori* and with random selection.
2. *Modeling issues*: Controlling for weather, socio-economic status, age groups and sex in analyses.

3. Evaluating the role of general traffic safety trends on helmet use independent of legislation. The important and influential factors include: traffic cameras for controlling speeds, blood alcohol level checkstops, implementation of graduated driver licensing programs, new developments in road construction for public and driver safety, and public education programs in the schools and communities.
4. *Enforcement:* Evaluating the role of general or specific police enforcement activities accompanying bicycle helmet legislation.

8.3 Bicycling exposure

Decreased bicycling activity has been one of the main concerns expressed by opponents of helmet legislation. Although other factors related to legislation such as adaptation, level of enforcement, extent of age coverage and longevity are also important issues that warrant discussion and future investigation, most follow-up studies have focused on bicycling exposure and head injury evaluation post-legislation. The results of our examination on the trend of bicycling per unit of time (hour) are presented in Chapter 4. This evaluation demonstrated that bicycling rate decreased in only two of the five groups of observation sites (schools and commuter routes) among legislation target age group (<18) post-legislation and also showed a simultaneous increase of cycling in other locations. These results refute claims that helmet legislation has a negative effect on cycling exposure.

Implications of findings

While other authors have challenged this assertion, like other protective devices (e.g., seat belts in cars) familiarity with the benefit of helmet use and having sufficient time to change behaviour can normalize helmet use among bicyclists. If bicycling is a means of transportation for adult cyclists, it seems unlikely cyclists would cease cycling after helmet legislation, although it may occur if it simply a recreational activity. For young children, who are more influenced by parental opinion and rules, helmet use would be perceived as a safety measure for their children activities, although this behaviour change is more complex for adolescents.

Cost, inconvenience, fashion, and limiting personal freedom have been mentioned as the most important factors for stopping bicycling. Except for cost, which has been demonstrated to be a legitimate reason in other studies, other reasons do not seem to play an important role in deceasing cycling exposure.

Implications for research

We must question that if people stop cycling after helmet legislation, would they replace cycling with other activities? For instance if they used to commute to work on a bike, would they walk, use public transportation or use their cars for transportation afterwards? On the other hand, if they used to bike for recreation, would they replace cycling with other activities (e.g., motorcycling, scooter riding, skate boarding, or something else). And we must know whether these changes differ for adults, adolescents, and children. Our recommendations for future research are as follows:

1. What proportion of bicyclists stopped cycling after legislation and why?
2. What were the most replacement activities after stopping use of bicycle?
3. What are other factors that might affect bicycling exposure; would bicycle-friendly environments, well-designed convenient helmets, interaction between drivers and bicyclists, safe bicycling policing be important to change bicycling exposure?
4. Repeating studies which are specifically designed for bicycling exposure examination.

8.4 ICD-9 to ICD-10 Transition

New international classification of disease coding (ICD-10) was introduced by WHO in alphanumeric format to overcome some limitations of ICD-9 (which was based on 3-digit numbers from 100-999 with 2-decimals). Validity and reliability of both ICD-9 and ICD-10 have been examined in several studies. Simultaneous bicycle helmet legislation and transition from ICD-9 to ICD-10 in Alberta necessitated an ED reliability study to ensure that bicycle injuries have been recorded similarly pre- to post-legislation. Using pedestrian injuries as a control group we demonstrated that ED coders are reliable in coding the external cause of bicycle injuries using ICD-9 and -10 systems. We also showed that ICD-9-CM and ICD-10-CA are valid classification tools in capturing bicycle injuries presenting to the ED. In our study more than half of the cases of pedestrian injuries were coded as fall or unspecified external cause of injuries. This can be an indication of poor information collection by triage nurses, physicians, and/or other health professionals in terms of place of injury or inaccurate information given by accompanying persons who transported the victims to the ED. This and other possible misclassification must be considered by the researchers when examining ICD coded administrative data base for external causes of injuries.

Implications of findings

Administrative databases are a valuable and rich source for epidemiologic data; however, assessing the validity of coding systems and also reliability of coders to assign appropriate codes are critical steps prior to starting any analysis. This research ensures that any scientific interpretation resulting from these data sources is based on accurate and reliable information. For those jurisdictions that switched their coding system, these examinations are more challenging and they may require a thorough investigation for both old and new coding systems.

Implications for research

Future studies on ICD-9 to ICD-10 transition should consider:

1. Examining the reliability of external cause of injuries for bicyclists on a large scale including more hospitals in a variety of locations.
2. Evaluating external cause of injuries on other road users as a potential control group for bicyclists and any possible misclassification of external causes of injuries.
3. For the jurisdictions that have switched from old to new coding systems, comparability ratios of ICD-10 to ICD-9 studies are necessary in addition to reliability assessments.

8.5 Bicycle injuries

Since head injuries are the main cause of death and disabilities among seriously injured bicyclists, the main purpose of helmet use is to prevent serious head and brain damage after any collision or fall while bicycling. Several Canadian and international studies have shown that the proportion of head injured cyclists requiring hospitalization decreased in the period after helmet legislation. We have demonstrated a similar reduction of head injury hospitalizations among bicyclists in all age groups; however, to a larger degree among the target age groups. We also found that the number of bicyclist with head injuries presenting to Alberta EDs decreased among children and youth <18 years of age who were the target of provincial legislation, yet not in adults. Studies in Canada and the USA demonstrated that mortality due to bicycling decreased after helmet legislation; however, due to a very low number of bicycling deaths during this study period, we did not attempt to compare bicycling deaths in Alberta to other studies.

