Public Health Ontario
PARTNERS FOR HEALTH

Santé publique Ontario
PARTENAIRES POUR LA SANTÉ

Impacts of Mandatory Bicycle Helmet Legislation

Knowledge Synthesis
August 2015

Public Health Ontario

Public Health Ontario is a Crown corporation dedicated to protecting and promoting the health of all Ontarians and reducing inequities in health. Public Health Ontario links public health practitioners, frontline health workers and researchers to the best scientific intelligence and knowledge from around the world.

Public Health Ontario provides expert scientific and technical support to government, local public health units and health care providers relating to the following:

- communicable and infectious diseases
- infection prevention and control
- environmental and occupational health
- emergency preparedness
- health promotion, chronic disease and injury prevention
- public health laboratory services

Public Health Ontario's work also includes surveillance, epidemiology, research, professional development and knowledge services. For more information, visit www.publichealthontario.ca

How to cite this document:
Ontario Agency for Health Protection and Promotion (Public Health Ontario), Berenbaum E, Ha P, Keller-Olaman S, Manson H. Impacts of mandatory bicycle helmet legislation. Toronto, ON: Queen's Printer for Ontario; 2015.

ISBN 978-1-4249-5662-3 [PDF]

Public Health Ontario acknowledges the financial support of the Ontario Government.

Impacts of Mandatory Bicycle Helmet Legislation

Authors

Erin Berenbaum, MSc
Research Coordinator,
Health Promotion, Chronic Disease & Injury Prevention (HPCDIP)
Public Health Ontario

Sue Keller-Olaman, MSc, PhD
Manager, Knowledge Synthesis Services (KSS)
Health Promotion, Chronic Disease & Injury Prevention (HPCDIP)
Public Health Ontario

Phat Ha, MPH
Research Coordinator,
Health Promotion, Chronic Disease & Injury Prevention (HPCDIP)
Public Health Ontario

Heather Manson, MD, FRCPC, MHSc
Chief, Health Promotion, Chronic Disease & Injury Prevention
Health Promotion, Chronic Disease and Injury Prevention (HPCDIP)
Public Health Ontario

Acknowledgements

Internal Reviewers

Justin Thielman, Epidemiologist,
Public Health Ontario

Charoula Tsamis, Senior Research Facilitator,
Public Health Ontario

Expert Advisors

Stacie Carey, Health Promotion Coordinator,
Parachute Canada

Lorna Boratto, Public Health Nurse,
Oxford County Public Health

Alison Macpherson, Associate Professor,
York University

Stephanie Gower, Research Consultant,
Toronto Public Health

Colleen Cooper, Public Health Nurse,
Waterloo Public Health

Jacob Larsen, Senior Safety Research Advisor,
Ministry of Transportation

Linda Yenssen, Manager,
Ontario Injury Prevention Resource Centre
Charles Gardner, Medical Officer of Health,
Simcoe Muskoka District Health Unit

Sue Shikaze, Health Promoter,
Halliburton, Kawartha, Pine Ridge District
Health Unit

Jackie Gervais, Health Promoter,
Niagara Region Public Health

Monique Beneteau, Health Promoter,
Peterborough County-City Health Unit

Robert Kyle, Medical Officer of Health,
Durham Region Health Unit

External Reviewers

Alison Macpherson, PhD, Associate Professor,
School of Kinesiology and Health Science, York
University

Daniel Fuller, PhD, Assistant Professor,
School of Public Health University of
Saskatchewan

Special Thanks

Sarah Morgan, Library Technician,
Public Health Ontario

Beata Pach, Manager, Library Services,
Public Health Ontario

Domna Kapetanos, Library Operations
Technician, Public Health Ontario

Disclaimer

This document was developed by Public Health Ontario (PHO). PHO provides scientific and technical advice to Ontario's government, public health organizations and health care providers. PHO's work is guided by the current best available evidence.

PHO assumes no responsibility for the results of the use of this document by anyone.

Contents

"With regard to the use of bicycle helmets, science broadly tries to answer two main questions. At a societal level, 'What is the effect of a public health policy that requires or promotes helmets?' and at an individual level, 'What is the effect of wearing a helmet?' Both questions are methodologically challenging and contentious."

"The current uncertainty about any benefit from helmet wearing or promotion is unlikely to be substantially reduced by further research. Equally, we can be certain that helmets will continue to be debated, and at length. The enduring popularity of helmets as a proposed major intervention for increased road safety may therefore lie not with their direct benefits—which seem too modest to capture compared with other strategies—but more with the cultural, psychological, and political aspects of popular debate around risk"

Goldacre & Spiegelhalter, 2013

Summary

Background

Cycling is an affordable form of transportation that can improve cardiovascular fitness and reduce the risk of chronic diseases while also reducing traffic congestion, air and noise pollution, and greenhouse gas emissions.[1] As with all modes of travel, cycling can involve collisions, which may cause injury and death. According to the Chief Coroner's Report of 2012, between 2006 and 2010 there were 129 deaths among cyclists of all ages in Ontario, and of these, 74% were not wearing a helmet at the time of their fatal injury;[2] however it is challenging to interpret this finding in the absence of other information such as the nature of the collision, etc. Legislation requiring all cyclists to wear helmets is thus seen as a potential intervention for preventing bicycle-related injuries and death, and the Chief Coroner's Report includes a recommendation for the enactment of all-age legislation.[2]

Although under Ontario's Highway Traffic Act, helmets have been required since 1995 for all Ontario cyclists less than 18 years of age,[3] the expansion of the law to include all ages is not universally supported. Some suggest that mandatory helmet legislation would have an overall positive impact on cyclists, increasing helmet use, and reducing risk of head injuries, without causing a reduction in cycling, and its associated benefits.[4-6] Others are concerned that helmet legislation may have a negative impact, increasing cyclists' risk compensation, discouraging cycling use and thus preventing associated health benefits, and that the costs of purchasing helmets to satisfy legislation may exceed any savings in reduced head injuries.[7-9] Finally, there are those who, in disputing the effectiveness of the legislation as a prevention strategy, point to jurisdictions where cycling participation is high and the risk of cycling injuries is low in the absence of bike helmet legislation.[10] This controversy suggests the need to evaluate the evidence regarding the effectiveness of bicycle helmet legislation and to further explore the possible mechanisms whereby bike helmet legislation contributes to outcomes in varied jurisdictional contexts.

Objectives

Given these varying perspectives, the *primary objective* of this synthesis was to evaluate the multiple impacts (e.g., health, economic, etc.,) of bicycle helmet legislation for cyclists (of all ages). The *secondary objective* was to explore, if possible, the context and mechanisms that may assist in explaining the differences in outcomes observed across jurisdictions.

Methods

Nine databases (MEDLINE, Embase, PsycINFO, SPORTDiscus, Environment Complete, Cochrane Database of Systematic Reviews, CINAHL, Transport Database and TRID) were searched along with grey literature from five jurisdictions (Canada, USA, U.K, Australia, International). References of review articles were hand searched for additional relevant material. The search resulted in 1229 peer-reviewed and 50 grey literature articles. Articles were included if they were a primary study, published between 1990 and 2013, which evaluated the impacts of mandatory bike helmet legislation for children, youth and adults,

and used an appropriate comparison group. Titles and abstracts were first screened by two independent reviewers followed by a full-text review of selected articles. Forty-one peer-reviewed and 16 grey literature articles were included in the review for a total of 57 articles. Two reviewers independently appraised 25% of the articles (n=15) to ensure consistent quality appraisal. After establishing agreement on quality rating, a single reviewer then extracted data and assessed the remaining 42 articles for methodological quality.

Results

Findings from the 57 articles included in this review suggest that mandatory bicycle helmet legislation was associated with increases in helmet use and helmet ownership, and decreases in hospitalizations, head injuries, severe injuries, injury severity and cycling related deaths, with mixed results regarding cycling participation and non-head injuries. Decreases among child and adolescent ridership were more commonly seen in jurisdictions with all-age rather than child-only helmet legislation, possibly mediated through reductions in adult role modeling; however role modelling was not measured.

Helmet legislation was also shown to be more cost-effective than community or school-based helmet programs and had minimal impact on knowledge and support for the law. More comprehensive legislation (i.e., all-age vs. child-only law) and supplementary educational or incentive programs were associated with greater law effectiveness.

However, as most studies do not report cycling exposure (e.g., number of people cycling, cycling trips, cycling distances travelled, or time spent cycling), it is not possible to fully characterize the impact of helmet legislation at the population level. Also, since most studies do not report cycling rates, it is not always possible to exclude decreased cycling (i.e., reduced number of people cycling) or increased cycling (i.e., increased modal share, whereby relatively fewer collisions and cycling-related injuries occurred as the number of cyclists on the road increased) as other possible explanatory mechanisms.

Limitations

As the review focused on outcomes of bike helmet legislation, by definition it did not include studies from jurisdictions without legislation (e.g., some European countries). However, pre/post and jurisdictional comparisons (e.g., comparing one province to another) were included in reviewed studies. This review did not examine the impact of helmet laws on the risk of head injuries per trip or per distance travelled as this information was not available in the current literature. Thus information on risk in relationship to exposure is incomplete.

This review also did not examine the potential health benefits/burdens due to increased or decreased activity-related chronic diseases (heart disease, stroke, dementia, diabetes, certain cancers) as might relate to the impact of helmet laws on cycling participation. A body of evidence suggests that the benefits of cycling far outweigh the risks (across various setting and scenarios), due to the large physical activity-related chronic disease impacts.[11]

Finally, we acknowledge the possibility of publication bias. Despite these limitations, this review forms a useful basis for decision-making regarding bike helmet legislation, and mechanisms and contextual factors that need to be considered to optimize cycling outcomes overall.

Conclusion

The results demonstrated a positive effect of bike helmet legislation for outcomes including helmet use and ownership, and cycling-related head injuries and deaths. Our assessment shows that, in the studies reviewed, the effect of bike helmet legislation on injury and deaths was mediated mainly through increased helmet use (and the protective effect of helmets); however, findings from the majority of studies were not adjusted for cycling exposure, and therefore other mechanisms are possible. To achieve the health benefits of cycling, while avoiding unintended negative impacts (such as reduced cycling participation), the implementation of helmet laws should be considered alongside other contextual factors (such as safe cycling infrastructure and cycling education) that may influence law effectiveness, cycling participation and/or cycling safety.

Background

Benefits of Cycling in Ontario and Canada

In Canada, more than 11.4 million people ages 12 and older reported cycling in the 2009 Canadian Community Health Survey (CCHS).[12] In Ontario, a survey of road users conducted by the Ministry of Transportation (2012) suggests that approximately 1.2 million adults in Ontario ride a bicycle daily during the spring, summer and fall, and 2.8 million ride at least once a week.[13]

Cycling provides health, environmental and economic benefits to both the individual and society. Cycling is a valuable form of physical activity.[14] Transportation-related physical activity such as cycling is associated with improved cardiovascular fitness and reductions in type II diabetes and cardiovascular disease,[15] and one study has shown that cycling to work reduced the risk of mortality by 40%.[16] Teschke et al., (2012) further noted that individuals who cycle or walk to work are less likely to be overweight or obese.[15] Cycling has the potential to improve the environment by reducing greenhouse gas emissions and improving air quality,[15,17] and has also been promoted to reduce traffic noise and congestion.[15]

There are also economic benefits associated with cycling. Due to low maintenance costs and no fuel requirements, cycling is an affordable form of transportation and has been shown to be a cost-efficient mode of transportation for journeys of five miles or less.[18] Additionally, Ernst et al., (2002) noted that the average annual amount spent on pedestrian/bike projects is $0.87 per person while the annual amount spent for roads and bridges is greater than $50 per person.[19]

Cycling provides health benefits that can be monetized, as estimated by Toronto Public Health's recent report "Road to Health".[20] At current levels of cycling in the City of Toronto, they estimated 49 annual lives saved, valued at $54 to $200 million. A recent systematic review of economic analyses of cycling and walking projects showed positive benefit–cost ratios, where some studies estimated the value attributed to each new walker or cyclist; these ranged from about €120 to €1300.[21]

Overall, small investments in cycling can lead to societal savings in terms of decreased health care costs, and reduced air pollution.

Burden of Cycling-Related Injury & Death in Ontario

As with all activities and modes of travel, there are safety and health risks associated with cycling. Some cyclists are injured or killed each year. According to the Ontario Injury Compass report on cycling, in 2005-06 there were 26,300 emergency department visits (22% head injury-related) and 1,374 hospitalizations (21% head injury-related) for cycling-related injuries.[22] Additionally, according to the Chief Coroner's Report of 2012, between 2006 and 2010 there were 129 deaths among cyclists of all ages in Ontario, an average of 26 deaths per year.[2] Of those, 74% were not wearing a helmet at the time of their fatal injury.[2] A separate case-control study using the same Ontario data found that cyclists who did not wear a helmet had a three-fold greater risk of dying after a head injury than those wearing a helmet.[23]

However, cycling-related deaths in Ontario are not as high in absolute terms as those due to other modes of on-road travel. Traffic data indicate that 18 cyclists were killed and 119 suffered major injuries in 2010, whereas traffic-related deaths from other modes of travel were as follows: 414 motor vehicle occupant deaths, 95 pedestrian deaths and 47 motorcyclist deaths. Similarly, in 2010, major injuries for other modes of transportation included 1661 motor vehicle occupants, 420 pedestrians, and 298 motorcyclists.[24]

Prevention of Cycling-Related Injuries and Deaths

From a population health perspective, various cycling injury prevention measures have been described, including primary prevention (e.g., separated cycling infrastructure, quiet streets, street lighting, bike lights, speed limits, safe driving laws) and secondary prevention (e.g., helmets, body armour) of cycling-related injuries and deaths.[25,26] In 2012, the Ontario Ministry of Transportation released the Ontario Cycling Strategy which focused on primary prevention including improvements to cycling infrastructure, legislation, education, monitoring, research, making highways and streets safer and promoting cycling awareness and behavioural shifts.[13]

Secondary prevention efforts such as the use of bicycle helmets may help to increase the safety of cyclists in the event of a crash. Bicycle helmets have the potential to considerably reduce the risk of head or brain injury after a crash by 30% to as much as 88%, and to reduce upper and mid-facial injury by 21% to 65%.[27,28] However, helmet effectiveness is dependent on individual compliance, maintenance, correct use and helmet condition, fit, quality, and availability.[29] In 2009, 36.5% of Canadians and 34.3% of Ontario residents reported wearing a bicycle helmet at all times.[12] Legislation requiring all cyclists to wear helmets is an intervention aimed at increasing helmet use in an effort to prevent cycling-related injuries and deaths.

Legislation of Helmet Use in Ontario and Canada

Helmet legislation in Canada varies across jurisdictions. All jurisdictions that legislate helmet use do so in Motor Vehicle Acts or Traffic Safety Acts. In Ontario, helmets have been required for all cyclists under 18 years of age under Ontario's Highway Traffic Act since 1995.[3] Child helmet laws targeting children 18 years of age and younger have also been enacted in Alberta (2002) and Manitoba (2013).[30] In contrast, New Brunswick (1995), British Columbia (1996), Nova Scotia (1997), and Prince Edward Island (2003) require cyclists of all ages to wear a helmet by law.[30] The remaining provinces and territories did not have any helmet legislation at the time this document was finalized.[30]

In Ontario, Private Member's Bill 129 sought to amend the Highway Traffic Act to require persons of all ages to wear helmets when operating a bicycle, scooter, skateboard or similar vehicle; however, the Bill did not proceed.[31] In 2011, the Chief Coroner for Ontario recommended mandatory helmet use for cyclists of all ages (among a number of other recommendations to improve cycling safety), with the impact of this legislative change to be evaluated in collaboration with the Ministry of Health and Long-Term Care and Public Health Ontario.[2]

In addition to the recommendation made by Chief Coroner of Ontario, a number of other organizations including the Ontario Medical Association (OMA),[32] the Association of Local Public Health Agencies (aLPHa),[33] the Canadian Pediatric Society[5] and SafeKids Canada[6] have issued statements of support for mandatory all-age bicycle helmet legislation. The Canadian Academy of Sport and Exercise Medicine (CASEM) have also noted their support for mandatory bicycle helmet use for all ages suggesting that all provincial and territorial governments enact legislation mandating that cyclists wear helmets.[34,35]

Impacts of All-Age Bike Helmet Legislation

There are mixed views within the research community regarding the impact of all-age mandatory helmet legislation on cyclists. There is evidence that mandatory helmet legislation would have a positive impact, increasing helmet use, and reducing risk of head injuries, without causing a reduction in cycling.[4-6] For instance, a systematic review by Macpherson et al., (2008) concluded that helmet legislation appears to be effective in increasing helmet use and decreasing head injury rates among the populations for which it is implemented, and found no evidence of change in bicycle use or other adverse consequences of legislation.[4]

Others have expressed concern that bike helmet legislation may have an overall negative impact, increasing risk-taking behaviour among some cyclists, and discouraging cycling among others, despite the fact that cycling has many health benefits and is an affordable form of active transportation. It has also been suggested that the cost of purchasing helmets and/or paying fines to satisfy legislation, the potential increased cost of chronic disease morbidity and mortality, and the potential increased costs of all types of cycling injuries may exceed potential savings in reduced head injuries.[9] Also, bike helmet legislation places the onus of responsibility for protection from injury and death on the vulnerable road user, who must choose between complying with the law versus not riding. Such arguments have been persuasive in Europe where helmet legislation has not been adopted and cycling is both more common and safer than in North America.[10] Additionally, helmet legislation generates costs for enforcement, signage and media promotion of the law.[36]

These differences in interpretation of the benefits and costs of bike helmet legislation underscore the complexity of decision making in this area. Unlike seatbelt laws or motorcycle helmet laws, bicycle helmet legislation has the potential to mitigate injury after a crash, but unless accompanied by other interventions to actively promote safe cycling, may discourage a form of physical activity that contributes to public health. This distinction highlights the need to evaluate the evidence regarding the impacts of mandatory bicycle helmet legislation, and the possible mechanisms through which these impacts occur.

Only three published reviews have systematically examined the effectiveness of helmet legislation and these are limited by study type, and/or outcome. Macpherson et al., (2008) conducted a Cochrane review examining the effects of bicycle helmet legislation on bicycle-related head injuries and helmet use, and unintended/adverse consequences.[4] However, their included studies were limited to pre-post studies with a control group and all included primary literature concerning child helmet laws enacted in North America, thereby missing literature from adult or all-age laws.

Karkhaneh et al, (2006) conducted a systematic review evaluating the effectiveness of legislative interventions to increase bicycle helmet use among all age groups. While their review was not limited by study type and incorporated both grey and peer-reviewed literature, it was limited to the outcome of helmet use only. Finally, the Department for Transport (UK) conducted a review which included an evaluation of the effectiveness of helmet legislation; however the methods through which the articles were identified were not clearly documented.[37]

To address these gaps, (limited outcomes or study types and/or lack of rigorous documented methodology) this review systematically examined the impacts of helmet legislation and was not limited by outcome or type of law. Further, this review explored where possible, the contexts and mechanisms underlying the impacts associated with helmet laws.

Objectives

The objectives of this knowledge synthesis were:

1. To evaluate the impacts of bicycle helmet legislation for cyclists (of all ages).
2. To explore the contexts and mechanisms that may assist in explaining differences in outcomes observed across jurisdictions.

The results of Objective 1 will help to inform Objective 2.

The impetus for this synthesis was the receipt of requests for information from several Medical Officers of Health and the Ontario Public Health Association's Health and Built Environment Working Group.

Research Questions

1. **What are the impacts of bicycle helmet laws for cyclists (of all ages)?**
2. **What does the available literature contribute to our understanding about contexts within and mechanisms by which those laws have achieved impact?**

To address the first research question, a systematic review examining the impacts of mandatory helmet legislation was conducted. To address the second research question, outcomes identified in the systematic review were explored to identify the contexts and possible mechanisms whereby bicycle helmet laws achieve their impact.

Methods

Literature Search Strategy

PEER-REVIEWED LITERATURE

A librarian-assisted electronic search was conducted by Public Health Ontario in July 2013. Articles were retrieved by searching the following electronic databases: MEDLINE, Embase, PsycINFO, SPORTDiscus, Environment Complete, Cochrane Database of Systematic Reviews, CINAHL, Transport Database and TRID. The search focused on the effectiveness of mandatory bicycle helmet legislation in various international jurisdictions. As shown in Table 1, a total of 2219 results were identified, with 1229 unique articles remaining after duplicates were removed. For a more detailed description of the search strategy, see Appendix A.

Table 1: Electronic Database Search Results (Peer-reviewed Literature)

Source	No. of Articles
MEDLINE	398
Embase	474
PsycINFO	63
SPORTDiscus	139
Environment Complete	41
Cochrane Database of Systematic Reviews	2
CINAHL	133
Transport Database	381
TRID	588
TOTAL	**2219**

GREY LITERATURE

A web search was performed using Google to identify grey literature regarding bicycle helmet legislation. The websites of major public health agencies such as www.phac-aspc.gc.ca and www.cdc.gov were the focus of the search. The websites of all Canadian provincial and territorial health ministries were searched, as well as corresponding international and national organizations. An additional Google search was performed, limiting the results to .gov, .org, and .edu domains only. (See Appendix A for list of websites searched). The reference lists of relevant citations were also searched for additional relevant

documents. As shown in Table 2, fifty citations were identified by this grey literature search. For a more detailed description of the search strategy, see Appendix A.

Table 2: Electronic Database Search Results (Grey Literature)

Jurisdiction	No. of Web Citations
Canada	16
USA	21
U.K	6
Australia	1
International	6
TOTAL	**50**

Study Selection

Each article was screened for inclusion by two reviewers working independently, first based on titles and abstracts and then based on a full-text review, with both levels of review applying inclusion and exclusion criteria. Disagreements between the two reviewers were resolved by consensus. To be included, articles had to: a) be published between 1990 and 2013; b) be a primary study or systematic review; c) evaluate the impact of mandatory bicycle helmet legislation on any age group; d) use an appropriate comparison group (i.e., pre/post group, another jurisdiction); and e) be available in English and/or French.

Articles were excluded if they: a) were published before 1990; b) were not a primary study or systematic review; c) did not clearly evaluate the impacts of mandatory bicycle helmet legislation; d) did not include an appropriate comparison group; e) were not available in English or French; f) were set in a developing country; or g) were duplicate articles when compared to those already included. See Appendix B for a complete list of inclusion and exclusion criteria.

PEER-REVIEWED LITERATURE

To establish consistency, two reviewers screened the first 100 titles and abstracts from the electronic database search. There were 6/100 (6%) discrepancies (where one reviewer chose to include the article and the other chose to exclude) leaving a 94% agreement between the two reviewers. Discrepancies were discussed until a consensus was reached for the remaining six articles. If both reviewers were unsure (due to missing details in the title/abstract), the article was treated as an 'included' article and the full-text version was retrieved. After both reviewers screened all 1229 titles and abstracts, 96.4%

agreement was achieved and 122 articles were selected for full text review. See Figure 1 for the complete study selection process.

The same two reviewers screened full-text articles using the inclusion and exclusion criteria (See Appendix B). One article was unavailable for review during the process and was not included in the report.[38] There was 95% agreement between reviewers in this second screening for inclusion of full-text versions. Discrepancies were discussed until consensus was reached. Of the 122 articles screened, 56 articles met inclusion criteria. Although the majority of relevant articles originated in peer-reviewed sources, 14 of the included articles were from grey literature sources as one of the included databases (i.e., TRANSPORT) contained both peer reviewed and grey literature.

Included review articles from this search were identified and their citations searched for any additional relevant primary studies that may have been missed in the original search. Three review articles were identified; however no additional primary studies were identified through the search of review reference lists. The review articles were then removed from the report to avoid redundancy of content given the overlap in primary studies already included. Overall, 53 studies were included.

GREY LITERATURE

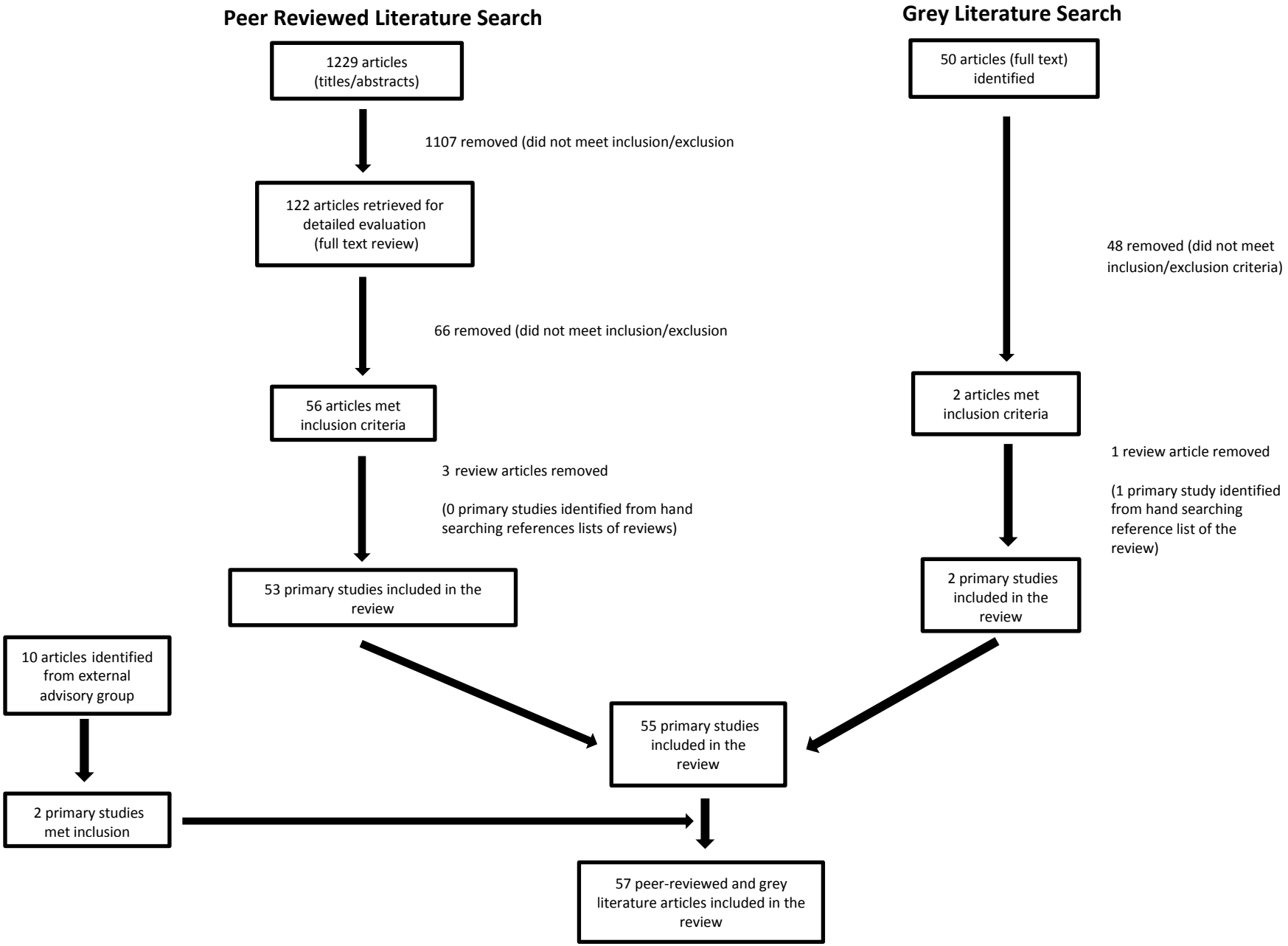
Two reviewers independently screened the full-text versions of all 50 grey literature articles retrieved by the search using inclusion and exclusion criteria (See Appendix B). Any discrepancies were discussed until a consensus was reached. There was 96% agreement between reviewers after screening was complete. After reviewing all 50 full articles, only two met inclusion criteria. One was a review article for which the reference list was searched for additional relevant studies. One additional article was identified through this references list search. Once the additional article was included, the review article was removed from the report to avoid redundancy across the included primary studies. Overall, two primary studies were identified by the grey literature search and were included in the report. See Figure 1 for the complete study selection process.

SUPPLEMENTARY ARTICLES FROM EXTERNAL ADVISORY COMMITTEE

In addition to the articles retrieved from the peer-reviewed and grey literature searches, the project advisory committee (a group of content experts) was provided with the finalized list of included articles selected from the search and was asked to suggest additional relevant articles that may have been missed. The additional articles recommended by the advisory committee were compiled and screened in duplicate using the inclusion and exclusion criteria. Ten articles were recommended by committee members and of those, two met our criteria and were included in the review.

Overall, 53 articles were identified through the peer-reviewed search, two were identified through the grey literature search and two were identified from the external advisory committee for a total of 57 articles included in the report.

Figure 1. Literature Search



Data Extraction

After all included studies were identified, one reviewer extracted data from the selected articles in the following areas: study type, study objective/description, population (age, gender, sample size, socioeconomic status (SES)), jurisdiction and context, legislation (year implemented, who it targeted, where it was implemented & implementation details), outcomes, main findings, conclusion (benefits, costs, general conclusion), and comments (limitations, and other). A second reviewer extracted data from a sample of 10 randomly-selected articles to ensure accuracy and consistency of the extraction process by the first reviewer.

Quality Appraisal

Two reviewers independently appraised 25% of the articles (n=15) for methodological quality, and established strong agreement on quality assessment (reported in detail below). The Effective Public Health Practice Project (EPHPP) instrument for assessing quantitative studies was used for critical appraisal. [39] The tool has demonstrated ability to adapt to the most current methods for systematic literature reviews related to the effectiveness of public health interventions.[39] The tool assesses study quality across six areas including: selection bias, design, confounders, blinding, data collection methods, withdrawal and dropouts and is considered to be both reliable and valid.[39] Content experts have indicated that the tool has adequate content validity, with good reliability with test-retest (inter-rater) reliability (as measured by the Kappa statistic) between 0.61 and 0.74.[39] Even greater reliability was found for overall grade assigned to each paper with an intra-class correlation coefficient (ICC) score of 0.77 (considered to be excellent agreement).[40] See Appendix C for the quality appraisal results for each study. Due to the very limited nature of the cost-effectiveness evidence, along with incompatibility with the EPHPP tool, quality appraisal of the cost-effectiveness studies was not assessed. Agreement on quality rating was assessed for each of the subsections and for overall agreement on the global score of strong, moderate, or weak quality. The two reviewers' scoring showed 82% agreement considering these six sub sections and global rating agreement across 15 of the included papers. Discrepancies between the two reviewers' ratings were discussed until consensus was reached. After establishing agreement on quality rating, a single reviewer then extracted data and assessed the remaining 42 articles for methodological quality.

The EPHPP tool is accompanied by a dictionary that clarifies any questions related to the evaluated components; however the reviewers also developed a supplementary dictionary with details specific to the types of studies being assessed (see Appendix C).

Characteristics of Included Studies

A total of 57 articles were included in the review. The majority (41/57) of the included articles were peer-reviewed with the remaining 16 coming from the grey literature. Most (43/57) studies compared

results from before and after legislation while 10 compared results across jurisdictions and four were cost effectiveness studies. Twenty-one studies took place in Australia, 17 were from the United States (USA), six from New Zealand, and 13 from Canada with five specifically looking at Ontario. Most studies described the effectiveness of all-age or child-only laws, with only one jurisdiction (New South Wales, Australia) having an adult only law. Some included studies examined the same legislative intervention on different populations, at a different time points, relative to different outcomes, or using different methods. We have sought to minimize the impact of any duplication by reporting together findings from different studies examining similar instances of the same legislative intervention. Characteristics of the studies included in this report are listed in Appendix D and Table 3.

Table 3: Characteristics of Included Studies by Jurisdiction, Year and Type of Law

Jurisdiction(s)	Year of Law(s)	Type of Law(s)	Studies (year)
Victoria, Australia	1990	All-Age Law	Cameron et al., (1992);[41] Cameron et al., (1994);[42] Carr et al., (1995);[43] Finch et al., (1993);[44] Finch et al., (1993);[45] McDermott et al., (1995);[46] Newstead et al., (1994);[47] Ozanne-Smith et al., (1990);[48] Sullivan et al., (1990);[49] Vulcan et al., (1992)[50]
Western Australia	1992	All-Age Law	Cooke et al., (1993);[51] Heathcote et al., (1993);[52] Heathcote et al., (1994);[53] Hendrie et al., (1999)[36]
South Australia	1991	All-Age Law	Marshall et al., (1994)[54]
Northern Territory, Australia	Adult Law (1992) All-Age Law (1992)	All-Age law and Adult Law	Van Zyl et al., (1993)[55]
New South Wales, Australia	Adult Law, (1991) Child Law, (1991)	Adult Law and Child Law	Olivier et al., (2013);[56] Voukelatos et al., (2010);[57] Walker et al., (1992);[58] Walter et al., (2011);[59] Williams et al., (1995)[60]
New Zealand	1994	All-Age Law	Clarke et al., (2012);[61] Hansen et al., (1995);[62] Moyes et al., (2007);[63] Povey et al.,(1999);[64] Scuffham et al., (2000);[65] Taylor et al., (2002)[66]
Various jurisdictions in the United States of America (USA)	1987-2013	Child-Laws	Chatterji et al., (2013)[67]

Jurisdiction(s)	Year of Law(s)	Type of Law(s)	Studies (year)
California, USA	1994	Child-Law	Castle et al., (2012);[68] Ji et al., (2006);[69] Lee et al., (2005)[70]
Florida, USA	1997	Child-Law	Borglund et al., (1999);[71] Delamater et al., (2003);[72] Kanny et al., (2001);[73] Liller et al., (2003)[74]
New York , USA	New York (1994)	Child Law	Abularrage et al., (1997);[75] Puder et al., (1999);[76] Shafi et al., (1998)[77]
Connecticut, USA	Connecticut (1993)	Child Law	Puder et al., (1999)[76]
Howard County, Maryland, USA	1990	Child-Law	Cote et al., (1992);[78] Dannenberg et al., (1993);[79] Hatziandreu et al., (1995)[80]
Oregon, USA	1994	Child-Law	Ni et al., (1997)[81]
Georgia, USA	1993	Child-Law	Schieber et al., (1996)[82]
Ohio, USA	1990	Child-Law	Macknin et al., (1994)[83]
Various Canadian Provinces	1995-2003	All-Age Laws & Child Laws	Dennis et al., (2010);[84] Dennis et al., (2013);[85] Macpherson et al., (2002)[86]
Nova Scotia, Canada	1997	All-Age Law	LeBlanc et al., (2002)[87]
British Columbia, Canada	1996	All-Age Law	Foss et al., (2000)[88]
Alberta, Canada	2003	Child-Law	Hagel et al., (2006);[89] Karkhaneh et al., (2011);[90] Karkhaneh et al., (2013)[91]
Ontario, Canada	1995	Child-Law	Macpherson et al., (2001);[92] Macpherson et al., (2006);[93] Parkin et al., (2003);[94] Wesson et al., (2000);[95] Wesson et al., (2008)[96]

The quality of the included studies was mixed, with the highest proportion of articles rated moderate in quality. All included studies were highly relevant to the issue under investigation and all could be applied within the scope of public health. The majority of studies had clearly described methodology which was appropriate in nearly all cases. However, due to the ecological nature of the included studies (i.e., studies of risk-modifying factors on health or other outcomes based on populations defined either geographically or temporally), the most common methodological issues were lack of an appropriate control group, risk of bias (particularly selection bias) and failing to describe ethical procedures. In

addition, most studies were before/after studies and did not use comparisons that allowed control for other factors that may have changed over the same period.

Due to the nature of the intervention (helmet legislation), contextual factors that are not easily controlled may hold great influence on the evaluated outcomes, making it difficult to attribute outcomes to the legislation itself. Selection bias was a potential issue for all studies, as random assignment was neither possible nor ethical. This may further limit the generalizability of findings.

Examining Context and Potential Mechanisms for Bike Helmet Effectiveness

To examine possible mechanisms, we first conducted a systematic review of the literature to identify the impacts of helmet legislation. The findings of that review were used to generate a model proposing potential mechanisms through which helmet legislation may achieve impact (see Figure 2). The model was then tested by further exploring the evidence from the included studies and comparing findings from each study against the proposed model. This approach may help to generate hypotheses about the contexts, mechanisms and outcomes related to the implementation of bike helmet legislation.

Findings from this analysis will enable decision makers to better understand how helmet legislation works and how it has been implemented most effectively.

Results

Findings from the 57 included studies are synthesized below by outcome as well as main finding (i.e., increase, decrease or no change), outcome type (e.g., cycling frequency, cycling participation) jurisdiction and specific study type (i.e., studies comparing head to non-head injuries, studies controlling for cycling exposure, etc.). A description of the contextual factors that may influence law effectiveness, and potential mechanisms of helmet legislation follows.

For a full description of individual study findings organized by jurisdiction and law type, see Appendix E.

Impacts of Bicycle Helmet Legislation

HELMET USE

Helmet legislation was consistently associated with increased helmet use. All 40 studies examining helmet use, through direct observations or self-report, demonstrated increases in helmet wearing following law implementation.[41,42,44-50,52,54,55,57,58-60,64-66,69,71-75,77,78 79-85,87-90,93-95] Comparison studies demonstrated that jurisdictions with helmet legislation had greater increases in helmet use than those without.[73,78,79,83,84] More comprehensive legislation (i.e., all-age vs. child only) was associated with greater increases in helmet use,[76,84] and combining legislation with an educational program also resulted in greater increases in helmet use.[72,75,78,79,83]

Two studies examined helmet use by socio-economic status.[54,94] Helmet use did not differ by socioeconomic status in South Australia;[54] however in an Ontario study, greater increases were seen among low and middle-income children, although this declined over time.[94]

HELMET OWNERSHIP

Among the three US studies and one Australian study that examined the impact of helmet legislation on helmet ownership, all indicated an increase in helmet ownership after introduction of the law.[44,79,81,82] In Georgia State, USA, where a child-only law was implemented, child helmet ownership (as reported by parents) was inversely related to rider (i.e., child) age and directly related to household income.[82] In Victoria Australia, which had an all-age law, greater increases in ownership were observed among adults (10%) than children (4%).[44]

INJURIES

Almost all studies reporting on injuries before and after helmet legislation reported decreases in the burden of cycling-related injury in terms of number of head injuries,[36,41-43,45,47,48,50,52,54,57,60,64-67,70,71,85,86,91,95] hospitalizations,[54,61,74] or deaths.[46,51,52,60] However, in most studies, injury or death rates were not adjusted for cycling exposure (e.g., number of people cycling, cycling trips, cycling distances

travelled, or time spent cycling) and therefore we cannot infer or draw conclusions about changes in cycling risk from the results provided. Cycling is not universal in the population, and is highly variable from place to place (within and between jurisdictions) and over time, so comparisons are most easily interpreted if exposure is measured and adjusted for. Studies which specifically account for exposure are noted.

Hospital Admissions

Hospital admissions were defined as those admissions to a hospital which included both head and non-head injuries without specifying the injury type. Three studies examined cycling-related hospital admissions (including head and/or non-head injuries).[54,61,74] In South Australia, New Zealand and Florida, decreases in the number of cycling-related hospital admissions (both head and non-head injuries) were observed following implementation of their respective helmet laws.[54,61,74] In South Australia, after adjusting for cycling exposure (i.e., taking into account the reduction in hospital admissions that could be attributed to a decrease in cycling exposure by examining reduction in hospitalization not-preventable by helmets), decreases in the number of cycling-related hospital admissions continued to be observed post law.[54] Although they did not control for cycling exposure, Liller et al., (2003) also found decreases in the number of cycling-related hospital admissions in Florida following the implementation of their law.[74]

Injury Severity

Bike helmet legislation was also found to be associated with reductions in the number of severe and serious injuries, as well as decreases in the severity of head injuries. Six studies examined the impact of helmet legislation on severe or serious head injuries. [43,60,61,63,68,71] Studies examining the impact of helmet laws in Victoria, New South Wales, New Zealand and Florida noted fewer severe or serious head and non-head injuries experienced following the implementation of the helmet law.[43,60,63,71] Additionally, in California, there was a decrease in the Injury Severity Scores (ISS) of child head injuries presenting in hospital from pre- to post- law.[68]

Cycling exposure was generally not taken into account in these studies. However, in New Zealand, after controlling for cycling exposure (i.e., annual number of injuries per million hours spent cycling), the number of *serious* cycling injuries declined 39% (between 1988-91 and 2003-07), while the number of overall cycling injuries actually increased (20% increase).[61] Other modes of travel had similar declines in serious injury rates in same period (decreases between 45-57%), which may suggest possible concurrent road safety interventions across all road users (e.g., speed limits); however an explanation for the increase in overall injuries was not offered.[61]

Head Injuries

Twenty-six studies examined the impact of helmet legislation on cycling-related head injuries.[36,41-43,45,47,48,50,52,54,56,57,59,60,64-66,68-71,85-87,91,95] In the majority of studies examined, positive effects on cycling-related head injuries were found.[36,41-43,45,47,48,50,52,54,57,60,64-66,70,71,85,86,91,95] Decreases in cycling-related head injuries following the implementation of the mandatory helmet law were found in Western, Australia,[52]

New Zealand,[64-66] Ontario, Canada,[95] and Florida.[71] Reductions in head injuries were also found in Victoria Australia[41,43,45,48,50] but this benefit was not sustained.[47]

In California, head injuries among adults and children decreased slightly from pre- to post- legislation, although this decrease was not significant.[68,69] However, an 18.2% reduction in the proportion of cycling-related non-fatal hospitalizations for traumatic brain injuries was found among children post-law.[70]

While none of these studies directly accounted for cycling exposure, a number of studies did try to examine changes in cycling by comparing pedestrian versus cyclist head injuries,[36,59,91] and by measuring both head and non-head injuries.[42,54,57,59,85,86,96] Among comparison studies (i.e., studies comparing head vs. non-head injuries, or pedestrian vs. cyclist injuries), Western Australia showed a significant decrease in the proportion of cyclists compared to pedestrians with head injuries in the years following the law compared to pre-law rates.[36] Similarly, in New South Wales there was a significant decrease in head injuries compared to arm injuries among cyclists at the time legislation was introduced, [56,57,59,60] while no significant effect was found among pedestrians.[59] The proportion of head to total injuries also decreased from pre- to post- law in Nova Scotia.[87]

One study compared changes in head injuries among children vs. adults.[91] An Alberta study found significant declines in the proportion of hospitalized cyclist head injuries among children after the child law was introduced, compared to increases observed among adults who were not targeted by the law.[91]

Additionally, in Canada, reductions in cycling-related head injuries among children and adults were greater in provinces with legislation (both child and all-age laws), compared to those without.[85,86]

Non-Head Injuries

While reductions in non-head injuries are not anticipated due to the legislation itself, such findings may reflect concurrent contextual factors or strategies that improve cycling safety in general. Overall, there is mixed evidence regarding the impact of helmet legislation on non-head injuries. Ten studies reported on the impact of helmet legislation on non-head injuries.[41,42,45,50,54,60,67,68,70,86] Some jurisdictions found reductions in non-head injuries following legislation[41,42,45,50,54,60,67,68], while others reported increases or no change.[70,86] For instance, in Victoria, Australia there were reductions in non-head injuries following the introduction of the law[41,42,45,50] with the greatest reductions noted among teenagers, followed by children, and adults.[41] Reductions in non-head injuries following legislation were also observed in South Australia,[54] New South Wales,[60] and the United States.[67]

Additionally, there was mixed evidence for the impact of helmet legislation on non-head injuries among children in California.[68,70] One study reported that intra-abdominal injuries among children decreased post-law,[68] while a second study reported more non-head injuries among children, and no-change among adults.[70] In contrast, among Canadian provinces, no significant difference in the change over time in non-head injuries between legislative and non-legislative provinces was found.[86] Finally, none of these studies reported on accounted for cycling exposure when reporting non-head injuries.

Quantifying the impact of helmet legislation on cycling injuries

Three studies[59,85,86] attempted to quantify the impact of helmet legislation on head injury and/or death rates by controlling for (through ratio comparison) other injury types[59] or comparing trends in cycling head injuries.[85]

Walter et al., (2011) found that there was a 25% to 29% decrease in head injuries (across all ages) attributable to helmet legislation, depending on whether arm or leg injuries were used as a comparison.[59] Macpherson et al. (2002) noted that the ratio of head-to-other injuries among children decreased from 0.67 to 0.41 from pre- to post-law in Canadian provinces where legislation was set in place.[86] In contrast, another Canadian time-series analysis by Dennis et al., (2013) found that after taking into account baseline trends in cycling-related head injuries, at one year post law, there was no significant effect of helmet legislation on hospital admissions for cycling-related head injuries per total admissions for either children or adults.[85]

Deaths

Overall, results from the nine studies examining helmet legislation show that it has an overall positive impact on cycling deaths[46,51,52,60,61,63,86,95,96]; however some non-significant results were observed.[61,63] In three jurisdictions in Australia (Victoria, Western and New South Wales) fewer cycling-related deaths were observed after introduction of the helmet law,[46,51,52,60] with the decrease observed being similar among children and adults.[60] However, in New Zealand, despite a small decrease,[61,63] no significant changes were found in the number of cycling-related fatalities from pre- to post- law.[63] Only one of these studies examining cycling deaths accounted for cycling exposure[61] (See Deaths per unit of cycling) while the others did not.[46,51,52,60,63,86,95,96]

Within Canada, provinces with legislation had fewer cycling related deaths than non-legislative provinces;[86] however mixed results were also seen.[95,96] Particularly, in Ontario, where a child law was introduced in 1995, one study found that the child helmet law was temporally associated with the reduction in deaths among children, with no significant changes in mortality rates observed for adults (who were not targeted by the law)[96] while another noted no change in the number of child cycling-related deaths after legislation.[95] However, none of these studies accounted for cycling exposure.