Implications of findings

There is evidence that the rates of bicycling injuries presenting to EDs or requiring hospitalization declined post-helmet-legislation. Compared with other vulnerable road users such as pedestrians, this decline is larger than expected. That is, temporal safety trends due to other community safety programs such as speed limits and photo-radar, impaired driving initiatives, and educational programs would not explain the declining cycling HI data. This evidence indirectly demonstrates the protective effects of bicycle helmets on serious head injuries, which is the main purpose of the helmet legislation.

Implications for research

Future studies on bicycle injuries should consider these issues:

1. Assessing health care utilization pre- to post-helmet legislation, specifically separating ED visits from hospitalizations.
2. Controlling for severity of injuries to bicyclists in studies of injury trends pre- to post-legislation using injury severity software programs and trauma systems data.
3. Examining the relationship of helmet legislation and head injuries and risk compensation theory.
4. Exploring the effect of helmet and other legislations on bicyclists' mortality rates.

In addition, detailed qualitative research would need to be completed to uncover unknown factors that influence the relationship between helmet legislation, bicycle helmet use and bicycling behaviour in different age groups. While qualitative research is able to explore individual perspective and reactions to community-wide interventions, as a starting point researchers should consider investigating personal reactions to helmet legislation, opinions on educational measures such as school programs and media, fashion or peer pressure related to helmet use, the role of parents and other family members in obeying legislation, the role of police penalties (tickets or fines), the role of health service providers encouraging helmet use, and the level of understanding of the importance of safe behaviour such as helmet use in normal activities.

8.6 Knowledge translation

Knowledge translation (KT) is an important part of all research activities. Despite some budgetary and logistical restrictions, we have attempted to share our study results with our community in the following ways:

1. We have presented our results in chapters 3, 4, 5, and 5 in three scientific conferences of the Canadian Society of Epidemiology and Biostatistics in 2009 and the Canadian Association of Emergency Physicians (CAEP) conference in 2010. We will present the results of chapter 7 in upcoming

Canadian Injury Prevention and Safety Promotion Conference 2011 in Vancouver.

4. We have presented the results of chapter 3, 4 (published) and 6 (in press 2011) to scientific peer reviewed journals.
5. We have generated a "myth buster" sheet for bicycle helmet use and distributed it to media and policy-makers.
6. Members of our research team had interviews with local media explaining the importance of helmet legislation in increasing helmet use among children and adults.
7. We had been interviewed by a number of local media regarding the effectiveness of legislation on bicycle helmet use.
8. We have advocated through the media for more helmet use in the community.

However, there are some restrictions that prevented us for more expansive KT activities. For instance, we have not received additional funding for this KT activities and an embargo policy by a scientific journal prevented the earlier release of results to the community in a timely manner.

8.7 Conclusions and remarks

Helmet use in Alberta was sub-optimal prior to the provincial legislation implemented in 2002. Implementation of bicycle helmet legislation was associated with an increase in helmet use among youth <18 as the target age group; however, 100% use has not been achieved and head injuries due to cycling continue to affect bicyclists, their families, communities and the health care system. While the rate of cycling activities declined in certain locations (schools and commuter routes) post-legislation, variable changes in cycling rates at other locations suggested a non-uniform role of legislation on cycling activity. Bicyclist ED visits and hospitalizations due to head injuries declined among the target age groups to a greater extent than expected based on the unchanging pedestrian control group HI rates. The validity of these observations suggests that the change was the result of helmet legislation rather than other temporal safety initiatives implemented during the study period.

8.8 References

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Appendix 1 Definition of bicycle and pedestrian injuries used by investigators for identifying cases from Emergency Department Information System (EDIS)

Bicycle injury:

The bicycle injury should have happened in a public area (e.g. streets, highways, parks, bicycle pathways, commuter route). They included:

- Bicycle rider or passenger hit by a motor-vehicle (including motorcycle, moped and other motorized vehicle)
- Bicycle had a collision with another bicycle
- Bicycle hit a stationary object
- Bicycle hit a moving object or being hit by that moving object (e.g. train, animal)
- Bicyclist fell off the bike
- Rider on a unicycle
- Bicyclists on a reclined bicycle or reclined tricycle
- Bicyclists on a tandem bicycle

Pedestrian injury:

Pedestrian is a person who shares the road or commuting route with other road users (motorized or non-motorized vehicles) or commuters in public places (e.g. parks streets, bicycle pathways, residential pathways). This is a public road way use, but non-motorized and non-wheeled transportation. They included:

- A person hit or run over by a motorized vehicle (including motorcycle, moped and others) in roadways
- A person hit or run over by a non-motorized vehicle (e.g. bicycle, tricycle, scooter and other) in roadways
- A person injured on a roadway while walking (e.g. tripped over curb or fell over tree root)
- A person walking on the roadway and injured due to hitting light poles, trapping in a hole, and hit by a loose object of traffic control device
- A person injured while walking on one side of the bicycle (not riding it) in a roadway