Deaths per unit of cycling compared with other modes of travel

Risk of injury or death needs to consider cycling exposure so that injury or death incidence per cyclist or per unit of cycling (e.g., per trip, per distance travelled, per time spent cycling) can be calculated. One study from New Zealand reported deaths per unit of cycling exposure with comparable data for other modes of travel.[61] They found that cyclist deaths per hour of cycling fell by about 11% post-legislation compared to a decrease of 55% in deaths per hour walking among pedestrians in the same period.[61]

CYCLING BEHAVIOUR

Fifteen studies examined helmet legislation impact on cycling behaviour and reported conflicting findings.[41,42,44-46,49,52-55,58,61,84,92,93] Cycling behaviour includes cycling frequency and participation.

In regards to cycling frequency, mixed impacts were seen. For instance, some reduction in cycling frequency was found in New Zealand.[61]

No significant changes in cycling frequency were found in both Western Australia (all ages)[53] and South Australia.[54] Many residents in Western Australia indicated that they had actually increased their cycling in the previous 12 months (post-law).[53] However some cyclists in Western Australia indicated that they had stopped cycling because of the law, while others reported they would cycle more if they were not legally required to wear a helmet.[53]

Observational studies in Australia suggest that there was little change (and in some cases increases) in cycling participation rates among adults;[41,42,44,46] however many studies reported decreases in cycling among school children[41,42,44-46,49,52,54,55] and recreational cyclists.[52] One observational study from New South Wales found decreases in cycling participation rates among both children and adults post law.[58]

Across Canadian provinces, despite some downward trends among youth in Prince Edward Island (PEI), there were otherwise no significant reductions in ridership among children or adults after implementation of legislation.[84] For instance, two Ontario studies found no significant decrease in overall cycling rates among children following implementation of the law;[92,93] indeed one of these found increases in child cycling rates, particularly in parks.[92]

The observed decrease in cycling participation rates among children and adolescents in Australian jurisdictions and Prince Edward Island with no significant decrease among Ontario youth maybe be due to differences in the types of law implemented. For instance, Victoria Australia, South Australia, Northern Australia and Prince Edward Island implemented all-age legislation, while Ontario's helmet law mandates only children younger than 18 years of age to wear a helmet. It is also important to note that studies typically assess short term measures of cycling participation, and that rates may return to baseline levels when measured for longer periods of time.

LAW AWARENESS AND SUPPORT

Conflicting results were reported across the four studies that examined awareness and support for the law.[52,53,79,81] In Western Australia, support was generally high (60-78%)[52] and was higher among metropolitan than rural residents;[53] however no change in level of support before and immediately after the law was found.[52,5352] In contrast, among middle school students in Oregon, support for the law generally low (8%-20%), but increased following the introduction of the child helmet law.[81]

With regards to awareness of the law, knowledge was high among children in Howard County, Maryland (87%) where a campaign took place,[79] yet low among students in Oregon, where no educational campaigns were reported (1-5%).[81]

COST EFFECTIVENESS

Results from the four studies that examined the cost-effectiveness of legislation varied widely across jurisdictions and age groups.[36,62,66,80] Generally, helmet legislation was found to be more cost-effective for children compared to adults,[62,66] and was more cost-effective than non-legislative helmet programs.[80] For instance, in the small cost-effectiveness study in Howard County, Maryland, the legislative program was more cost effective than the community wide or school-based program.[80] Costs per head injury avoided varied widely and were estimated at US $36 643 for children in Howard County (1995)[80] and AU $150 900 (approx. US $92 848) in Western Australia (1998) (all ages).[36] Costs per death avoided again varied widely and were estimated at US $17 935 341 among children in Howard Country[80] and NZ $890 041 - $1 014 850 (approx. US $408 843 - $466 175) among adults in New Zealand (2000).[66] Additionally, costs per hospitalization avoided in New Zealand ranged from NZ $3 304-$4 252 (approx. US $2 017-$2 596) for children to NZ $49 143- $56 035 (approx. US $30 010- $34 219) for adults (1994).[62] (Note: Estimated US costs were calculated based on exchange rate at time of study publication.)

In the cost-effectiveness studies reviewed, only injury-related costs were considered; no studies reviewed here included health benefits related to cycling. Net benefits of the legislation in New Zealand were positive for children, but not for adolescents or adults (Net benefits of NZ $0.3 million (children), NZ $-0.2million (adolescents) and NZ $-1.5 million (adults).[66] Overall, the helmet law in this jurisdiction was cost saving for children but was costly for adult cyclists.[66]

Context of Helmet Legislation Implementation

All helmet laws evaluated in the included studies were enacted between 1990 and 2003. Nearly all jurisdictions had fines for non-compliance, for example $15 USD in Florida[73] and $150 NZD in New Zealand[63] based on their own currency. Enforcement efforts were minimal in many jurisdictions where cited.[42,46,67,82,96]

Incentive programs such as helmet rebate schemes were provided in a number of jurisdictions[36,42,46,50,54,55,60,75,85] allowing for example, $10 off the purchase of a standardized approved helmet.[54] Additionally, nearly all jurisdictions introduced a helmet promotion campaign prior to or just following the introduction of the law.[36,42,43,45,47,50,54,55,60,63,67,71,73,75,85,87-89,94] These campaigns often involved media awareness/public education[36,42,43,45,47,50,54,55,60,63,67,71,73,75,85,87-89,94] and school-based programs[42,50,54,55,60,65,73,78-80,83,88,95] (See Appendix F).

CONTEXTUAL FACTORS ASSOCIATED WITH HELMET USE AFTER A LAW

Factors that influence the effectiveness of a proposed all-age helmet law should be examined. However, due to limited contextual evidence provided by authors in the evaluated reports (and unsuccessful efforts to obtain this information from alternative sources) few contextual elements could be associated with law effectiveness.

One contextual element that was associated with increased helmet use was the application of community or school-based programs or incentive programs to supplement the introduction of the law.[72,75,78-81,83] For instance, in five separate studies within the US, jurisdictions that combined legislation with an educational or incentive program demonstrated greater increases in helmet use than jurisdictions with a law alone or no helmet program or law.[72,75,78,79,83] Educational programs also resulted in greater knowledge of the law among children in jurisdictions where an educational campaign took place compared to those where no educational campaign was reported.[81] These benefits increased when educational or incentive programs were combined with the introduction of helmet legislation, as one study noted that community-wide or school-based programs, when evaluated on their own, were not as cost-effective as legislation.[80]

Potential Mechanisms of Helmet Legislation

POTENTIAL MECHANISMS

Consistent with other reviews, we found that across most studies, cycling related head-injuries, non-head injuries, hospitalizations and deaths decreased following the implementation of helmet legislation, although most studies did not account for cycling exposure. Although inconsistently reported, we observed variable impacts on ridership and the ratio between head and non-head injuries. Together these findings suggest that helmet legislation may impact distal outcomes through a number of possible mechanisms or pathways, which include: 1) increased helmet use in response to the legislation and the concurrent promotion of bicycle helmets; 2) decreased ridership which may or may not be as a result of the legislation; 3) increased ridership resulting in "safety in numbers" that may be due to concurrent or coincidental promotion or improvements in cycling infrastructure; or 4) a combination of these mechanisms. See Figure 2.

The purpose of this section is to further explore these possible mechanisms, including an assessment of the evidence within included studies that supports or refutes the plausibility of each based on the pattern of injury and other findings. To test the proposed mechanisms described above, report findings from each included study were compared against the proposed pathways. See Appendix G.

Thirty-seven studies were missing data from at least one of the specified outcomes (cycling, helmet use, head injuries, non-head injuries and head: non-head injury ratio) and therefore it could not be determined with certainty whether the evidence supports or disputes the proposed mechanisms.[36,43,44,46,49,51,53,55,56,58,61-63,67,68,70,72-84,86,88-94,96]

Mechanism 1 – Increased Helmet Use

Mechanism 1 specifies that observed reductions in cycling-related injuries and deaths may be due to increased helmet use in response to the legislation, which was found among all jurisdictions described. Bicycle helmets have been shown reduce head injury risk after a crash by 30% to 88%.[27,28] Therefore, mechanism 1 postulates that helmet use increases that resulted from helmet legislation may have reduced cyclists' head injury risk, resulting in fewer head injuries, hospitalizations and deaths.

Testing Mechanism 1

Eighteen included studies reported evidence supporting the mechanism of decreased head injuries through increased helmet use.[41,42,45,47,48,50,52,54,57,59,60,64-66,71,85,87,95] However, most of these studies did not control for cycling exposure (e.g., by adjusting for number of cycling trips per day). As helmets have been shown to be effective in reducing head injuries,[27] it is suggested that increased helmet use would reduce the number of head injuries observed. Fifteen studies reported both increased helmet use and decreased head injury rates after implementation of legislation.[41,42,45,47,48,50,52,54,57,60,64-66,85,95] Additionally, three studies reported increased helmet use together with a decreased head-injury to non-head injury ratio.[57,59,87] By using non-head injuries as a comparison, these studies provide increased support for the mechanism of decreased head injuries through increased helmet use.

Only one study by Ji et al., (2006) reported evidence conflicting with the first proposed mechanism wherein increased helmet use was reported without a corresponding reduction in head injuries.[69] However, the authors conclude that failure to find that helmet legislation alone significantly reduced head injury rates was likely due to study limitations such as short study duration and the data source itself (i.e., trauma registry), which was biased toward capturing more serious injuries.

Mechanism 2 – Concurrent or Coincidental Decreased Ridership

Mechanism 2 proposes that decreased ridership, which some studies noted after the introduction of legislation, may have contributed to the observed reductions in head injuries, hospitalizations and deaths by reducing population-level cycling exposure. Decreased ridership together with decreases in non-head injuries found in some jurisdictions were consistent with fewer cyclists on the road, and therefore fewer cycling-related crashes, injuries and deaths post-legislation (See Figure 2). Mechanism 2 postulates that, through a reduction in the number of cyclists on the road (i.e., the denominator), an observed reduction in head injuries, non-head injuries and deaths may occur.

It is also important to note that decreased ridership may have also contributed to a relative increase in the proportion of riders wearing helmets, if those who stopped cycling were individuals who were less likely to wear a helmet. If the legislation caused non-helmet wearers to stop cycling, without impacting those who were already wearing a helmet, then there may have been fewer cyclists on the road, but a greater proportion wearing helmets (appearing as increased helmet use). Finally, a reduction in cycling modal share as a result of decreased ridership could also have negatively impacted injuries and deaths, as modal share is known to be protective. It is important to note that changes in ridership may not have been attributable to the legislation itself, as there may have been pre-existing trends of ridership that began before helmet legislation was introduced.

Testing Mechanism 2

Three studies from Victoria, Australia[41,42,45] and one study from South Australia[54] provided evidence to support a second possible mechanism – decreased injuries through reduced ridership. For instance, all four studies reported decreases in ridership among children and/or adolescents[41,42,45,54] or across all ages[41] as well as overall decreases in *non*-head injury rates.[41,42,45,54] While increases in helmet use would likely impact head, but not non-head injuries, decreases in ridership would likely impact both head and non-head injuries, since fewer cyclists on the road reduces the risk for any type of cycling injury.

Therefore, studies that report decreases in both non-head injuries and decreased cycling rates suggest that helmet legislation may be impacting injury rates in part through decreased ridership rather than increased helmet use, or that decreased ridership occurred concurrent with the introduction of bike helmet legislation.

Mechanism 3 – Concurrent or Coincidental Increased Ridership

A third possible mechanism to explain reductions in injuries, hospitalization and deaths is a concurrent or coincidental increase in ridership at the time of bike helmet legislation. Increases in ridership have a protective effect on cyclists through 'safety in numbers' or 'cycle modal share', whereby relatively fewer collisions and cycling-related injuries occurred as the number of cyclists on the road increased.[97] Increased ridership may have increased cyclists' safety through 'safety in numbers', therefore reducing risk of head and non-head injuries, hospitalizations and deaths for cyclists.

It is important to note that changes in ridership may not be attributable to the legislation itself, as there may have been pre-existing ridership trends that began before helmet legislation was introduced.

Additionally, cycling promotion initiatives or cycling infrastructure improvements around the same time that helmet legislation was introduced could have increased ridership following helmet legislation.

Testing Mechanism 3

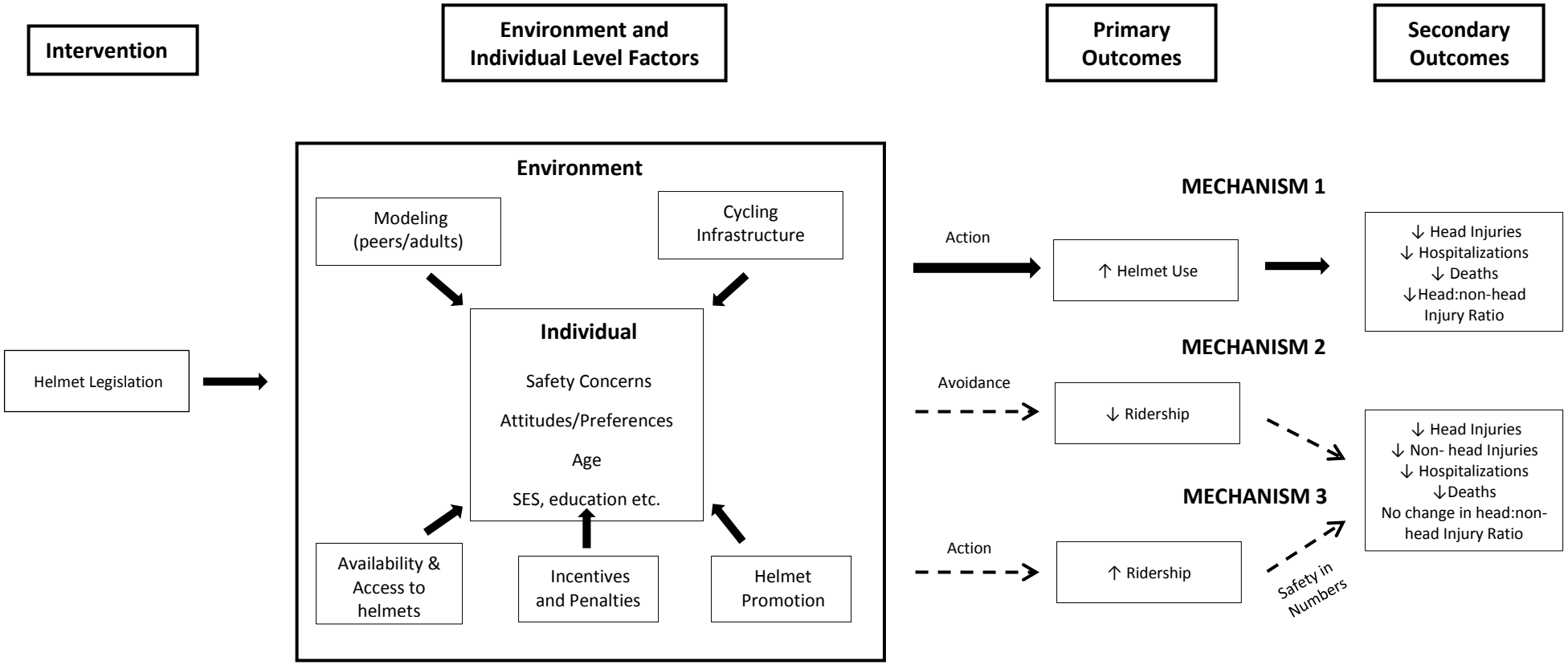
Three studies from Victoria, Australia provided evidence that demonstrated increased ridership concurrent with, or coincidental with, introduction of the helmet law.[41,42,45] All three studies reported increased ridership among adults[41,42] or all ages (adults and children)[45] after the introduction of legislation, as well as decreased head and non-head injuries. This finding is consistent with the possibility that more cyclists on the road or 'safety in numbers' may have had a protective effect on cyclists, reducing their relative risk of injuries.

Additional Factors – Safer Cycling Infrastructure

Changes to cycling infrastructure concurrent or coincidental with helmet legislation may make cycling safer, independent of helmet laws. However, most jurisdictions that implemented helmet legislation in the 1990s and early 2000s (Canada, the US, Australia, New Zealand) focused their cycling safety programs almost exclusively on helmets.[46,50,51,55,73,79,85]

On the other hand, changes to other elements of traffic safety, aimed primarily at driving (e.g., drinking and driving laws and enforcement, licensing and testing of young drivers and elderly drivers, car braking systems, road design, etc.,) occurred throughout the same time frame as the legislation[57] and resulted in a steady concurrent decline in traffic crashes of all types. However, due to the lack of contextual details provided in the studies, it was not possible to explore safer cycling infrastructure as a possible mechanism.

Figure 2. Proposed Mechanisms of Helmet Legislation



Discussion

Overall, the included studies in this review showed that mandatory helmet legislation effectively increased helmet use and helmet ownership, and decreased hospitalizations, head injuries, injury severity and severe injuries, and cycling-related deaths. However, in the majority of studies, cycling exposure was not reported. There were mixed results regarding cycling behaviour, non-head-injuries and law knowledge and awareness. Our results are similar to those reported in other reviews that have noted that helmet legislation increases helmet use,[4,5,34,98] and reduces head injury risk.[4-6,34] Helmet legislation was cost-saving for children but was costly for adult cyclists; however, the health benefits of cycling were not taken into account. The results also reinforced that there is an added benefit of combining an educational or incentive program with the introduction of a helmet law to further increase helmet use.

Taken together, these findings suggest that the observed pattern of injuries, hospital admissions and deaths may be the result of several mechanisms, including: increased helmet use as a response to helmet legislation and helmet promotion; changes to cycling behaviour (e.g., decreased or increased ridership) in response to, or coincidental with, helmet legislation; and/or concurrent or coincidental improvements to the safe cycling infrastructure. Overall, the available evidence supports increased helmet use after introduction of helmet legislation. This was also associated with decreased severity of head injuries and decreased proportion of head to non-head injuries. However, evidence also indicates cycling decreases in some jurisdictions, associated with decreases in both head and non-head injuries. Finally, some evidence supported increased cycling participation and reduced injury consistent with possible “safety in numbers”, accompanying bicycle helmet use, possibly due to cycling promotion.

Influence of Individual and Environmental Factors

Whether or not individuals decide to increase their helmet use, or increase, decrease or change their cycling behaviour may be dependent on a number of individual, peer group and environmental influences or a combination of these (Figure 2). Individual characteristics such as safety concerns,[99] attitudes and preferences[100] toward helmet wearing may impact individual behaviour, in addition to environmental factors such as modeling of helmet use by others,[101] and the presence of a safe cycling infrastructure.[102]

Helmet legislation may instill safety concerns within individuals, helping to persuade them to increase helmet use or to avoid riding. Loubeau (2000) noted that young teenagers do not perceive cycling as a high-risk activity and believe that serious head injuries and deaths caused by cycling are extremely rare.[99] However, in a 2002 telephone survey of 1000 Canadian adults, almost all Canadians (97%) ‘strongly agreed’ or ‘somewhat agreed’ that wearing a helmet for activities such as cycling can prevent serious injury and 95% ‘strongly agreed’ or ‘somewhat agreed’ that it is important always to wear a helmet while participating in activities such as cycling.[100] Yet they also reported that the main reasons why Canadians do not wear helmets are because they 'don't bother' (14%), 'appearance' (14%), and because helmets are 'not cool' (13%), 'uncomfortable' (11%) and 'inconvenient/cumbersome' (10%).[100]

Similarly, in a UK study by the Department of Transport London (2010), examining cyclists' perceptions of helmet legislation, participants felt that helmets had a negative effect on their appearance.[103] They also felt that helmet legislation would be an infringement of personal liberties, and some argued that they would be less likely to cycle if they were obliged to wear a helmet.[103] This demonstrates that safety may be relatively unimportant in the way helmets are conceptualized, even by many of those who wear them.[103] The authors note that while helmets are perceived to provide safety in situations that are dangerous, it is unlikely that many cyclists have given very much thought to the safety features helmets provide.[103] The authors further suggest that shifting this perspective, by emphasizing the dangers from which helmets can protect them, might actually discourage people from cycling.[103]

Despite negative perceptions of helmet wearing by some cyclists, a Canadian study by Clare (2011) noted that two main safety concerns of cyclists were 'careless drivers' and 'traffic conditions'.[102] Clare (2011) found that the provision of more bicycle lanes, paths, route signage, and parking facilities was associated with higher rates of bicycle use among the general public.[102] Helmet legislation introduced into an environment with sufficient cycling infrastructure may be less likely to negatively impact ridership among cyclists.

Individual factors such as age and socioeconomic status may also influence whether or not an individual chooses to comply with the law and wear a helmet. In a systematic review conducted by the Department of Transport, London, both age and socioeconomic status (SES) were noted as possible barriers or facilitators to helmet use.[37] They reported that teenagers were less likely than children and adults to report or be observed wearing a helmet. Additionally, they found that rates of helmet use/ownership were highest among young children followed by adults and teenagers, respectively.[37] Social background has also been shown to influence helmet use as helmet ownership and use has been found to be positively associated with income and educational level where greater helmet use was found among more affluent areas.[37]

Lastly, adult role models and peers may impact whether or not an individual decides to comply with the helmet law and wear a helmet. Role models including parents or peers can change perceptions and behavior. In a study by Khambalia et al., (2005), helmeted adult cycling companions were positively associated with child helmet use while adult cycling companions not wearing helmets were negatively associated with child helmet use.[101] Additionally, Gielen et al., (1994) noted that children who reported that their friends wore helmets were nine times more likely to wear helmets than those whose friends did not wear a helmet.[104]

Together, the characteristics of the individual and their social and physical environment interact to impact whether or not an individual chooses to wear a helmet, and/or increase or decrease their cycling in the face of mandatory helmet legislation. If an individual is placed within a supportive environment (e.g., access to helmets, positive role models and helmet promotion) they may be more likely to choose to wear a helmet while cycling.

Other Components of a Comprehensive Strategy for Safer Cycling

Mandatory bike helmet legislation exists as part of a larger comprehensive cycling strategy in which additional factors may influence law effectiveness and/or cycling safety. These may include safe cycling infrastructure (e.g., separated bike lanes), regulations and enforcement (e.g., one metre passing rule), and bicycle commuter education.[97]

These factors may have contributed to cyclists' low injury rates, despite low helmet use, in European countries such as Denmark or the Netherlands where good infrastructure, stronger legislation to protect cyclists, and a cycling culture exist.[7]

In addition to safe cycling infrastructure, in many European countries, cycling safety is improved through cycle modal share or 'safety in numbers'.[29] Safety in numbers is the effect in which fewer collisions and cycling injuries occur as the number of cyclists on the road increases.[97] Elvik et al., (2009) reports that as the number of pedestrians and cyclists increases, with a corresponding decrease in motorists, the risk to each pedestrian or cyclist decreases non-linearly.[105] More people are likely to ride when there is safe infrastructure to support them, thus increasing the number of cyclists on the road and improving safety for all riders.[97]

Teschke (2012) notes that helmet laws have not always succeeded in making people feel safe enough to increase cycling rates.[29] For instance, in Ontario, 78% of Ontarians believe that more people would cycle if there were better cycling infrastructure.[13] Additionally, Pucher et al., (2005) note that in Canada more bike paths and lanes are needed to encourage people to cycle, and that the perception that road cycling is dangerous is a large barrier to increasing cycling behaviour.[17] Even cities with the highest cycling rates in British Columbia have significantly lower cycling rates than those of safer European countries such as Germany, Denmark, and the Netherlands.[29] Therefore, primary prevention efforts such as improvements in cycling infrastructure are needed to improve the safety of cyclists.

Fortunately, the 2012 Ontario Cycling Strategy focused on improving cycling infrastructure, and making highways and streets safer.[13] This might include creating more bike paths, cycling-friendly transit connectors, updating traffic laws and policies based on current research, better enforcement of rules of the road and increasing road-user skills and education.[13] These improvements to the cycling environment were likely to increase cycling behaviour independent of helmet legislation. Together with a mandatory helmet law, these primary prevention efforts will contribute to a comprehensive strategy for safer cycling, helping to improve the safety of Ontario cyclists.

Limitations

There are a number of limitations to be considered. First, findings were limited by the types of studies available in the literature. Many studies were quasi-experimental and few had appropriate control groups making it difficult to identify causal relationship between the helmet legislation and subsequent outcomes. We could only infer associations. Additionally, many studies relied on survey or observational data that was limited by self-report and selection bias.

Our findings were also limited by the types of outcomes and contextual information reported in the literature. For instance, not all studies provided information about the context in which legislation was implemented, and most studies reported on only a few select outcomes. This lack of information limited the assessment regarding which contextual components were associated with greater law effectiveness and may have biased results towards more positive associations because proposed negative outcomes (e.g., cycling rates, risk compensation) were seldom reported.

Lastly, there may have been some duplication in results as many studies used similar sources of data (e.g., VicRoads data, Transport Accident Commission (TAC) reports, coroner's data etc.). However, the authors of this report have minimized the impact of this duplication by reporting these findings together.

Additionally, all studies reporting on injuries before and after helmet legislation reported numbers and rates of injuries, hospitalizations, or deaths. However the majority of these injury or death rates did not adjust for exposure to cycling (e.g., number of people cycling, cycling trips, cycling distances travelled, or time spent cycling). Thus information on risk in relationship to exposure is incomplete.

It is also important to note that while our report contained a comprehensive review of the literature regarding helmet legislation, prominent cycling jurisdictions that do *not* have helmet laws, such as Denmark and the Netherlands, were by definition, not included.

This review also did not examine the potential health benefits/burdens due to increased or decreased activity-related chronic diseases (heart disease, stroke, dementia, diabetes, certain cancers) as might relate to the impact of helmet laws on cycling participation. A body of evidence suggests that the benefits of cycling far outweigh the risks (across various setting and scenarios), due to the large physical activity-related chronic disease impacts.[11]

Finally, we acknowledge the possibility of publication bias. Despite these limitations, this review forms a useful basis for decision-making regarding bike helmet legislation, and mechanisms and contextual factors that need to be considered to optimize cycling outcomes overall.

Conclusion

Overall, mandatory helmet legislation was associated with increased helmet use and helmet ownership, fewer hospitalizations, fewer severe injuries, decreased injury severity and fewer cycling related deaths with mixed results regarding non-head injuries and cycling behaviours. Decreases in head injuries were also found and it is plausible that these were due to increased helmet use; however other mechanisms are also possible. Decreases in child and adolescent cycling participation were most evident in jurisdictions with all-age rather than child helmet legislation. Helmet legislation was shown to be more cost-effective than community or school-based helmet programs and had little impact on knowledge and support for the law. More comprehensive legislation (i.e., all-age vs. child law) and supplementary incentive programs were associated with greater law effectiveness particularly for the outcome of helmet use for both children and adults. Educational programs were found to increase law effectiveness for children, particularly for the outcome of law awareness.

Many of the included papers were published in English-speaking jurisdictions similar to Ontario with a high degree of reliance on motor vehicles and low cycling rates. While our report contains a comprehensive review of literature regarding helmet legislation, prominent cycling jurisdictions that do *not* have helmet laws, such as Denmark and the Netherlands, were by definition, not included.

Together these results demonstrate a positive effect for a majority of the outcomes including helmet use and ownership, injury and death rates. In the majority of studies reviewed, there was evidence to support decreased head injuries and deaths in association with increased helmet use occurring after bike helmet legislation, although most studies did not adjust for cycling exposure. Findings consistent with reduced injury and deaths through decreased ridership (fewer cyclists on the road), or increased ridership (safety in numbers) were also noted, although fewer studies reported results (e.g., ridership data) by which these mechanisms could be assessed.

The implementation of helmet laws must be considered along with additional factors that may influence law effectiveness, cycling participation and/or cycling safety. Together, the characteristics of the individual and their social and physical environment may interact to impact whether or not an individual chooses to wear a helmet, and/or to increase or decrease their cycling in the face of mandatory helmet legislation. To achieve the health benefits of cycling, while avoiding unintended negative impacts (such as reduced cycling participation), the implementation of helmet laws should be considered alongside other contextual factors (such as safe cycling infrastructure and cycling education) that may influence law effectiveness, cycling participation and/or cycling safety.

References

1. Hamer M, Chida Y. Active commuting and cardiovascular risk: a meta-analytic review. Prev Med. 2008;46(1):9-13.

2. Office of the Chief Coroner for Ontario. Cycling death review: a review of all accidental cycling deaths in Ontario, from January 1st, 2006 to December 31st, 2010 [Internet]. Toronto, ON: Queen's Printer for Ontario; 2012 [cited 2015 Jul 23]. Available from: http://www.mcscs.jus.gov.on.ca/english/DeathInvestigations/office_coroner/PublicationsandReports/CyclingDeathReview/DI_Cycling_Death_Review.html

3. *Highway Traffic Act*, R.S.O. 1990, c. H.8.,s.104. Available from: http://www.e-laws.gov.on.ca/html/statutes/english/elaws_statutes_90h08_e.htm

4. Macpherson A, Spinks A. Bicycle helmet legislation for the uptake of helmet use and prevention of head injuries. Cochrane Database Syst Rev. 2008;16(3):CD005401.

5. Canadian Paediatric Society. Bicycle helmet use in Canada: the need for legislation to reduce the risk of head injury. Paediatr Child Health. 2013;18(9):457-80. Available from: http://www.cps.ca/documents/position/bike-helmets-to-reduce-risk-of-head-injury

6. Safe Kids Canada. Position statement on bicycle helmet legislation [Internet]. Toronto, ON: Parachute; 2010 [cited 2015 Jul 23]. Available from: http://www.parachutecanada.org/downloads/policy/Helmet_legislation_position_statement_EN_FINAL.pdf

7. Goldacre B, Spiegelhalter D. Bicycle helmets and the law. BMJ. 2013;346:f3817.

8. Phillips RO, Fyhri A, Sagberg F. Risk compensation and bicycle helmets. Risk Anal. 2011;31(8):1187-95.

9. Robinson DL. Bicycle helmet legislation: can we reach a consensus? Accid Anal Prev. 2007;39(1):86-93.

10. Pucher J, Buehler R. Making cycling irresistible: lessons from the Netherlands, Denmark and Germany. Transport Rev. 2008;28(4):495-528.

11. Woodcock J, Tainio M, Cheshire J, O'Brien O, Goodman A. Health effects of the London bicycle sharing system: health impact modelling study. BMJ. 2014;348:g425. Available from: http://www.bmj.com/content/348/bmj.g425.long

12. Statistics Canada. Bicycle helmet use, 2009 [Internet]. Ottawa, ON: Government of Canada; 2010 [cited 2013 Dec 12]. Available from: http://www.statcan.gc.ca/pub/82-625-x/2010002/article/11274-eng.htm

13. Ontario. Ministry of Transportation. #CycleON: Ontario's cycling strategy [Internet]. Toronto, ON: Queen's Printer for Ontario; 2013 [cited 2014 Feb 3]. Available from: http://www.mto.gov.on.ca/english/pubs/cycling-guide/pdfs/MTO-CycleON-EN.pdf

14. Canadian Society for Exercise Physiology. Canadian physical activity guidelines for adults 16- 64 years [Internet]. Ottawa, ON: Canadian Society for Exercise Physiology; 2011 [cited 2015 Jul 23]. Available from: http://www.csep.ca/CMFiles/Guidelines/CSEP_PAGuidelines_adults_en.pdf

15. Teschke K, Reynolds CO, Riesc FJ, Gougec B, Wintersd M. Bicycling: health risk or benefit? UBC Medical Journal. 2012;3(2):6-11. Available from: http://www.ubcmj.com/pdf/ubcmj_3_2_2012_6-11.pdf

16. Andersen LB, Schnohr P, Schroll M, PhD D, Ole Hein H. All-cause mortality associated with physical activity during leisure time, work, sports, and cycling to work. Arch Intern Med. 2000;160(11):1621-28.

17. Pucher J, Buehler R. Cycling trends & policies in Canadian cities. World Transp Policy Pract. 2005;11(1):43-61. Available from: http://www.eco-logica.co.uk/pdf/wtpp11.1.pdf

18. Granville S, Rait F, Barber M. Sharing road space: drivers and cyclists as equal road users [Internet]. Edinburgh: Scottish Executive Central Research Unit; 2001 [cited 2015 Jul 23]. Available from: http://www.gov.scot/resource/doc/156597/0042065.pdf

19. Ernst M, McCann B. Mean streets 2002 [Internet]. Washington, DC: Surface transportation policy project;2002 [cited 2015 Jul 23]. Available from: http://transact.org/wp-content/uploads/2014/04/Mean_Streets_2002.pdf

20. Toronto Public Health. Road to health: improving walking and cycling in Toronto [Internet]. Toronto, ON: City of Toronto; 2012 [cited 2015 Jul 23]. Available from: http://www.toronto.ca/legdocs/mmis/2012/hl/bgrd/backgroundfile-46520.pdf

21. World Health Organization Regional Office for Europe. Health economic assessment tools (HEAT) for walking and for cycling: Methodology and user guide, 2014 update: economic assessment of transport infrastructure. Copenhagen: World Health Organization Regional Office for Europe; 2014 [cited 2015 Jun 23]. Available from: http://www.euro.who.int/__data/assets/pdf_file/0010/256168/ECONOMIC-ASSESSMENT-OF-TRANSPORT-INFRASTRUCTURE-AND-POLICIES.pdf?ua=1

22. Ontario Injury Prevention Resource Centre. Cycling injuries [Internet]. Ontario Injury Compass. 2009;6(8). Toronto, ON: Ontario Injury Prevention Resource Centre; 2009 [cited 2014 Aug 6]. Available from: http://www.oninjuryresources.ca/downloads/compass/2009-08-0ICompass-Cycling5.pdf

23. Persaud N, Coleman E, Zwolakowski D, Lauwers B, Cass D. Non-use of bicycle helmets and risk of fatal head injury: a proportional mortality, case-control study. CMAJ. 2012;184(17):E921-3. Available from: http://www.cmaj.ca/content/184/17/E921.long

24. Ontario. Ministry of Transportation. Ontario road safety annual report 2010. Toronto, ON: Queen's Printer for Ontario; 2011. Available from: http://www.mto.gov.on.ca/english/publications/pdfs/ontario-road-safety-annual-report-2010.pdf

25. Teschke K, Harris MA, Reynolds CC, Winters M, Babul S, Chipman M, et al. Route infrastructure and the risk of injuries to bicyclists: a case-crossover study. Am J Public Health. 2012;102(12):2336-43. Available from: http://www.ncbi.nlm.nih.gov/pmc/articles/PMC3519333/

26. Reynolds CC, Harris MA, Teschke K, Cripton PA, Winters M. The impact of transportation infrastructure on bicycling injuries and crashes: a review of the literature. Environ Health. 2009:8:47,069X-8-47. Available from: http://www.ehjournal.net/content/8/1/47

27. Thompson DC, Rivara FP, Thompson R. Helmets for preventing head and facial injuries in bicyclists. Cochrane Database Syst Rev. 2000;(2):CD001855.

28. Elvik R. Corrigendum to: "Publication bias and time-trend bias in meta-analysis of bicycle helmet efficacy: a re-analysis of Attewell, Glase and McFadden, 2001" [Accid Anal Prev. 43 (2011) 1245–1251]. Accid Anal Prev. 2013;60:245-53.

29. Teschke K. Bicycling injuries, helmets, & helmet legislation. Prepared as expert testimony for a Provincial Traffic Court case: Regina vs. Van Der Eerden [Internet]. Vancouver, BC: University of British Columbia, Cycling in Cities; 2012 [cited 2015 Jul 24].

30. Safe Kids Canada. Bike helmet legislation chart [Internet]. Toronto, ON: Parachute; 2014 [cited 2015 Jul 24]. Available from: http://horizon.parachutecanada.org/wp-content/uploads/2014/09/Bike-Helmet-Legislation-Chart-2014.pdf

31. Bill 129, An act to amend the Highway Traffic Act, 1st Sess, 38th Leg, Ontario, 2004. Available from: http://www.ontla.on.ca/bills/bills-files/38_Parliament/Session1/b129.pdf

32. Ontario Medical Association. OMA policy paper: enhancing cycling safety in Ontario [Internet]. Toronto, ON: Ontario Medical Association; 2011 [cited 2015 Jul 27]. Available from: https://www.oma.org/Pages/ContactUs.aspx

33. Association of Public Local Public Health Agencies (alPHa). Petition the Ontario government to enact an all-ages provincial bicycle helmet legislation, alPHa Resolution A12-8 [Internet]. Toronto, ON: alPHA; 2012 [cited 2015 Jul 27]. Available from: http://c.ymcdn.com/sites/www.alphaweb.org/resource/collection/1BA1FB32-FCDB-48B1-8DE8-8E50E023FADA/A12-8_BikeHelmets.pdf

34. Goudie R, Page JL. Canadian Academy of Sport and Exercise Medicine position statement: mandatory use of bicycle helmets. Clin J Sport Med. 2013;23(6):417-8. Available from: http://casem-acmse.org/wp-content/uploads/2013/07/CASEM-bike-helmet-position-statement-CJSM.pdf

35. Canadian Academy of Sports Medicine. Position statement: mandatory use of bicycle helmets (revised February 2000) [Internet]. Ottawa, ON: Canadian Academy of Sports Medicine; 2000 [cited 2015 Jul 27]. Available from: http://sirc.ca/sites/default/files/content/docs/newsletters/archive/mid-june09/documents/S-972579.pdf

36. Hendrie D, Legge M, Roseman D, Kirov C. An economic evaluation of the mandatory bicycle helmet legislation in Western Australia. Paper presented at: Green Light for the Future: Insurance Commission of Western Australia Conference on Road Safety. 1999; Perth, AU. Available from: http://rsc.wa.gov.au/Documents/Cyclists/ors-cyclists-report-helmets-evaluation.aspx

37. U.K. Department for Transport. Bicycle helmets: review of effectiveness (no.30). London: Crown Copyright; 2002.

38. Morgan M, Peberdy J, Rogerson P. Bicycle helmet usage rates in Victoria: 1990-1991 and other bicycle safety factors. Hawthorne, AU: Victoria Road Safety and Traffic Authority; 1991.

39. Thomas BH, Ciliska D, Dobbins M, Micucci S. A process for systematically reviewing the literature: providing the research evidence for public health nursing interventions. Worldviews Evid Based Nurs. 2004;1(3):167-84.

40. Armijo-Olivo S, Stiles CR, Hagen NA, Biondo PD, Cummings GG. Assessment of study quality for systematic reviews: a comparison of the Cochrane collaboration risk of bias tool and effective public health practice project quality assessment tool methodological research. J Eval Clin Pract. 2012;18(1):12-8.

41. Cameron MH, Heiman L, Neiger D. Evaluation of the bicycle helmet wearing law in Victoria during its first 12 months. Report No. 32. Victoria, AU: Monash University Accident Research Centre; 1992.

42. Cameron MH, Vulcan AP, Finch CF, Newstead SV. Mandatory bicycle helmet use following a decade of helmet promotion in Victoria, Australia: an evaluation. Accid Anal and Prev. 1994;26(3):325-37.

43. Carr D, Skalova M, Cameron MH. Evaluation of the bicycle helmet wearing law in Victoria during its first four years. Report No. 76. Victoria, AU: Monash University Accident Research Centre; 1995. Available from: http://monash.edu.au/miri/research/reports/muarc076.pdf

44. Finch CF, Heiman L, Neiger D. Bicycle use and helmet wearing rates in Melbourne, 1987-1992: the influence of the helmet wearing law. Report No. 45. Victoria, AU: Monash University Accident Research Centre; 1993. Available from: http://www.monash.edu/miri/research/reports/muarc045.pdf

45. Finch CF, Newstead SV, Cameron MH, Vulcan AP. Head injury reductions in Victoria two years after introduction of mandatory bicycle helmet use. Report 51. Victoria, AU: Monash University Accident Research Centre; 1993. Available from: http://www.monash.edu/miri/research/reports/muarc051.pdf

46. McDermott FT. Bicyclist head injury prevention by helmets and mandatory wearing legislation in Victoria, Australia. Ann R Coll Surg Engl. 1995;77(1):38-44. Available from: http://www.ncbi.nlm.nih.gov/pmc/articles/PMC2502490/

47. Newstead SV, Cameron MH, Gantzer S, Finch CF. Bicyclist head injuries in Victoria three years after the introduction of mandatory helmet use. Report No. 75. Victoria, AU: Monash University Accident Research Centre; 1994. Available from: http://www.monash.edu.au/miri/research/reports/muarc075.pdf

48. Ozanne-Smith J, Sherry K. Bicycle related injuries: head injuries since helmet legislation. Hazard. 1990(6):1-8.

49. Sullivan G. Initial effects of mandatory bicycle helmet wearing legislation. Hawthorne, AU: Victoria Road Safety and Traffic Authority; 1990.

50. Vulcan AP, Cameron MH, Watson WL. Mandatory bicycle helmet use: experience in Victoria, Australia. World J Surg. 1992;16(3):389-97.

51. Cooke CT, Margolius KA, Cadden GA. Cycling fatalities in Western Australia. Med J Aust. 1993;159(11-12):783-5.

52. Heathcote B. Bicyclist helmet wearing in Western Australia: a 1993 review. Hawthorne, AU: Victoria Road Safety and Traffic Authority; 1993.

53. Heathcote B, Maisey G. Bicycle use and attitudes to the helmet wearing law. East Perth, AU: Traffic Board of Western Australia; 1994.

54. Marshall J, White M. Evaluation of the compulsory helmet wearing legislation for bicyclists in South Australia. Office of Road Safety Report Series 8/94. Walkerville, AU: South Australian Department of Transport, Office of Road Safety; 1994.

55. van Zyl R. Bicycle helmet wearing in the Northern Territory. Darwin, AU: Road Safety Council of the Northern Territory;1993.

56. Olivier J, Walter SR, Grzebieta RH. Long term bicycle related head injury trends for new south wales, australia following mandatory helmet legislation. Accid Anal Prev. 2013;50:1128-34.

57. Voukelatos A, Rissel C. The effects of bicycle helmet legislation on cycling-related injury: the ratio of head to arm injuries over time. J Austral Coll Road Safety. 2010;21(3):50-6.

58. Walker MB. Law compliance among cyclists in New South Wales, April 1992; a third survey. New South Wales, AU: NSW Roads and Traffic Authority, Network Efficiency Branch; 1992. Available from: http://www.rms.nsw.gov.au/documents/roads/using-roads/bicycles-law-compliance-among-cyclists-nsw-1992.pdf

59. Walter SR, Olivier J, Churches T, Grzebieta R. The impact of compulsory cycle helmet legislation on cyclist head injuries in New South Wales, Australia. Accid Anal Prev. 2011;43(6):2064-71.

60. Williams M. Evaluation of the NSW introduction of compulsory bicycle helmet legislation. Research note 17/94. Haymarket, AU: Roads and Traffic Authority, Road Safety and Traffic Management Directorate; 1995.

61. Clarke CF. Evaluation of New Zealand's bicycle helmet law. N Z Med J. 2012;125(1349):60-9.

62. Hansen P, Scuffham PA. The cost-effectiveness of compulsory bicycle helmets in New Zealand. Aust J Public Health. 1995;19(5):450-4.

63. Moyes SA. Changing pattern of child bicycle injury in the bay of plenty, New Zealand. J Paediatr Child Health. 2007;43(6):486-88.

64. Povey LJ, Frith WJ, Graham PG. Cycle helmet effectiveness in New Zealand. Accid Anal Prev. 1999;31(6):763-70.

65. Scuffham P, Alsop J, Cryer C, Langley JD. Head injuries to bicyclists and the New Zealand bicycle helmet law. Accid Anal Prev. 2000;32(4):565-73.

66. Taylor M, Scuffham P. New Zealand bicycle helmet law -- do the costs outweigh the benefits? Inj Prev. 2002;8(4):317-20. Available from: http://injuryprevention.bmj.com/content/8/4/317.long

67. Chatterji P, Markowitz S. NBER working paper series: Effects of bicycle helmet laws on children's injuries. Working paper 18773 [Internet[. Cambridge, MA: National Bureau of Economic Research; 2013 [cited 2015 Jul 27].

68. Castle SL, Burke RV, Arbogast H, Upperman JS. Bicycle helmet legislation and injury patterns in trauma patients under age 18. J Surg Res. 2012;173(2):327-31.

69. Ji M, Gilchick RA, Bender SJ. Trends in helmet use and head injuries in San Diego County: the effect of bicycle helmet legislation. Accid Anal Prev. 2006;38(1):128-34.

70. Lee BH, Schofer JL, Koppelman FS. Bicycle safety helmet legislation and bicycle-related non-fatal injuries in California. Accid Anal Prev. 2005;37(1):93-102.

71. Borglund ST, Hayes JS, Eckes JM. Florida's bicycle helmet law and a bicycle safety educational program: did they help? J Emerg Nurs. 1999;25(6):496-500.

72. Delamater AM, Patino AM. Bicycle helmet wearing in children: a seven-year, observational study in Broward County, Florida. Child Health Care. 2003;32(4):287-95.

73. Kanny D, Schieber R,A., Pryor V, Kresnow M. Effectiveness of a state law mandating use of bicycle helmets among children: an observational study. Am J Epidemiol. 2001;154(11) 1072-76. Available from: http://aje.oxfordjournals.org/content/154/11/1072.long

74. Liller KD, Nearns J, Cabrera M, Joly B, Noland V, McDermott R. Children's bicycle helmet use and injuries in Hillsborough County, Florida, before and after helmet legislation. Inj Prev. 2003;9:177-79. Available from: http://injuryprevention.bmj.com/content/9/2/177.long

75. Abularrage JJ, Deluca AJ, Abularrage CJ. Effect of education and legislation on bicycle helmet use in a multiracial population. Arch Pediatr Adolesc Medi. 1997;151(1):41-4.

76. Puder DR, Visintainer P, Spitzer D, Casal D. A comparison of the effect of different bicycle helmet laws in 3 New York suburbs. Am J Public Health. 1999;89(11):1736-38. Available from: http://www.ncbi.nlm.nih.gov/pmc/articles/PMC1508999/

77. Shafi S, Gilbert JC, Loghmanee F, Allen JE, Caty MG, Glick PL, et al. Impact of bicycle helmet safety legislation on children admitted to a regional pediatric trauma center. J Pediatr Surg. 1998;33(2):317-21.

78. Coté TR, Sacks JJ, Lambert-Huber DA, Dannenberg AL, Kresnow MJ, Lipsitz CM, et al. Bicycle helmet use among Maryland children: effect of legislation and education. Pediatrics. 1992;89(6):1216-20.

79. Dannenberg AL, Gielen AC, Beilenson PL, Wilson MH, Joffe A. Bicycle helmet laws and educational campaigns: an evaluation of strategies to increase children's helmet use. Am J Public Health. 1993;83(5):667-74. Available from: http://www.ncbi.nlm.nih.gov/pmc/articles/PMC1694700/

80. Hatziandreu EJ, Sacks JJ, Brown R, Taylor WR, Rosenberg ML, Graham JD. The cost effectiveness of three programs to increase use of bicycle helmets among children. Public Health Rep. 1995;110(3):251-9. Available from: http://www.ncbi.nlm.nih.gov/pmc/articles/PMC1382115/

81. Ni H, Sacks JJ, Curtis L, Cieslak PR, Hedberg K. Evaluation of a statewide bicycle helmet law via multiple measures of helmet use. Arch Pediatr Adolesc Med. 1997;151(1):59-65.

82. Schieber RA, Kresnow M, Sacks JJ, Pledger EE, O'Neil JM, Toomey KE. Effect of a state law on reported bicyle helmet ownership and use. Arch Pediatr Adolesc Med. 1996;150:707-12.

83. Macknin ML, Medendorp SV. Association between bicycle helmet legislation, bicycle safety education, and use of bicycle helmets in children. Arch Pediatr Adolesc Med. 1994;148(3):255-59.

84. Dennis J, Potter B, Ramsay T, Zarychanski R. The effects of provincial bicycle helmet legislation on helmet use and bicycle ridership in Canada. Inj Prev. 2010;16(4):219-24.

85. Dennis J, Ramsay T, Turgeon AF, Zarychanski R. Helmet legislation and admissions to hospital for cycling related head injuries in Canadian provinces and territories: Interrupted time series analysis. BMJ. 2013;346:f2674. Available from: http://www.bmj.com/content/346/bmj.f2674.long

86. Macpherson AK, To TM, Macarthur C, Chipman ML, Wright JG, Parkin PC. Impact of mandatory helmet legislation on bicycle-related head injuries in children: a population-based study. Pediatrics. 2002;110(5):e60.

87. Leblanc JC, Beattie TL, Culligan C. Effect of legislation on the use of bicycle helmets. CMAJ. 2002;166(5):592-5. Available from: http://www.cmaj.ca/content/166/5/592.long

88. Foss RD, Beirness DJ. Bicycle helmet use in British Columbia: effects of the helmet use law [Internet]. Chapel Hill, NC: University of North Carolina Highway Safety Research Center; 2000 [cited 2015 Jul 27]. Available from: http://www.hsrc.unc.edu/pdf/2000/bc_rpt.pdf

89. Hagel BE, Rizkallah JW, Lamy A, Belton KL, Jhangri GS, Cherry N, et al. Bicycle helmet prevalence two years after the introduction of mandatory use legislation for under 18 year olds in Alberta, Canada. Inj Prev. 2006;12(4):262-5. Available from: http://www.ncbi.nlm.nih.gov/pmc/articles/PMC2586783/

90. Karkhaneh M, Rowe BH, Saunders LD, Voaklander DC, Hagel BE. Bicycle helmet use four years after the introduction of helmet legislation in Alberta, Canada. Accid Anal Prev. 2011;43(3):788-96.

91. Karkhaneh M, Rowe BH, Saunders D, Voaklander DC, Hagel BE. Trends in head injuries associated with mandatory bicycle helmet legislation targeting children and adolescents. Accid Anal Prev. 2013;59:206-12.

92. Macpherson AK, Parkin PC, To TM. Mandatory helmet legislation and children's exposure to cycling. Inj Prev. 2001;7(3):228-30. Available from: http://injuryprevention.bmj.com/content/7/3/228.long

93. Macpherson AK, Macarthur C, To TM, Chipman ML., Wright JG, Parkin PC. Economic disparity in bicycle helmet use by children six years after the introduction of legislation. Inj Prev. 2006;12(4):231-35. Available from: http://www.ncbi.nlm.nih.gov/pmc/articles/pmid/16887944/

94. Parkin PC, Khambalia A, Kmet L, Macarthur C. Influence of socioeconomic status on the effectiveness of bicycle helmet legislation for children: a prospective observational study. Pediatrics. 2003;112(3 Pt 1):e192-6.

95. Wesson D, Spence L, Hu X, Parkin P. Trends in bicycling-related head injuries in children after implementation of a community-based bike helmet campaign. J Pediatr Surg. 2000;35(5):688-9.

96. Wesson DE, Stephens D, Lam K, Parsons D, Spence L, Parkin PC. Trends in pediatric and adult bicycling deaths before and after passage of a bicycle helmet law. Pediatrics. 2008;122(3):605-10.

97. Toronto. Medical Officer of Health. Improving safety for bicycle commuters in Toronto. Staff report [Internet]. Toronto, ON: City of Toronto; 2013 [cited 2015 Jul 27]. Available from: http://www.toronto.ca/legdocs/mmis/2013/hl/bgrd/backgroundfile-59896.pdf

98. Karkhaneh M, Kalenga JC, Hagel BE, Rowe BH. Effectiveness of bicycle helmet legislation to increase helmet use: a systematic review. Inj Prev. 2006;12(2):76-82. Available from: http://www.ncbi.nlm.nih.gov/pmc/articles/PMC2564454/

99. Loubeau P. Exploration of the barriers to bicycle helmet use among 12 and 13 year old children. Accid Anal Prev. 2000;32(1):111-5.

100. Canada Safety Council. Helmets: attitudes and actions [Internet]. Ottawa, ON: Canada Safety Council; 2002 [cited 2014 Jan 27]. Available from: https://canadasafetycouncil.org/sports-active-living/helmets-attitudes-and-actions

101. Khambalia A, MacArthur C, Parkin P. Peer and adult companion helmet use is associated with bicycle helmet use by children. Pediatrics. 2005;116(4):939-42.

102. Clare BM. Cycling use and attitudes towards cycling in Halifax Regional Municipality and the Region of Waterloo [dissertation]. Waterloo, ON: University of Waterloo; 2011. Available from: https://uwspace.uwaterloo.ca/handle/10012/5901?show=full

103. Department for Transport: London. Cycling, safety and sharing the road: qualitative research with cyclists and other road users. Road Safety Web Publication No.17. London, UK; Queen's Printer and Controller of Her Majesty's Stationary Office; 2010. Available from: http://www.cyclist.ie/wp-content/uploads/2010/11/Dept-of-Trans-London-RS-Cycling-ORU-Report-1110-2.pdf

104. Gielen A, Joffe A, Dannenberg A, Wilson M, Beilenson P, De Boer M. Psychosocial factors associated with the use of bicycle helmets among children in counties with and without helmet use laws. J Pediatr. 1994;124(2):204-10.

105. Elvik R. The non-linearity of risk and the promotion of environmentally sustainable transport. Accid Anal Prev. 2009;41:849-55.

106. Robinson DL. Confusing trends with the effect of helmet laws. Pediatrics. 2003;P3R(7).

Appendix A: Search Strategy

SEARCH STRATEGY FOR EMPIRICAL LITERATURE

Databases

MEDLINE (n=398)
Embase (n=474)
PsycINFO (n=63)
SPORTDiscus (n=139)
Environment Complete (n=41)
Cochrane Database of Systematic Reviews (n=2)
CINAHL (n=133)
Transport Database (n=381)
TRID (n=588)

Search Yield

Total results: 2219
Duplicates removed: 990
Total unique results: 1229

Search Strategies

Ovid MEDLINE(R) In-Process & Other Non-Indexed Citations and Ovid MEDLINE(R) 1946 to Present

#	Searches	Results
1	exp Legislation as Topic/	133958
2	Government Regulation/	17144
3	Social Control, Formal/	11261
4	Law Enforcement/	2235
5	Mandatory Programs/	2095
6	exp Social Control Policies/	118828
7	"Legislation & Jurisprudence".fs.	206560
8	(law$ or legislat$ or regulat$ or policy or policies or bylaw$ or mandatory or compulsory or compel$ or voluntary or deregulat$).ti,ab.	1544625
9	1 or 2 or 3 or 4 or 5 or 6 or 7 or 8	1830132
10	Bicycling/	7255

#	Searches	Results
11	(bicycl$ or bike$ or biking or cycling or cycle or cyclist$).ti,ab.	354,597
12	10 or 11	355,981
13	Head Protective Devices/	2,403
14	Protective Devices/	5,726
15	(helmet$ or ((protecti$ or safety) adj2 (gear or device$ or equipment$ or head$))).ti,ab.	9,101
16	13 or 14 or 15	14,298
17	9 and 12 and 16	398

Embase 1974 to 2013 Week 26

#	Searches	Results
1	Law/	79,543
2	exp Legal Aspect/	736,936
3	Act/	634
4	Deregulation/	2,877
5	Government Regulation/	19,304
6	Law Enforcement/	6,884
7	Mandatory Program/	1,772
8	Social Control/	14,000
9	Policy/	66,478
10	Health Care Policy/	134,245
11	(law$ or legislat$ or regulat$ or policy or policies or bylaw$ or mandatory or compulsory or compel$ or voluntary or deregulat$).ti,ab.	1,763,793
12	1 or 2 or 3 or 4 or 5 or 6 or 7 or 8 or 9 or 10 or 11	2,458,571
13	Bicycle/	5,342
14	(bicycl$ or bike$ or biking or cycling or cycle or cyclist$).ti,ab.	409,789

#	Searches	Results
15	13 or 14	410,796
16	Helmet/	3,314
17	Protective Equipment/	9,153
18	(helmet$ or ((protecti$ or safety) adj2 (gear or device$ or equipment$ or head$))).ti,ab.	11,309
19	16 or 17 or 18	18,877
20	12 and 15 and 19	474

PsycINFO 1967 to July Week 1 2013

#	Searches	Results
1	Laws/	11,583
2	Legislative Processes/	1,889
3	Government Policy Making/	14,478
4	Health Care Policy/	5,965
5	Social Control/	1,812
6	(law$ or legislat$ or regulat$ or policy or policies or bylaw$ or mandatory or compulsory or compel$ or voluntary or deregulat$).ti,ab.	243,778
7	1 or 2 or 3 or 4 or 5 or 6	250,485
8	Transportation/	977
9	Ground Transportation/	227
10	(bicycl$ or bike$ or biking or cycling or cycle or cyclist$).ti,ab.	27,005
11	8 or 9 or 10	28,034
12	Safety Devices/	563
13	(helmet$ or ((protecti$ or safety) adj2 (gear or device$ or equipment$ or head$))).ti,ab.	1,024
14	12 or 13	1,299
15	7 and 11 and 14	63

CINAHL with Full Text

#	Searches	Results
S1	(MH "Legislation+")	27,697
S2	(MH "Government Regulations")	9,036
S3	(MH "Public Policy+")	55,388
S4	(MH "Social Control")	955
S5	(MH "Cycling/LJ")	23
S6	TI (law* OR legislat* OR regulat* OR policy OR policies OR bylaw* OR mandatory OR compulsory OR compel* OR voluntary OR deregulat*) OR AB (law* OR legislat* OR regulat* OR policy OR policies OR bylaw* OR mandatory OR compulsory OR compel* OR voluntary OR deregulat*)	118,493
S07	S1 OR S2 OR S3 OR S4 OR S5 OR S6	180,135
S08	(MH "Bicycles")	275
S09	(MH "Cycling Injuries")	46
S10	(MH "Cycling")	4,051
S11	TI (bicycl* OR bike* OR biking OR cycling OR cycle OR cyclist*) OR AB (bicycl* OR bike* OR biking OR cycling OR cycle OR cyclist*)	15,759
S12	S8 OR S9 OR S10 OR S11	17,202
S13	(MH "Head Protective Devices")	935
S14	(MH "Protective Devices")	2,230
S15	TI (helmet* OR ((protecti* OR safety) N2 (gear OR device* OR equipment* OR head*))) OR AB (helmet* OR ((protecti* OR safety) N2 (gear OR device* OR equipment* OR head*)))	2,826
S16	S13 OR S14 OR S15	4,961
S17	S7 AND S12 AND S16	133

Environment Complete

#	Searches	Results
S1	TI (law* OR legislat* OR regulat* OR policy OR policies OR bylaw* OR mandatory OR	235,907

#	Searches	Results
	compulsory OR compel* OR voluntary OR deregulat*) OR AB (law* OR legislat* OR regulat* OR policy OR policies OR bylaw* OR mandatory OR compulsory OR compel* OR voluntary OR deregulat*)	
S2	TI (bicycl* OR bike* OR biking OR cycling OR cycle OR cyclist*) OR AB (bicycl* OR bike* OR biking OR cycling OR cycle OR cyclist*)	79,818
S3	TI (helmet* OR ((protecti* OR safety) N2 (gear OR device* OR equipment* OR head*))) OR AB (helmet* OR ((protecti* OR safety) N2 (gear OR device* OR equipment* OR head*)))	3,566
S4	S1 AND S2 AND S3	41

Cochrane Database of Systematic Reviews

#	Searches	Results
S1	TI (law* OR legislat* OR regulat* OR policy OR policies OR bylaw* OR mandatory OR compulsory OR compel* OR voluntary OR deregulat*) OR AB (law* OR legislat* OR regulat* OR policy OR policies OR bylaw* OR mandatory OR compulsory OR compel* OR voluntary OR deregulat*)	379
S2	TI (bicycl* OR bike* OR biking OR cycling OR cycle OR cyclist*) OR AB (bicycl* OR bike* OR biking OR cycling OR cycle OR cyclist*)	114
S3	TI (helmet* OR ((protecti* OR safety) N2 (gear OR device* OR equipment* OR head*))) OR AB (helmet* OR ((protecti* OR safety) N2 (gear OR device* OR equipment* OR head*)))	16
S4	S1 AND S2 AND S3	2

SPORTDiscus with Full Text

#	Searches	Results
S1	TI (law* OR legislat* OR regulat* OR policy OR policies OR bylaw* OR mandatory OR compulsory OR compel* OR voluntary OR deregulat*) OR AB (law* OR legislat* OR regulat* OR policy OR policies OR bylaw* OR mandatory OR compulsory OR compel* OR voluntary OR deregulat*)	65,521
S2	TI (bicycl* OR bike* OR biking OR cycling OR cycle OR cyclist*) OR AB (bicycl* OR bike* OR biking OR cycling OR cycle OR cyclist*)	68,946
S3	TI (helmet* OR ((protecti* OR safety) N2 (gear OR device* OR equipment* OR head*))) OR AB (helmet* OR ((protecti* OR safety) N2 (gear OR device* OR equipment* OR head*)))	4,576

#	Searches	Results
S4	S1 AND S2 AND S3	139

Transport Database Pre-1987 to June 2013

#	Searches	Results
1	(law$ or legislat$ or regulat$ or policy or policies or bylaw$ or mandatory or compulsory or compel$ or voluntary or deregulat$).ti,ab.	90,102
2	(bicycl$ or bike$ or biking or cycling or cycle or cyclist$).ti,ab.	22,872
3	(helmet$ or ((protecti$ or safety) adj2 (gear or device$ or equipment$ or head$))).ti,ab.	4,200
4	1 and 2 and 3	381

TRID

#	Searches	Results
1	(law* OR legislat* OR regulat* OR policy OR policies OR bylaw* OR mandatory OR compulsory OR compel* OR voluntary OR deregulat*) AND (bicycl* OR bike* OR biking OR cycling OR cycle OR cyclist*) AND (helmet* OR headgear)	588

SEARCH STRATEGY FOR GREY LITERATURE

Database

Grey literature (web search)

Search Yield

Add table with how many studies were from each jurisdiction

Search Strategy

(bike* OR bicycl* OR biking OR cycling OR cycle OR cyclist) AND (helmet* OR protective equipment OR head protective devices OR safety gear OR head safety) AND (legislation OR law OR regulation OR policies OR bylaw) AND (mandatory OR compulsory)

A web search was performed using Google to identify grey literature regarding cycling helmet legislation. The websites of major public health agencies were the focus of the search, such as www.phac-aspc.gc.ca and www.cdc.gov. The websites of all Canadian provincial and territorial health ministries were searched, as well as those of international and national organizations (see below for a list of websites searched). Additionally, a Google search was performed, limiting the results to .gov, .org., and .edu domains. References in highly relevant results were also examined.

Websites Searched

Canadian Public Health Information

Federal
Health Canada | hc-sc.gc.ca
Public Health Agency of Canada | phac-aspc.gc.ca

Provincial
Alberta Health and Wellness | health.alberta.ca
British Columbia Centre for Disease Control (BCCDC) | bccdc.ca
British Columbia Ministry of Health | gov.bc.ca/health
Manitoba Health | gov.mb.ca/health
New Brunswick Department of Health | gnb.ca
Newfoundland Department of Health and Community Services | health.gov.nl.ca
Northwest Territories Department of Health and Social Services | hlthss.gov.nt.ca
Nova Scotia Department of Health and Wellness | gov.ns.ca/dhw
Nunavut Department of Health and Social Services | hss.gov.nu.ca
Ontario Ministry of Health and Long-Term Care | health.gov.on.ca
Public Health Ontario | oahpp.ca
Prince Edward Island Department of Health and Wellness | gov.pe.ca
Quebec Ministère de la Santé et des Services sociaux | msss.gouv.qc.ca
Institut national de santé publique du Québec (INSPQ) | inspq.qc.ca
Saskatchewan Ministry of Health | health.gov.sk.ca
Yukon Health and Social Services | hss.gov.yk.ca

National Collaborating Centres
National Collaborating Centres for Public Health | nccph.ca
National Collaborating Centre for Aboriginal Health | nccah-ccnsa.ca
National Collaborating Centre for Determinants of Health | nccdh.ca
National Collaborating Centre for Environmental Health | ncceh.ca
National Collaborating Centre for Healthy Public Policy | ncchpp.ca
National Collaborating Centre for Infectious Diseases | nccid.ca
National Collaborating Centre for Methods and Tools | nccmt.ca

Canadian Public Documents

Canadian Public Documents Custom Search |
https://www.google.com/cse/home?cx=007843865286850066037:3ajwn2jlweq

Ontario Government Documents Collection

OurOntario.ca Ontario Government Documents Collection | http://govdocs.ourontario.ca/search

Other

Centers for Disease Control and Prevention | http://www.cdc.gov/
European Center for Disease Control and Prevention |http://www.ecdc.europa.eu/en/Pages/home.aspx

Public Health England | http://www.hpa.org.uk/AboutTheHPA/
Public Health Observatories England |http://www.apho.org.uk/
Department of Health Australia |http://www.health.gov.au/
SmartRisk | http://www.parachutecanada.org/smartrisk
Ontario Injury Prevention Resource Centre| http://www.oninjuryresources.ca/

Appendix B: Inclusion and Exclusion Criteria

INCLUSION CRITERIA

Studies had to:

1. Be published between 1990 and 2013
2. [Note: early bicycle helmet laws, e.g., Australia were enacted in 1991]
    a) Be a primary study or systematic review
    b) Evaluate the impact of mandatory bicycle helmet legislation on:
    c) prevalence of helmet use
    d) injury (by type)and/or mortality rates
    e) cyclist behavior (i.e., participation rates (e.g. cycling prevalence), risk compensation)
    f) cost-effectiveness of legislation
    g) adverse outcomes (i.e., other pro cycling policies, cycling infrastructure),
    h) attitudes
3. Use an appropriate comparison group (i.e., pre/post, another jurisdiction with no-legislation or another jurisdiction)
4. Be available in the English and/or French language

EXCLUSION CRITERIA

Articles were excluded if they:

1. Were published before 1990
2. Were not a primary study or systematic review (i.e., letters to the editor or opinion pieces)
3. Did not clearly evaluate the impact of mandatory bicycle helmet legislation on any of the following:
    a) prevalence of helmet use
    b) injury or mortality rates
    c) cyclist behavior (i.e., participation rates, risk compensation),
    d) cost-effectiveness of legislation
    e) adverse outcomes (i.e., other pro cycling policies, cycling infrastructure),
    f) attitudes
4. Did not include an appropriate comparison group
5. Were not available in English or French
6. Were set in a developing country
7. Duplicated articles
8. Conference proceedings

Appendix C: Quality Appraisal

Quality Appraisal Results (EPHPP)

Study	Selection Bias	Study Design	Confounders	Blinding	Data Collection Method	Withdrawals and Dropout	Overall Rating
Abularrage et al., (1997)[75]	Strong	Moderate	Weak	Weak	Strong	n/a	**Weak**
Borglund et al., (1999)[71]	Moderate	Moderate	Strong	Moderate	Strong	n/a	**Strong**
Cameron et al., (1992)[41]	Strong	Moderate	Strong	Weak	Strong	n/a	**Moderate**
Cameron et al., (1994)[42]	Moderate	Moderate	Moderate	Weak	Strong	n/a	**Moderate**
Carr et al., (1995)[43]	Strong	Moderate	Strong	Moderate	Strong	n/a	**Strong**
Castle et al., (2012)[68]	Strong	Moderate	Moderate	Moderate	Strong	n/a	**Strong**
Chatterji et al., (2013)[67]	Moderate	Moderate	Strong	Moderate	Strong	n/a	**Strong**
Clarke et al., (2012)[61]	Moderate	Moderate	Weak	Weak	Weak	n/a	**Weak**
Cooke et al., (1993)[51]	Strong	Moderate	Weak	Weak	Strong	n/a	**Weak**
Cote et al., (1992)[78]	Strong	Moderate	Moderate	Weak	Strong	n/a	**Moderate**
Dannenberg et al., (1993)[79]	Moderate	Moderate	Moderate	Weak	Weak	Weak	**Weak**
Delamater et al., (2003)[72]	Strong	Moderate	Weak	Weak	Strong	Strong	**Weak**
Dennis et al., (2010)[84]	Moderate	Moderate	Moderate	Weak	Weak	Strong	**Weak**

Study	Selection Bias	Study Design	Confounders	Blinding	Data Collection Method	Withdrawals and Dropout	Overall Rating
Dennis et al., (2013)[85]	Strong	Moderate	Moderate	Moderate	Strong	n/a	**Strong**
Finch et al., (1993)[44]	Strong	Moderate	Strong	Weak	Strong	n/a	**Moderate**
Finch et al., (1993)[45]	Strong	Moderate	Moderate	Weak	Strong	n/a	**Moderate**
Foss et al., (2000)[88]	Strong	Moderate	Moderate	Weak	Strong	n/a	**Moderate**
Hagel et al., (2006)[89]	Strong	Moderate	Moderate	Weak	Strong	n/a	**Moderate**
Hansen et al., (1995)[62]	Cost-effectiveness study	n/a	n/a	n/a	n/a	n/a	**n/a**
Hatziandreu et al., (1995)[80]	Cost-effectiveness study	n/a	n/a	n/a	n/a	n/a	**n/a**
Heathcote et al., (1993)[52]	Strong	Moderate	Strong	Weak	Moderate	n/a	**Moderate**
Heathcote et al., (1994)[53]	Strong	Moderate	Moderate	Weak	Weak	n/a	**Weak**
Hendrie et al., (1999)[36]	Cost-effectiveness study	n/a	n/a	n/a	n/a	n/a	**n/a**
Ji et al., (2006)[69]	Strong	Moderate	Moderate	Moderate	Strong	n/a	**Strong**
Kanny et al., (2001)[73]	Strong	Moderate	Moderate	Weak	Strong	n/a	**Moderate**
Karkhaneh et al., (2011)[90]	Strong	Moderate	Moderate	Weak	Strong	n/a	**Moderate**
Karkhaneh et al., (2013)[91]	Strong	Moderate	Strong	Moderate	Strong	n/a	**Strong**

Study	Selection Bias	Study Design	Confounders	Blinding	Data Collection Method	Withdrawals and Dropout	Overall Rating
LeBlanc et al., (2002)[87]	Strong	Moderate	Weak	Weak	Strong	n/a	**Weak**
Lee et al., (2005)[70]	Strong	Moderate	Strong	Moderate	Strong	n/a	**Strong**
Liller et al., (2003)[74]	Moderate	Moderate	Weak	Weak	Strong	n/a	**Weak**
Macknin et al., (1994)[83]	Moderate	Moderate	Weak	Weak	Weak	n/a	**Weak**
Macpherson et al., (2001)[92]	Strong	Moderate	Weak	Weak	Strong	n/a	**Weak**
Macpherson et al., (2002)[86]	Strong	Moderate	Strong	Moderate	Strong	n/a	**Strong**
Macpherson et al., (2006)[93]	Strong	Moderate	Moderate	Weak	Strong	n/a	**Moderate**
Marshall et al., (1994)[54]	Moderate	Moderate	Moderate	Weak	Weak	n/a	**Weak**
McDermott et al., (1995)[46]	Moderate	Moderate	Weak	Weak	Weak	n/a	**Weak**
Moyes et al., (2007)[63]	Strong	Moderate	Weak	Moderate	Moderate	n/a	**Moderate**
Newstead et al., (1994)[47]	Strong	Moderate	Moderate	Weak	Strong	n/a	**Moderate**
Ni et al., (1997)[81]	Strong	Moderate	Moderate	Weak	Weak	n/a	**Weak**
Olivier et al., (2013)[56]	Strong	Moderate	Moderate	Moderate	Strong	n/a	**Strong**
Ozanne-Smith et al., (1990)[48]	Weak	Moderate	Moderate	Moderate	Strong	n/a	**Moderate**
Parkin et al., (2003)[94]	Strong	Moderate	Moderate	Weak	Strong	n/a	**Moderate**

Study	Selection Bias	Study Design	Confounders	Blinding	Data Collection Method	Withdrawals and Dropout	Overall Rating
Povey et al.,(1999)[64]	Strong	Moderate	Moderate	Moderate	Strong	n/a	**Strong**
Puder et al., (1999)[76]	Strong	Moderate	Strong	Weak	Strong	n/a	**Moderate**
Schieber et al., (1996)[82]	Strong	Moderate	Moderate	Weak	Weak	n/a	**Weak**
Scuffham et al., (2000)[65]	Strong	Moderate	Moderate	Weak	Strong	n/a	**Moderate**
Shafi et al., (1998)[77]	Strong	Moderate	Weak	Moderate	Strong	n/a	**Moderate**
Sullivan et al., (1990)[49]	Strong	Moderate	Moderate	Weak	Strong	n/a	**Moderate**
Taylor et al., (2002)[66]	Cost-effectiveness study	n/a	n/a	n/a	n/a	n/a	**n/a**
Van Zyl et al., (1993)[55]	Strong	Moderate	Moderate	Weak	Strong	Moderate	**Moderate**
Voukelatos et al., (2010)[57]	Strong	Moderate	Moderate	Moderate	Strong	n/a	**Strong**
Vulcan et al., (1992)[50]	Strong	Moderate	Moderate	Weak	Strong	n/a	**Moderate**
Walker et al., (1992)[58]	Moderate	Moderate	Strong	Weak	Strong	n/a	**Moderate**
Walter et al., (2011)[59]	Strong	Moderate	Strong	Moderate	Strong	n/a	**Strong**
Wesson et al., (2000)[95]	Strong	Moderate	Moderate	Moderate	Strong	n/a	**Strong**
Wesson et al., (2008)[96]	Strong	Moderate	Weak	Weak	Strong	n/a	**Weak**
Williams et al., (1995)[60]	Strong	Moderate	Moderate	Weak	Weak	n/a	**Weak**

EPHPP Supplementary Dictionary

Question Number	Criteria	Notes
A (Q2)	**"What percentage of selected participants agreed to participate?"**	• If it is an observational study or involves collecting data from injury/hospital records then this question is 'not applicable'. The overall rating score for this section will be based on AQ1 only.
C (Q1)	**"Were there important differences between groups prior to the intervention?"**	• If this was not assessed or described, then use 'can't tell'. • If it was a pre-post study (and did not assess differences between the pre- and post- groups) then use 'can't tell'.
D (Q2)	**"Were the study participants aware of the research question"?**	• If methods involve assessing medical records then the answer is likely 'no' (unless specified that participants were informed). • If methods involve observations and says 'unobtrusive observations", then select 'no', if not select 'can't tell'.
E (Q1,Q2)	**How do we determine if a method is valid or reliable?**	• If info about testing reliability and validity is provided then make decision based on what is described. • If no reliability and validity info is provided then make the following decisions for the specified methods: **Are the following methods valid?** • Direct observations = select 'yes' (valid) • Self-report = select 'no'(not valid) (unless reported that they measured and tested validity) • Medical records = select 'yes' (valid) **Are the following methods reliable?** • Direct observations = select 'yes' (reliable) • Self-report = 'no' (not reliable) • Medical records = 'yes' (reliable)
F (Q1)	**Were withdrawals and drop outs reported in terms of numbers and/or reasons per group?**	• This is often 'n/a' since most studies don't follow the same participants throughout the study.
F (Q2)	**"Indicate the percentage of participants completing the study"**	• Because most of the studies are quasi-experimental and not RCTs (and often different participants in pre and post groups), this question is not applicable in most situations and therefore select 'n/a'

Appendix D: Characteristics of Included Studies

CHARACTERISTICS OF INCLUDED STUDIES

Reference	Type of Literature	Study Type	Jurisdiction	Year Law Implemented	Target Population (Age)
Abularrage et al., (1997)[75]	Peer-reviewed	Comparison across jurisdictions	New York, USA	1994	Children (<14 yrs.)
Borglund et al., (1999)[71]	Peer-reviewed	Pre/Post or Time Series	Florida, USA	1997	Children (<18yrs)
Cameron et al., (1992)[41]	Grey	Pre/Post or Time Series	Victoria, Australia	1990	All ages
Cameron et al., (1994)[42]	Peer-reviewed	Pre/Post or Time Series	Victoria, Australia	1990	All ages
Carr et al., (1995)[43]	Grey	Pre/Post or Time Series	Victoria, Australia	1990	All ages
Castle et al., (2012)[68]	Peer-reviewed	Pre/Post or Time Series	California, USA	1994	Children (<18 yrs.)
Chatterji et al., (2013)[67]	Grey	Pre/Post or Time Series	Various states in the USA	Various laws between 1987-2008	Children (various age cut-offs)
Clarke et al., (2012)[61]	Peer-reviewed	Pre/Post or Time Series	New Zealand	1994	All ages
Cooke et al., (1993)[51]	Peer-reviewed	Pre/Post or Time Series	Western Australia, Australia	1992	All ages
Cote et al., (1992)[78]	Peer-reviewed	Comparison across jurisdictions	Howard County, Maryland, USA	1990	Children (<16 yrs.)
Dannenberg et al., (1993)[79]	Peer-reviewed	Comparison across jurisdictions	Howard County, Maryland, USA	1990	Children (<16 yrs.)
Delamater et al., (2003)[72]	Peer-reviewed	Comparison across jurisdictions	Florida, USA	1998	Children (<16 yrs.)
Dennis et al.,	Peer-		British Columbia,	1996 (BC)	All ages (BC, NB,

Reference	Type of Literature	Study Type	Jurisdiction	Year Law Implemented	Target Population (Age)
(2010)[84]	reviewed	Comparison across jurisdictions	Canada New Brunswick, Canada Nova Scotia, Canada Prince Edward Island, Canada Alberta, Canada Ontario, Canada	1995 (NB) 1997 (NS) 2003 (PEI) 2002 (AL) 1995 (ON)	NS, PEI, Children (<18 yrs.) (AL, ON)
Dennis et al., (2013)[85]	Peer-reviewed	Comparison across jurisdictions	New Brunswick, Canada British Columbia, Canada Nova Scotia, Canada Prince Edward Island, Canada Ontario, Canada Alberta, Canada	1995 (NB) 1996 (BC) 1997 (NS) 2003 (PEI) 1995 (ON) 2002 (AL)	Children (<18 yrs.) (ON, AL) All ages (NB, BC, NS, PEI)
Finch et al., (1993)[44]	Grey	Pre/Post or Time Series	Victoria, Australia	1990	All ages
Finch et al., (1993)[45]	Grey	Pre/Post or Time Series	Victoria, Australia	1990	All Ages
Foss et al., (2000)[88]	Grey	Pre/Post or Time Series	British Columbia, Canada	1996	All ages
Hagel et al., (2006)[89]	Peer-reviewed	Pre/Post or Time Series	Alberta, Canada	2002	Children (<18 yrs.)
Hansen et al., (1995)[62]	Peer-reviewed	Cost-Effectiveness	New Zealand	1994	All ages
Hatziandreu et al., (1995)[80]	Peer-reviewed	Cost-Effectiveness	Howard County, Maryland, USA	1990	Children (<16 yrs.)
Heathcote et al., (1993)[52]	Grey	Pre/Post or Time Series	Western Australia, Australia	1992	All ages
Heathcote et al., (1994)[53]	Grey	Pre/Post or Time Series	Western Australia, Australia	1992	All ages
Hendrie et al., (1999)[36]	Grey	Cost-Effectiveness	Western Australia, Australia	1992	All ages

Reference	Type of Literature	Study Type	Jurisdiction	Year Law Implemented	Target Population (Age)
Ji et al., (2006)[69]	Peer-reviewed	Pre/Post or Time Series	California, USA	1994	Children (<18 yrs.)
Kanny et al., (2001)[73]	Peer-reviewed	Comparison across jurisdictions	Florida, USA	1997	Children (<16 yrs.)
Karkhaneh et al., (2011)[90]	Peer-reviewed	Pre/Post or Time Series	Alberta, Canada	2002	Children (<18 yrs.)
Karkhaneh et al., (2013)[91]	Peer-reviewed	Pre/Post or Time Series	Alberta, Canada	2002	Children (<18 yrs.)
LeBlanc et al., (2002)[87]	Peer-reviewed	Pre/Post or Time Series	Nova Scotia, Canada	1997	All ages
Lee et al., (2005)[70]	Peer-reviewed	Pre/Post or Time Series	California, USA	1994	Children (<18 yrs.)
Liller et al., (2003)[74]	Peer-reviewed	Pre/Post or Time Series	Florida, USA	1997	Children (<16 yrs.)
Macknin et al., (1994)[83]	Peer-reviewed	Comparison across jurisdictions	Beachwood, Ohio, USA Orange, Ohio, USA	1990 (Beachwood, Ohio) 1991 (Orange, Ohio)	Children (<16 yrs.)
Macpherson et al., (2001)[92]	Peer-reviewed	Pre/Post or Time Series	Ontario, Canada	1995	Children (<16 yrs.)
Macpherson et al., (2002)[86]	Peer-reviewed	Comparison across jurisdictions	Ontario, Canada New Brunswick, Canada British Columbia, Canada Nova Scotia, Canada	1995 (ON) 1995 (NB) 1996 (BC) 1997 (NS)	Children (<18 yrs.) (ON) All ages (NB, BC, NS)
Macpherson et al., (2006)[93]	Peer-reviewed	Pre/Post or Time Series	Ontario, Canada	1995	Children (<18y yrs.)
Marshall et al., (1994)[54]	Grey	Pre/Post or Time Series	South Australia, Australia	1991	All ages
McDermott et al., (1995)[46]	Peer-reviewed	Pre/Post or Time Series	Victoria, Australia	1990	All ages

Reference	Type of Literature	Study Type	Jurisdiction	Year Law Implemented	Target Population (Age)
Moyes et al., (2007)[63]	Peer-reviewed	Pre/Post or Time Series	New Zealand	1994	All ages
Newstead et al., (1994)[47]	Grey	Pre/Post or Time Series	Victoria, Australia	1990	All ages
Ni et al., (1997)[81]	Peer-reviewed	Pre/Post or Time Series	Oregon, USA	1994	Children (<16 yrs.)
Olivier et al., (2013)[56]	Peer-reviewed	Pre/Post or Time Series	New South Wales, Australia	1991	Children (<16 yrs.) Adults (>16 yrs.)
Ozanne-Smith et al., (1990)[48]	Grey	Pre/Post or Time Series	Victoria, Australia	1990	All ages
Parkin et al., (2003)[94]	Peer-reviewed	Pre/Post or Time Series	Ontario, Canada	1995	Children (<18 yrs.)
Povey et al.,(1999)[64]	Peer-reviewed	Pre/Post or Time Series	New Zealand	1994	All ages
Puder et al., (1999)[76]	Peer-reviewed	Comparison across jurisdictions	Rockland, New York, USA New York, USA Connecticut, USA	1992 (Rockland, NY) 1994 (NY state) 1993 (CT state)	All ages (Rockland, NY) Children (<14 yrs.) (NY) Children (<12 yrs.) (CT)
Schieber et al., (1996)[82]	Peer-reviewed	Pre/Post or Time Series	Georgia, USA	1993	Children (<16 yrs.)
Scuffham et al., (2000)[65]	Peer-reviewed	Pre/Post or Time Series	New Zealand	1994	All ages
Shafi et al., (1998)[77]	Peer-reviewed	Pre/Post or Time Series	New York, USA	1994	Children (<14 yrs.)
Sullivan et al., (1990)[49]	Grey	Pre/Post or Time Series	Victoria, Australia	1990	All ages
Taylor et al., (2002)[66]	Peer-reviewed	Cost-Effectiveness	New Zealand	1994	All ages
Van Zyl et al., (1993)[55]	Grey	Pre/Post or Time Series	Northern Territory, Australia	1992	Adults (>17 yrs,) All ages

Reference	Type of Literature	Study Type	Jurisdiction	Year Law Implemented	Target Population (Age)
Voukelatos et al., (2010)[57]	Peer-reviewed	Pre/Post or Time Series	New South Wales, Australia	1991	Children (<16 yrs.) Adults (>16 yrs.)
Vulcan et al., (1992)[50]	Peer-reviewed	Pre/Post or Time Series	Victoria, Australia	1990	All ages
Walker et al., (1992)[58]	Grey	Pre/Post or Time Series	New South Wales, Australia	1991	Children (<16 yrs.) Adults (>16 yrs.)
Walter et al., (2011)[59]	Peer-reviewed	Pre/Post or Time Series	New South Wales, Australia	1991	Children (<16 yrs.) Adults (>16 yrs.)
Wesson et al., (2000)[95]	Peer-reviewed	Pre/Post or Time Series	Ontario, Canada	1995	Children (<16 yrs.)
Wesson et al., (2008)[96]	Peer-reviewed	Pre/Post or Time Series	Ontario, Canada	1995	Children (<18 yrs.)
Williams et al., (1995)[60]	Grey	Pre/Post or Time Series	New South Wales, Australia	1991	Children (<16 yrs.) Adults (>16 yrs.)

Appendix E: Detailed Study Findings

Findings from the 57 included studies are described below. All included studies were primarily from English speaking developed jurisdictions. Most studies compared results from before and after the legislation while others compared results across jurisdictions or were cost-effectiveness studies. The most commonly used methods of data collection were observational surveys to evaluate helmet use and cycling behaviour, use of health records to evaluate injuries and deaths, and self-report surveys to examine attitudes and knowledge about the law.

Findings are synthesized narratively by law type (e.g., child, adult or all-age laws), jurisdiction, and outcome. The context in which each law was enacted is provided for each jurisdiction, followed by the effectiveness of the law organized by outcome for each jurisdiction.

Australia

Twenty-one studies examined the effectiveness of bicycle helmet legislation in Australia. The greatest proportion of studies (10/21) examined the all-age law helmet law in Victoria, Australia. Five studies examined both child and adult law in New South Wales, Australia and the remaining studies described findings from Western, Northern and South Australia. All but one study conducted pre/post analyses comparing outcomes prior to and following the implementation of the helmet legislation. The remaining study examined the cost-effectiveness of the bicycle helmet legislation in New South Wales Australia.

ALL-AGE LAWS

Victoria, Australia (All-Age Law, 1990)

Context

Introduced in July, 1990, Victoria Australia was the first jurisdiction (state or country) to have a mandatory bicycle helmet law.[43,44,46,47] It was created following extensive canvassing of comments from bicyclists by the Road Traffic Authority, convincing them to develop a strategy recommending that mandatory bicycle helmet legislation be introduced.[42] The law was implemented under the Road Safety Act of 1986 and required "all persons bicycling on the road, on a footpath, on a separate bicycle path, or in a public park to wear a securely fitted approved bicycle helmet".[42]

Exemptions were given to those who would have had extreme difficulty in complying. These were difficult to obtain and fewer than 50 exemptions were given in the first year of the law.[42,45] The maximum penalty for non-compliance with the law was $100; however it was rarely applied. Instead, $15 Bicycle Offence Penalty notices were issued, or a Bicycle Offence report (no monetary penalty) was sent to the parents of children who were not wearing a helmet.[42,45,47] A low-to-moderate level of enforcement took place immediately following the introduction of the law.[42,46]

The law was preceded by a decade of helmet promotion which included education, mass media campaigns, support by professional associations and community groups, consultations with bicycle groups, and financial incentives.[42,43,45,47,50]

For instance, prior to the introduction of the law in 1984, a helmet rebate scheme was announced by the Minister of Transport stating that the government would pay a rebate of $10 to anyone who purchased an Australian-made helmet.[42,46,50] In 1982, the Road Safety & Traffic Authority also established a helmet purchasing scheme where parents could order helmets through schools at a 33% discount.[50]

In addition to the school rebate scheme, a bicycle safety helmet education program called Bike-Ed was developed for students aged 9-13 years.[42,50] Bike-Ed was a course designed to teach children to ride bicycles safely. In 1983, the Education department decided that helmets must be worn when participating in all school cycling activities at state schools.[42,50]

A number of mass media campaigns were also undertaken in the years prior to the introduction of the law. In 1984, a health promotion task force was developed and a mass media campaign targeting parents of primary school children (emphasizing the seriousness of head injuries and the protection provided by helmets) was implemented.[42,46] Several other mass media campaigns involving the press, radio, TV, and pamphlets persisted throughout the 1980's to continue to the promotion of helmet wearing.[46,50]

Concurrent Safety Initiatives

Of note, major drink/driving and speeding initiatives were implemented in Victoria around the same time that the law was introduced (1989 and 1990 respectively).[42,43,45]

Effectiveness of Helmet Legislation in Victoria, Australia

Ten studies examined the impact of the mandatory all-age bicycle helmet legislation in Victoria, Australia by comparing the impact both before and after the introduction of the law.[41-50]

Helmet Use and Ownership

Nine studies compared pre- and post-law helmet wearing rates among cyclists using observational data.[41,42,44-50] Observational data was collected by surveying cyclists passing by in a designated area and time and observing whether or not they were wearing a helmet. All studies demonstrated an increase in helmet wearing rates following the introduction of the law with three studies concluding significant ($p<0.001$) increases from pre- to post-legislation.[42,45,47] Pre-legislation helmet wearing rates ranged from 5% in 1982/1983 to 36% in 1990 (65% and 35% among primary and secondary school children in 1990) and increased to upward ranges of 75% to 89% in the first year post-legislation (95% and 85% among primary and secondary school children).[44,45,49] Although teenagers (12-17 years) had the lowest rates of helmet use, they demonstrated the greatest increase in helmet wearing after the introduction of the law, followed by a 45.5% increase among adults and a 20% increase among primary school children.[49]

The increase in helmet use coincided with an increase in helmet ownership; there was a 4%, 8% and 10% increase in helmet ownership among children, teenagers and adults respectively between 1991 and 1992, one year following the introduction of the law.[44]

Injuries

Comparisons of both pre- and post-legislation injury rates, using data from the Victoria Hospital Admissions records, Transport Accident Commission (TAC) insurance claims and the Victoria Injury Surveillance System (VISS) demonstrated significant decreases in head injury rates,[43,47] decreases in non-head injury rates[41,42,45,50] and reductions in the number of severe and serious injuries[43] following the introduction of the law.

Head Injuries

Seven studies found decreases in head injuries following the implementation of the mandatory helmet law when compared with pre-law injuries.[41-43,45,47,48,50] In a time series modelling study by Carr et al., (1995), it was estimated that in the first four years after the introduction of the law there was a 39.5% ($p=0.0001$) reduction in the number of head injury admissions (all crashes) across Victoria.[43] Other studies have demonstrated a 36%-51% reduction in the number of bicyclists killed or admitted to hospital after sustaining a head injury in the first year post-law, and a 48-70% reduction after the second year of the law with the greatest reduction seen among teenagers (64% reduction).[41,42,45,48,50] However, Newstead et al., (1994) suggests that this benefit was lost in the third year post-law as hospital admission records failed to show any additional benefit over pre-law trends in reducing head injury rates in the three years post law.[47] Additionally, insurance claim data suggested that there was an increase in head injuries between the second and third year post law.[47]

Ozanne-Smith and colleagues suggest that the reduction in cyclists admitted to the hospital for head injuries may be due to the increased protection of helmets, a potential decrease in cycling (and thus reduced risk exposure), or due to the more cautious riding behaviour of cyclists as a result of the publicity associated with the law.[48] However, it is unclear whether the law or other factors are responsible for the observed reduction.

Non-Head Injuries

There were also reductions in the number persons with non-head injuries admitted to hospitals following the introduction of the law. In the first year of the law non-head injury rates were 23% less than pre-law rates in 1989.[42] In 1992 (two years post-law), non-head injuries decreased 28%-30% compared with pre-law rates in 1989.[42,45,50] Reductions were greatest among teenagers (35% decrease) followed by children (27%) and adults (11%).[41]

Injury Severity and Deaths

Carr et al., (1995) demonstrated a 20% reduction in both serious and severe head injuries following the introduction of the law.[43] Additionally, bicycling fatalities decreased from 77 deaths in the 3 years prior to legislation to 41 deaths in the three years following legislation.[46]

Cycling

Observational studies examining the number of cyclists on the road, cycling exposure (billions of seconds/ week) and bicycle usage are conflicting. Some studies have noted an overall increase in cycling since the introduction of the law,[45] particularly among adult cyclists.[41,42] However decreases in cycling were evident among child and adolescent populations.[41,42,45,46,49]

Within the first year of the law, child and adolescent cycling rates were noted to have decreased.[41,42,44-46] Between 1990 and 1991 observational surveys indicated that there was a 24% reduction in the number of child cyclists (5-11 years) and a 46% reduction among adolescents.[44] Overall, bicycle use (estimate of total cycling time in Melbourne metropolitan area over one week) for children and adolescents decreased 33% between 1990 and 1991 (36% decrease compared with pre-law levels).[44]

Other studies demonstrated similar decreases between 3%-36% in cycling exposure (measured in billions of seconds/week) among children in the first year of the law (1990-1991) and lessened to a 11% decrease by 1992.[41,42,44,45] Even greater reductions in cycling exposure were seen among adolescents, ranging from a 43-44% reduction in the first years of the law (1990-1991) and 45-46% reduction by 1992 compared with pre-law rates.[41,42,44,45]

Observational studies of adults, however, demonstrated increases in cycling exposure (measured in billions of seconds), usage and number of cyclists observed on the road.[41,42,46,49] Within the first year of the law cycling exposure increased 44% (58% increase from 1977/78);[41,42] by year two (1991-1992), adult cycling exposure further increased 34%.[44]

Despite the differences among children, adolescents and adults cycling rates, compared with pre-legislation rates in 1987/88, overall bicycle use (across all age groups) increased 9% by 1991 and 12% by 1992.[42,45] Two additional studies reported a decrease in cycling exposure among the general population between 1987 and 1992.[41,44]

Summary

Overall, the mandatory all-age bicycle helmet law resulted in increased helmet wearing, decreased head injuries, non-head injuries and severe and/or serious injuries. There some evidence of was an overall increase in cycling exposure among adults, with decreased exposure observed among children and adolescents and mixed results regarding the impact on cycling rates of the general population.

Western Australia (All-Age Law, 1992)

Context

Western Australia introduced their mandatory all-age bicycle helmet legislation in January, 1992.[36,51-53] Prior to the law (December 1991), a telephone survey was conducted asking metropolitan household members over age 18 about their knowledge of and support for the legislation. Among respondents, 94.8% were aware of the proposed legislation, with 78% in favour and 22% against it.[36]

Implementation involved public education and mass media campaigns, enforcement, the purchase of helmets, and the administration of the helmet rebate scheme.[36] For instance, between December 1987 and 1988 mass media campaigns took place, with additional media campaigns continuing in 1991 to further promote helmet use.[36] These media campaigns were complimented with a bicycle helmet rebate scheme implemented in addition to a helmet subsidy scheme operating in schools between 1988 and 1990.

Helmet use was enforced by the bicycle safety section of the Western Australia Police Service six months following the introduction of the law with enforcement officials giving out unofficial cautions, official cautions, compulsory lecture sessions, infringements and briefs.[36,52] There was a $25 fine for non-compliance with the law; however infringement notices and fines were cancelled if the recipient provided proof of purchase of a helmet within 14 days.[36,53]

Effectiveness of Helmet Legislation in Western Australia

Four studies examined the impact of the mandatory all-age bicycle helmet legislation in Western Australia.[36,51-53] They examined helmet use, attitudes towards the law, deaths, cycling rates, head injuries and cost-effectiveness of the law using household telephone surveys, observations and health records. Three of these studies compared the impact both before and after the introduction of the law and the remaining study examined the cost-effectiveness of the legislation.

Helmet Use

Heathcote et al., (1993) examined changes in helmet use following the implementation of the law by conducting observational surveys at commuter recreational and school sites in Perth in between 1991 and 1993.[52] Overall helmet use rates increased from 39% in 1991 (pre-legislation), to 62% in 1992 (post-law) and 81% in 1993 (one year post legislation).[52] Following the introduction of the law, between 1992 and 1993, the greatest increases in helmet use were seen among high school students (31%-32% increase), and recreational cyclists (24% increase).[52]

Attitudes

Heathcote et al., (1994, 1993) conducted two separate studies in Perth (surrounding metropolitan and country areas) examining adult residents' attitudes towards the new helmet law through telephone surveys.[52,53] In 1991, prior to the legislation, 78% of respondents supported the legislation, while 22% were against it, with females indicating greater support than males.[52] After the law had been implemented (end of 1992), the level of support had not changed with 78% of respondents supporting (48% unconditional support) and 22% against the legislation.[52] In the following year, 60% of adults supported the law unconditionally; support was higher among metropolitan residents (79%) than country residents (73%).[53] Following the implementation of the law, between 1992 and 1993 'definite support' for the law increased 9.3% among metropolitan residents and 16.7% among country residents.[53]

Deaths

Only two studies reported on cycling fatalities in Western Australia, both indicating a reduction in cycling deaths following the introduction of the law.[51,52] According to police data, there was only one bicycle related fatality in 1992 (post-law) compared with an average of 8.3 fatalities per year in the six years prior to the introduction of the law.[51] In a similar study using police department, health department or coroner's office files, Cooke et al., (1993) found a reduction in the cycling fatalities, reporting one death in the year following the introduction of the law, and a total of 63 cycling related deaths in the eight years prior, averaging 7.8 cycling deaths per year.[51]

Cycling

The observational surveys conducted by Heathcote et al., (1993) also examined cycling participation by measuring the number of commuters, recreational cyclists and school children riding their bicycles in designated observer locations.[52] Since 1988, they observed a steady decline in the number school children cycling to school and an increase among commuters.[52] However, the rate of decline did not change between 1991-1992 (post-law) indicating that the law was not a significant factor in the decline. They did, however, observe an accelerated drop in the number of recreational cyclists immediately after the legislation was introduced.[52]

In a later study, Heathcote et al., (1994) conducted telephone surveys to Perth and surrounding country residents about their cycling behaviours.[53] Cycling behaviour in the previous 12 months increased from 48% in 1989 (pre-law) to 51% in1993 (post-law); however cycling frequency (weekly, monthly, and yearly) were similar between the two years.[53] Additionally, the survey indicated that the law may have been responsible for a small decrease in the frequency of cycling as, 30% of males and 23% of females reported that they had decreased their cycling in the last 2 years, 3.6-5% of respondents' indicated that they had stopped cycling because of the law, and 25%-28% reported that they would cycle more if they were not legally required to wear a helmet. Moreover, 22.7% of metropolitan and 19.6% of country residents indicated that the main reason for reducing their cycling was due to the helmet law.[53] However, 31% of metropolitan and country residents indicated that they had increased their cycling in the last two years.

Head Injuries and Cost Effectiveness

In 1999, Hendrie et al. conducted an economic evaluation of the mandatory helmet law in Western Australia. They examined cost-effectiveness of the legislation based on its effectiveness in reducing head injuries and the cost of the legislation to the community.[36]

Using hospital record data, they found a significant protective effect (p=0.0001) of the law where the proportion of cyclists with head injuries was 16% less than the proportion of injured pedestrians with head injuries in the years following the law, compared with pre-law rates where the proportion of injured cyclists with head injuries was 6% greater than that of pedestrians with head injuries.[36] Similarly, Heathcote et al., (1993) found that in 1992 (post-law) head injuries were 44% less than in 1991 (pre-legislation).[52]

Between 1992 and 1998, public education campaigns, enforcement, purchase of helmets, and the administration of the helmet rebate schemes cost the community approximately $21.6 million (94% of

this cost was spent on purchasing helmets).[36] Based on this data, the cost-effectiveness ratio of the helmet wearing legislation (based on the change in number of bicyclists' head injuries and the cost to the community) varied from $70 300 to $150 900 per head injury saved. The resulting Net Present Value (benefits minus costs) of the bicycle helmet legislation ranged between -$10.6 million and $2.0 million.[36] The authors concluded that because there are no established thresholds against which to compare the cost-effectiveness, there is no clear answer as to whether the helmet legislation had been effective in an economic sense; however the authors did suggest that it is unlikely that helmet legislation would have achieved net savings of any sizeable amount.[36] It is important to note, however, that other outcomes, such as the impact of legislation on cycling, physical fitness and related health conditions were not taken into account.

Summary

The introduction of Western Australia's mandatory all-age bicycle helmet legislation was associated with high levels of support for the law, increases in helmet use, particularly among high school students and recreational cyclists, and a trend towards decreased cycling participation among school children and recreational cyclists. Additionally there was a decrease in cycling-related deaths and head injuries following the introduction of the law. However the cost-effectiveness of the law in terms of costs of head injuries saved remains unclear, but it is unlikely that the savings associated with the helmet legislation were of a sizeable magnitude.

South Australia (All-Age Law, 1991)

Context

In July, 1991 helmet wearing was made compulsory in South Australia under the Road Traffic Act.[54] The legislation mandated that "a person must not ride, or ride on a bicycle unless the person is wearing a safety helmet that complies with the regulations and is properly adjusted and securely fastened". Postal workers and those wearing a turban for religious reasons were exempt from the legislation.[54] Those who failed to comply with the law were fined $41 and received a Traffic Infringement Notice. Parents were responsible for paying fines of cyclists under the age of 16.

Prior to the law, in 1984, a policy of public education and promotion created by the South Australian State Cabinet aimed at increasing helmet use and acceptance among cyclists was created. However, legislation was ruled out at this time due to concerns about costs, low usage rates and enforcement difficulties.[54]

Between 1985 and 1990 the promotion of voluntary bike helmet use continued with television and radio commercials, distribution of bike helmet information kits within schools and print media within bicycle shops and primary schools. Additionally, a bicycle helmet rebate scheme was introduced in 1989 providing a $10 rebate towards the purchase of an Australia Standards helmet for school children.[54]

Effectiveness of Helmet Legislation in South, Australia

One study by, Marshall et al., (1994) examined the effectiveness of the all-age mandatory bicycle helmet legislation on helmet use, number of hospital admissions for cyclist causalities and cycling exposure in South Australia using household surveys, observational surveys and hospital records.[54]

Helmet Use

Data from household surveys and observational studies demonstrated a positive effect of the legislation on helmet use.[54] Between 1990 (pre-law) and 1993 (post-law) helmet use was shown to significantly increase in both males ($p<0.001$) and females ($p<0.001$) increasing from 15% to 90.0% in children (15 years and younger) and from 41.6% to 85.5% in adults (greater than 15 years of age).[54] Observational studies in schools indicated no significant difference in helmet wearing rates when analyzed by region, sex or socioeconomic status.[54]

Hospital Admissions

After controlling for ridership and hospital admission policies, data from the South Australian Health Commission Hospital Inpatients Record System (ISIS) indicated a 12.1% decrease one year post-law and a 24.7% decrease two years post-law in the number of cycling related hospital admissions that were preventable by the use of a helmet when compared with rates one and two years pre-law respectively.[54] Additionally, preventable injuries decreased 43.6% between 90/91 and 91/92.[54] Non-preventable injuries (i.e., non-head injuries) decreased by 26.6% in the year after the law was introduced.[54]

Cycling

Although Marshall et al., were not able to determine the effect of the law on the number of cyclists due to inconsistencies in data sources, the reduction of hospital admissions for all cycling related injuries suggest that there was a decrease in cycling exposure following the introduction of the law.[54] Also, an observational study conducted in 1994 indicated a 38% reduction in the number of children cycling to school.[54] Ridership data from household surveys examining the frequency of cycling behavior among cyclists indicated no significant differences among children and adult residents between 1990 (pre-law) and 1993 (post-law).[54]

Summary

Marshall et al's., (1994) study suggests a positive effect of the South Australia all-age helmet law on helmet use and hospital admissions for injuries preventable by helmet use. These decreases may be a reflection of a reduction in the number cyclists as reported by observational surveys of school children; however results are inconclusive due to inconsistencies in data sources.

STAGGERED ADULT AND ALL-AGE LAWS

Northern Territory, Australia (Adult Law 1992, All-Age Law 1992)

Context

In January 1992, Northern Territory Australia introduced a mandatory bicycle helmet law for adults aged 17 years and older, followed by an all-age helmet law in July 1992.[55] The staggered introduction of the law was based on data from the previous five years (1987-91), in which eight cyclists were killed, 431 cycling injuries were reported and 70% of those injured were adults over 17 years of age.[55]

The law was introduced along with a bicycle helmet scheme to increase community awareness and create subsidy arrangements so that helmets could be affordable to many families. As an outcome of the 1986 BIKESAFE conference, a bike helmet scheme was developed to promote helmet use among children who ride their bikes to primary school.[55] Donations from service clubs and a contribution from the Road Safety Council's budget contributed to a Bicycle Helmet Seed Fund to provide helmets to children on the condition that they wore it at least 80% of the time and then purchased it after 3 months.[55] In 1991 a bike helmet subsidy scheme was introduced in Northern Territory primary schools and was later introduced in high schools in 1992. With this scheme a $10 subsidy was provided to students who purchased a Standard Australia approved helmet. In 1993 the scheme was later extended to toddlers with a $20 subsidy due the more expensive cost of toddler helmets.[55]

Additionally, a number of initiatives took place to promote the use of helmets. The Road Safety Council Field Officers created a large promotion program for students involving videos, demonstrations, pamphlets and newspaper articles highlighting the need to wear a helmet.[55] Within schools, the Northern Territory Police Community Relation section ran a program in 1989 where students who obeyed safety rules (including wearing a helmet) were nominated by School-Based Constables to win monthly prizes through draws.[55]

There was also promotion of voluntary helmet use prior to the law (1990-91) using public awareness campaigns involving radio, television and cinema advertisements including a Federal Office of Road Safety publicity campaign.[55]

Effectiveness of Helmet Legislation in Northern Territory, Australia

One study by van Zyl et al., (1993) examined the effectiveness of the mandatory bike helmet laws on helmet use and cycling behaviour in the Northern Territory of Australia using observational surveys.[55]

Helmet Use

Van Zyl et al., (1993) conducted observational surveys at primary and secondary elementary schools and commuter sites in the Northern Territory of Australia recording whether or not cyclists wore helmets as they left school grounds or passed by.[55] The observational survey indicated an increase in helmet use by primary and secondary school children and adult commuters following the enactment of the legislation. Between 1991 (pre-law) and 1992 (post-law) primary school children increased their helmet use from

56% to 82%, secondary school children increased from 27% to 71% and adult commuters increased their helmet use from 40% to 85%.[55]

Cycling

Although not a primary objective of their study, van Zyl et al., (1993) noted that the number of primary school cyclists remained unchanged both prior to and following the introduction of the helmet law (from 987 cyclists observed in April 1992 to 995 in August 1992); however the number of secondary school children observed riding their bicycle to school dropped from 931 students in April 1992 to 595 students by August 1992.[55]

Summary

The results from Zyl et al., (1993) suggest that the adult and all-age helmet laws introduced in the Northern Territory of Australia were effective in increasing helmet use among all age groups (both children and adults) without influencing cycling rates among primary school children; however, the law deterred some secondary school students from cycling.

STAGGERED ADULT AND CHILD LAWS

New South Wales, Australia (Adult Law, 1991, Child Law, 1991)

Context

On January 1, 1991 mandatory bicycle helmet legislation was enacted in New South Wales, Australia for adults 16 years of age and older. In July, 1991 (a few months later) mandatory bicycle helmet legislation was enacted for children under the age of 16.[56] The staggered introduction was created to allow for adult role models prior to the introduction of the child law, and to disperse the cost of helmet purchases for families.[60] The legislation aimed to increase helmet use, reduce bicycle fatalities, serious injury rates and head trauma sustained by cyclists.

Exemptions to the law were given for medical and religious purposes; however all exemptions were removed one year after the introduction of the law (January, 1992).[60] Fines for non-compliance were issued to riders 15 years of age or older, and cautions or warnings given to parents of children up to 14 years of age. In addition to giving out fines, the police were engaged in a number of supporting activities to reinforce helmet wearing including bicycle education days, safety checks, and helmet adjustments.[60]

The law was widely supported by medical professionals, the Bicycle Institute of New South Wales and the Roads and Traffic Authority's Bicycle Advisory Council.[60] Additionally, in a survey conducted in 1989, 86% of cyclists and non-cyclists favored compulsory helmet wearing on main streets and believed that helmets saved lives. Many individuals in the bicycling fraternity were against the legislation.[60] However a public attitude survey indication that over 80% of riders never wore a helmet prior to legislation.[60]

In 1986 a helmet rebate scheme was introduced to increase voluntary helmet use and reduce the risk of head injuries to cyclists on the road prior to the introduction of the law;[60] however the scheme was

unsuccessful as there were delays in processing and the $5 (10% discount) rebate was considered too low. In 1988 an additional rebate scheme of $12 (25% discount) was conducted with greater success.[60]

Prior to the law, a number of activities took place to promote the use of helmets. In December 1990, a month prior to the introduction of the adult helmet law, the Minister for Roads launched a media campaign to raise public awareness about the social and economic need for cyclists to wear a helmet.[60] The campaign involved television, radio, cinema, and magazine advertisements.

In June, 1991, a month prior to the implementation of the child helmet law, an advertising campaign along with school-based initiatives was launched.[60] The campaign involved magazine, radio and newspaper ads along with brochures, posters, bookmarks, stickers, and pencils.[60] Additionally, information resource kits with road safety teaching materials were provided to kindergarten to grade 12 teachers in all primary and secondary schools in the state.

Concurrent Safety Initiatives

Other safety measures undertaken to reduce the risk to cyclists included the introduction of random breath testing of motor vehicle drivers in 1982 and intensive road safety advertising in 1989.[57]

Effectiveness of Helmet Legislation in New South Wales, Australia

Five studies examined the effectiveness of the child and adult mandatory bicycle helmet legislation introduced in New South Wales by comparing injuries (head and non-head injuries), helmet use and deaths both pre- and post-legislation.[56-60] Most studies used data from hospital and health records, direct observations and self-reported surveys.

Helmet Use

Of the four studies examining helmet use in New South Wales, all reported increased helmet use following the introduction of the law.[57-60] Observational surveys indicated that helmet use increased for all ages from approximately 18% to 78% three years after the introduction of the law with a slight delay in the increase for children due to the later implementation of the child law.[57] Similar rates were seen using observational surveys among commuter and recreational cyclists both with an 80% helmet wearing rate in 1993.[60] Between 1990 (pre-legislation) and 1993 (post-legislation) children under the age of 16 increased their helmet use from 12% to 74% while adults use increased from 26% to 83%.[60] Walker et al., (1992) noted increases in helmet use of 44.5% and 8% among children and adults respectively between pre- and post-law.[58] Additionally, Walter et al., (2011) noted that helmet use increased from approximately 20% to more than 60% among children and over 70% for adults within two months of the legislation coming into effect.[59]

Head- and Non-Head Injuries

Four studies examined the effect of the helmet law on head injuries using trends in non-head injuries as a comparison; all studies demonstrated a protective effect of the helmet law on head injuries.[56,57,59,60] While both head and non-head injuries declined over the years,[60] analyses were based on the assumption that even if cycling rates declined, relative injury rates (i.e., head versus non-head injury rates) should remain unchanged unless there is some factor differentially impacting one type of injury

but not the other (i.e., helmet law impact head injuries but should have no effect on arm or leg injuries).[57]

Walter et al., (2011) noted that among cyclists, there was a significant decrease in head injuries compared to arm injuries at the time of introduction of the legislation, while no significant effect was found among pedestrians; this additional benefit was attributed to the compulsory helmet legislation.[59] Depending on whether arm or leg injuries were used for comparison the legislation accounted for 25-29% of the decrease in head injuries among cyclists.[59]

Olivier et al. (2013) used the same initial dataset as Walter et al. (2011), and continued the analysis forward in time to determine if the legislation effect continued.[56] They concluded that it had. Olivier et al., (2013) noted that in 2006 rates of head injuries were 46% less than that of arm injuries compared with 19% fewer head than arm injuries immediately post-law.[56] In 1991 there were 590 head injuries and 660 arm injury hospitalizations reported while in 2006 there were 1004 head injuries and 1622 arm injuries.[56] The authors suggest that the additional safety benefit in 2006 was associated with an increase in cycling infrastructure spending. Olivier et al., (2013) reported an increase in infrastructure associated with an 8.5% decline per annum in head injuries and a slight decline in arm injuries that was preceded by a steady increase of 6% per annum.[56]

Voukelatos et al., (2010) noted that the ratio of head-to-arm injuries was already declining prior to the introduction of the law; however the steepest decline took place between 1988-89 and 1990-91 at the same time that the legislation was enacted.[57] This trend was evident for all age groups with the greatest decline for children 5 to 14 years of age occurring between 1990-91 and 1991-92 demonstrating a strong temporal association with the time enactment of the child law in July 1991.[57] However, the authors suggest that it is likely that factors other than helmet legislation (such as road safety improvements) may also have contributed to this reduction and that the helmet legislation may not be the main factor contributing to the reduction in head injuries in cyclists over time as there were a series of changes in road safety conditions prior to 1991 which contributed to a safer road environment benefiting cyclists.[57]

Serious Injuries and Deaths

Using New South Wales Heath Statistics data, Williams et al., (1995) examined bicyclist fatalities and serious injuries two years prior to and following the introduction of the helmet laws.[60] Between 1990 and 1993, overall cyclist fatalities decreased 60% (from 21 to 8 fatalities) and serious injuries declined 21% (from 1880 to 1451 serious injuries).[60] Among children, cycling fatalities decreased 57% and serious injuries decreased 26%, while among adults, cycling fatalities and injury rates decreased 62% and 21% respectively. As a comparison measure, Williams reported changes in injuries to other road users over the same period: fatalities fell 24%, serious injuries 15%, and other injuries 19%. As another comparator, they showed a 29-34% decline in cyclist head injuries vs. a 17% decline to an 18% increase in other injuries.[60]

Cycling

Walker et al. (1992) examined cycling rates through the use of observational surveys and noted that there was a decrease in cycling following the introduction of the law.[58] Between 1990 and 1991 the number of child cyclists on the road decreased by 36% and adult cyclists decreased by 14%.[58]

Summary

Overall the introductions of New South Wales' child and adult helmet laws were associated with increases in helmet use across all ages, and decreases in relative head injuries, fatalities and serious injuries among cyclists. One study monitored cycling and noted decreases in cycling participation by both children and adults. Non-head injury rates also decreased over the legislation period, interpreted by investigators as an indication of decreased cycling. In the decades following the legislation, ratios of head to arm injuries have continued to decline, interpreted as an indicator of increased helmet use. It is likely that there are other factors impacting cycling injuries, such as improved infrastructure.

New Zealand

ALL-AGE LAW

New Zealand (All-Age Law, 1994)

Context

New Zealand was one of the first countries to implement national all-age mandatory bicycle helmet legislation. The law, enacted on January 1, 1994, required all cyclists to wear standard approved cycle helmets for all on-road cycling.[65] Penalties for non-compliance ranged from $55-$150.[61,63,65]

Prior to the introduction of the law, programs promoting regular helmet use increased helmet wearing rates from nearly 0% in 1986 to 84%, 62% and 39% in 1992 for primary school children, secondary school children and adults respectively.[65] Another campaign initiated by the Eastern Bay of Plenty Child Injury Prevention Trust took place following the law between 1998 and 2002, and involved the media, public meetings, and school principals to discourage children under nine years old from riding their bicycles to school to reduce collisions with motor vehicles.[63]

Effectiveness of Helmet Legislation in New Zealand

Five studies examined the effectiveness of the national all-age mandatory bicycle helmet legislation in New Zealand.[61-66] Four studies conducted pre/post analyses comparing outcomes prior to and following the implementation of the law[61,63-65] and two studies examined its cost effectiveness.[62,66] One study is noteworthy because they calculated injury or fatality incidence rates per time of cycling exposure.[61]

Helmet Use

According to observational surveys conducted by Scuffham et al., (2000), helmet use (all ages) increased from 65% in 1993 to 98% in 1994.[65] Primary school children (aged 5-12 years) increased their helmet use 12-33% from pre- to post-legislation, secondary school children (aged 13-18) increased use 32-56% and adults increased use 48-58% within the first four years of legislation.[64-66] Helmet wearing rates increased immediately following the law in 1994 but later plateaued at high levels (>85%).[64]

Injuries

According to an analysis by Moyes et al., (2007) of Whakatane Hospital's Emergency Department data, the mean total number of child cycling injuries per annum increased significantly ($p<0.01$) between 1982-86 and 1998-2005.[63]

Clarke (2012) examined cyclist injuries for the entire country and found that injury incidence rates for cyclists have increased or have not declined as much as in other modes of travel.[61] The number of serious cycling injuries (AIS >3; (AIS= anatomical scoring system for ranking the severity of an injury from 1 = minor to 6 = survivable) decreased from 377 in 1988-91 to 138 in 2003-07. Despite the increase in cyclists annual number of injuries per million hours spent travelling between 1988-91 and 2003-07 (20% increase), the change in *serious* injuries declined 39% (since 1988-91). Other modes of travel had similar declines in serious injury rates in same period (decreases between 45-57%).

Most studies reported a reduction in the numbers of head injuries following the introduction of the law[64-66] with the exception of Moyes et al. (2007) who found that the reduction in the number of head injuries per annum between 1982-86 and 1998-2005 was small and not significant (p=0.87).[63] Povey et al. (1999) examined New Zealand hospital records and concluded that the increase in helmet use associated with the introduction of the law was associated with a 30% reduction in in overall head injuries.[64] The estimated reduction in head injuries among primary school children, secondary school children and adults was 24%, 32% and 28% respectively.[64] Scuffham et al., (2000) estimated the number of averted head injuries (difference between predicted and observed head injuries) between 1994 and 1996. They estimated an overall 18.7% aversion rate among all age groups with and 6.2% of head injuries averted among primary school children, 16.2% averted among secondary school children and 24.5% among adults over the two year time period (1994-96).[65] Similarly, Taylor et al., (2002) noted that in the first three years post law, there was an annual average reduction of 4, 10.3, and 23.8 cyclists admitted to hospital for head injuries among children, adolescents and adults respectively.[66]

Deaths

Two studies examining the effects of the New Zealand bike helmet legislation reported no change in the number of bicycle related deaths after the introduction of the law.[61,63] Clarke et al., (2012) noted a 3% difference in the ratio of cyclist to pedestrian deaths between 1989-93 (pre-law) and 2006-09 (post-law).[61] When cycling exposure was taken into account, cyclist deaths per hour of cycling fell by about 11% compared to a fall of 55% for pedestrians between 1989-90 and 2006-09.[61] Similarly, Moyes et al., (2007) found no significant change (p= 0.37) in the mean number of child deaths per annum among children in the Bay of Plenty between 1982-86 (pre-law) and 1998-05 (post-law).[63]

Cycling

Survey data from the New Zealand Ministry of Transport indicated that between 1989-90 (pre-law) and 1997-98 (post-law), the average number of hours cycled per week decreased by 40%.[61] The number of hours cycled per person decreased from 56hrs per person pre-law (1989-90) to 50hrs per person post-law (2006-09) representing a 51% decrease.[61]

Cost Effectiveness

Two studies examined the cost-effectiveness of the New Zealand helmet law for three age groups: children (5–12 years), adolescents (13–18 years), and adults (19 years and above) and concluded that the law was cost saving for children but was costly for adults.[62,66] Hansen and Scuffham (1995) compared the costs to cyclists of either buying a helmet or quitting cycling with the number of expected deaths and hospitalizations to be prevented over the average lifespan of a helmet.[62] They found that the costs per life saved ranged from $88,379 for children to $1,014,850 for adults. Costs per hospitalization avoided ranged from $3,300 to $56,035 with the lowest costs among children and adolescents. However, additional costs and benefits such as cost of enforcement, and the likelihood of helmets reducing head injuries were not taken into account due to unavailable data.

In a similar study by Taylor and Scuffham, (2002) cost-effectiveness of the New Zealand helmet law was estimated using the cost of purchasing helmets, the value of injuries averted and additional healthcare

costs averted from reduced injuries.[66] They estimated that the benefit-cost ratio (total societal costs averted/cost of helmets) of the law was greater than for children (2.61) and lower than one for adolescents (0.85) and adults (0.74) translating into a net benefits of $0.3 million for children, and net costs of -$0.2million for adolescents and -$1.5 million for adults.[66]

Summary

Evidence from the six studies examining the New Zealand national all-age helmet law demonstrated that the law was associated with increases in helmet use among all ages, reductions in head injuries and a small decline impact on cycling-related deaths compared to pedestrians. A decrease in cycling duration among cyclists was noted from pre- to post-law. Injury incidence rates for cycling have increased for cycling or have not declined as much as in other modes of travel. Cost-effectiveness studies of the law suggested that the law offers a net benefit for children but not adults.

United States of America (USA)

CHILD LAWS

Jurisdictions in the United States of America (USA) (Child Laws, 1987-2013)

Context

Since 1987, in the United States of America (USA), 21 states including the District of Columbia and many communities have implemented helmets laws targeting children from birth to 18 years of age.[67] Enforcement rates across jurisdictions have varied and penalties for the law have been minor. Verbal warnings were given for the first offence and fines were waived if helmets were purchased. The laws were often accompanied by education and public campaigns making it difficult to isolate the effects of the law itself.[67]

Effectiveness of Helmet Legislation in US Jurisdictions

One study by Chatterji et al., (2013) examined the direct and indirect effects of child bike helmet laws on injuries in the USA using hospital data from 21 states and the District of Columbia.[67] They examined the association of helmet laws with reductions in head and non-head injuries from cycling and other wheeled sports.[67] Overall, bicycle helmet laws were associated with a 13.7% reduction in the number bicycle-related head injuries, 9% reduction in non-head bicycle related injuries, and an 11% increase in all types of injuries from wheeled sports (e.g., roller skating, scooter riding) among children 5-19 years of age.[67] Although the laws appeared to have a positive effect on head injury rates among children, the reduction in non-head injuries and the increase in injuries from other wheeled sports suggest a possible substitution effect in which children are switching from cycling to other wheeled sports in response to the law.[67]

California, USA (Child Law, 1994)

Context

In 1994, California was the sixth state to implement statewide helmet legislation requiring all children 18 years and younger to wear a helmet when riding on public bicycle paths and roads.[61,68,70] No citations were issues in the first year of implementation and un-helmeted cyclists were given only warnings. However, in January, 1995, one year after the implementation of the law, police began issuing written citations to those not complying with the law.[69]

Effectiveness of Helmet Legislation in California, USA

Three studies examined the effects of the California law by comparing helmet use and injuries prior to and following the law by examining hospital and trauma records.[68-70]

Helmet Use

Ji et al., (2006) evaluated the effect of California's bicycle helmet law on helmet use in San Diego County by examining data from the San Diego Trauma Registry.[69] Between 1992 and 1996 they found a significant increase ($p<0.001$) in helmet use (from 13.2% pre-law to 31.7% post law) among adult and child residents in San Diego County.[69] Among this group of hospital patients, helmet use increased by an average of 43% per year with an average 84% increase in helmet use among children who experienced trauma. Additionally, in 1996, four years after the law was introduced, patients injured by cycling were 2.86 times more likely to be wearing a helmet at the time of the injury compared with the pre-law period.[69] Castle et al., (2012) also found a slight increase (from 7% pre-law to 12% post-law) in the number children with cycling related head injuries that wore helmets, however the increase was not significant ($p=0.3$).[68]

Injuries

Castle et al., (2012) conducted a retrospective review of child trauma patients in Los Angeles between 1992 and 2009, and found a significant decrease ($p<0.0001$) in the Injury Severity Scores (ISS) of presentations despite an increase in the total number of cycling injuries at this time.[68] Head injuries decreased slightly from pre- to post- legislation, however this decrease was not significant ($p=0.35$).[68-70] Ji et al., (2006) found non-significant decreases in head injuries from pre- to post-law among children or adults (not targeted by the law),[69] but a significant 18.2% reduction in the proportion of injuries that were traumatic brain injuries (comparing pre and post legislation rates) was found among children.[70]

Non-Head Injuries

Evidence from two studies reporting on non-head injuries among children following the implementation of the child helmet law is mixed. Castle et al., (2012) found that intra-abdominal (non-head) injuries decreased from 13% pre-law to 6% all total bicycle-related injuries post law.[68] Lee et al., (2005) however, reported a 9% increase in the proportion of all other injuries among children when comparing pre- and post-legislation proportions, and no significant change in the proportions of non-head injuries among adults.[70]

Summary

Overall, the California child helmet law was associated with significant increases in helmet use among both children and adults and decreases in the severity of injuries among children. However, there was an increase in the total number of cycling injuries and no significant decrease in head injuries (but a significant reduction in the proportion of traumatic brain injuries) among children at this time. Additionally, there is mixed evidence regarding the impact of helmet legislation on non-head injuries among children.

Florida, USA (Child Law, 1997)

Context

On January 1st, 1997, Florida enacted statewide helmet legislation mandating that all bicyclists younger than 16 years of age wear a helmet while riding.[73] The law was part of the Healthy People 2010 objective to have all 50 states adopt child helmet laws to increase helmet use and reduce head injuries.[73] As part of the legislation, counties were allowed to exempt themselves from the law after having a public hearing; three counties chose to 'opt out'.[73]

No fines were issued in the first year of the law; verbal warning and safety brochures were handed out to those not complying. After one year, a $15-$27 fine was issued to violators of the law.[72,73]

In the year prior to the law, a community wide educational campaign involving nurses working in emergency departments and pediatric referral trauma centers was implemented.[71] The program involved visits to elementary schools by trauma service nurses who discussed safe biking and helmet use and risks of not wearing a helmet.[73] They also provided information on the helmet law. This was complemented by fairs, school rodeos and print media campaigns. Within the emergency department, bicycle crash victims received helmet safety packets at discharge demonstrating how to wear helmets correctly and were shown a video about helmet safety.[73] Educational packets were also given to parents containing tips on getting their children to wear a helmet. Children indicating that they would wear a helmet if they could afford one were provided with a helmet at no cost and discounted helmets were available for purchase.[73]

Additionally, community incentive programs took place involving police officers distributing toy and food coupons to any child they saw wearing a helmet while riding his or her bicycle, and giving away helmets to lower income children.[72,74]

Effectiveness of Helmet Legislation in Florida, USA

Four studies examined the effect of Florida's helmet legislation on helmet use and head injuries.[71-74] Three studies examined pre- and post- law helmet use and head injuries, while the remaining study compared the law's effects across two counties with and without helmet laws or community incentive programs.[72]

Helmet Use

All studies demonstrated a significant impact of the helmet legislation on helmet use.[71-74] Two studies compared pre-law and post-law helmet wearing rates using observations and trauma medical records and found significant increases in helmet use among children following the introduction of the law.[71,74] Trend tests by Liller et al., (2003) revealed that the increase in helmet use following the law was significantly ($p<0.0001$) greater than what would have been predicted from pre-law trends.[74] Additionally, the odds of a child wearing a helmet in 1997 (year of law) was eight times greater than in the preceding year (OR 8.3; 95% CI 6.1 to 11.4).[74] Liller et al., (2003) noted significant increases in helmet use among 5-13 years in children from 3.6% in 1993 to 67% in 1998.[74] Significant increases in helmet use

of 25% and 27% were seen among children 7-9 years and 10-12 years respectively.[71] The greatest gains in helmet use were among the youngest age groups in which bicycle safety programs were targeted.[71]

Two additional studies comparing helmet use among jurisdictions with and without helmet legislation or community incentive programs also noted the benefit of the helmet legislation on helmet use.[72,73] In an observational study by Kanny et al., (2001) examining child cyclists at elementary schools, they found a significant difference in helmet use between counties with a law vs. those without (p= .001).[73] Children living in counties with a law were 2.3 times more likely to wear a bicycle helmet than children in counties exempt from the law after controlling for gender and race (OR = 2.3 95 % CI: 2.1- 2.8).[73] In another observational study of children in elementary and middle schools, Delamater et al., (2003) compared the effects of the Florida state helmet law on two communities in Broward County in which one had incentive intervention program prior to the introduction of the law and the other did not.[72] Although helmet use increased in both communities following the implementation of the law, the community with the incentive program more than doubled their helmet use (from 5.8% to 12%) while helmet use in the other community remained low (from 1.5% to 2.4%) demonstrating the added benefit of community programs in enhance law effectiveness.[72]

Injuries

Two studies examined the effect of the Florida state legislation on injury rate, both noting decreases following the implementation of the law.[71,74] Liller et al., (2003) examined Florida Department of Transportation records and found a significant decline in the number of all bicycle-related motor vehicle injuries among in children 5-13 years of age in Hillsborough County, in the years following the law compared with pre-law.[74] They calculated rates based on population denominators (rather than cycling exposure) and found a parallel decline. Decreases in state injury rates were also observed for adults aged 15 years and older, but were not as great as those declines seen in the age group targeted by the law.[74] Borglund et al., (1999) also noted slight decreases in the number of severe and minor head injuries and greater number of helmeted than non-helmeted children with Injury Severity Scores (ISS) less than six in Broward County, post law.[71]

Summary

Florida's child helmet law was effective in increasing helmet use among children, particularly those of the youngest age group who were targeted by bike safety programs. The community incentive program appeared to further enhance this positive effect. Decreases in injury rates were observed among both children and adults with greater declines observed among children who were targeted by the law. Severe head injuries were also reduced among children post-law.

New York and Connecticut, USA (Child Law 1994 & Child Law 1993)

Context

Since June 1st, 1994 the state of New York enforced a law requiring all children 14 years of age and younger to wear a helmet when riding a bicycle.[77] Prior to the state law, in 1992 Rockland County, New York was the first county in the US to make a law requiring all cyclists, regardless of age, to wear a

helmet.[76] Connecticut state followed shortly after, in 1993, requiring all cyclists 12 years of age and younger to wear a helmet on the "travelled proration of any highway".[76]

Both the New York and Rockland county laws had a $50 fine for those not wearing a helmet; however the fine was waived if a helmet was purchased after the first offence.[76,77] The Connecticut law did not have any fine.[76] In New York, cost subsidies were provided and some local bicycle shops agreed to honour a $10 discount coupon provided by some promotional campaigns.[75,77]

Since 1990, the regional pediatric trauma center in Buffalo, New York conducted prevention programs involving community education and the distribution of helmets.[77] In 1994, just prior to the New York state law, a bicycle helmet campaign was conducted and included the distribution of educational packets, prescriptions for bicycle helmets by local physicians, newspaper advertisements and a "Bicycle Helmet Day" at a local hospital.[75] The educational packets contained information regarding the new law, fact sheets, and a $10 discount coupon towards the purchase of bicycle helmet.[75]

Effectiveness of Helmet Legislation in New York and Connecticut, USA

Among the three studies examining the helmet legislation in New York and Connecticut, two studies compared helmet use across different jurisdictions with varying degrees of law implementation,[75,76] while the remaining study examined helmet use before and after the law.[77]

Helmet Use

Three studies examined helmet laws in New York and found significant increases in helmet use following the introduction of helmet legislation.[75-77] Increases were greater in jurisdictions that had more comprehensive legislation or education campaigns.[75-77] For instance, Shafi et al., (1998) used records from the regional trauma center in Western New York, to examine the impact of the child helmet law on helmet use of children involved in bicycle crashes.[77] While they found a significant increase ($p<0.0001$) in helmet use from 2% pre-law to 26% post-law among children involved in crashes, helmet use remained low.[77]

These low levels of helmet use may be enhanced through the use of educational campaigns. For example, Abularrage et al., (1997) compared the effectiveness of the New York state child helmet law in two counties in New York.[75] One county (Queen's, New York) implemented an educational campaign prior to the introduction of the law while the other county (Brooklyn, New York) did not. Using two observational surveys both prior to and following the introduction of the law, they found a significant increase ($p<0.001$) in helmet use following the law in Queens county while a non-significant decrease in helmet use was observed in Brooklyn, suggesting that legislation alone may be inadequate for ensuring increased bicycle helmet use.[75] Like Shafi et al., Abularrage also noted that while the increase in the intervention group was promising, the post-legislation helmet use rates among children (13.9%) were still low.[75]

In a similar cross-sectional observational study by Puder et al., (1998), comparing all-age legislation in Rockland, New York with two child helmet laws in Westchester, New York and Fairfield, Connecticut, more comprehensive all-age legislation was found to lead to greater rates of helmet use compared with

legislation targeting children only. For instance, using observations of helmet use in all three counties, the authors noted that Westchester and Fairfield (where child legislation was implemented) had significantly lower rates of helmet use ($p=0.028$ and $p<0.001$) compared with Rockland where all-age legislation was implemented.[76] Additionally, Westchester which had more comprehensive legislation, targeting children 14 years and younger, had greater helmet use (24%) than Fairfield whose legislation targeted children up to age 12 (14%).[76]

Summary

New York's child helmet law significantly increased helmet use among children. Helmet wearing rates remained low but appeared to be enhanced through the use of educational campaigns or and more comprehensive (i.e., all-age vs. child only) legislation.

Howard County, Maryland, USA (Child Law, 1990)

Context

In 1990, Howard County, Maryland passed a law requiring all children 16 years of age and younger to wear an approved safety helmet when riding a bicycle on county roads and paths.[79] Fines for non-compliance ranged from $25-$100 and were waived if a helmet was purchased.[78,80] Warning letters were sent to parents of un-helmeted children after the first two offences; parents were issued a citation after the third offence.[78]

At the introduction of the law, an educational campaign was launched involving the distribution of safety handbooks to elementary and middle school students, a bicycle safety unit as part of health education within elementary school classes, and a bicycle safety curriculum in some middle schools.[79] Local media coverage, bicycle rodeos and police officer visits to schools encouraging helmet use and promoting the law also took place.[78-80]

Effectiveness of Helmet Legislation in Howard County, USA

Three studies examined Howard County's child helmet law.[78-80] Two studies compared the effects of the law with other counties who had either a bicycle helmet educational program or no helmet promoting initiatives.[78,79] The remaining study compared the cost effectiveness of the Howard County law with other community wide or school-based programs.[80]

Helmet Use

Three studies demonstrated increases in both observed and self-reported helmet use among children in Howard country following the introduction of the law.[78-80] Of these, two studies compared the effects of the Howard County helmet law and educational program with two additional Maryland counties; Montgomery County (which implemented a bike helmet education program and no legislation) and Baltimore County (which had neither an educational or legislation helmet program).[78,79] Both self-reported and observed helmet use increased among two of the three counties (Baltimore had decreased

helmet use between 1990 and 1991); Howard County had demonstrated the greatest increases in helmet use.[78,79] In Howard County, observed helmet use increased significantly ($p<0.0001$) from 4% in 1990 (pre-legislation) to 47% in 1991 (post-legislation)[78,80] and the proportion of child respondents who reported that they "always" or "usually" wore a helmet increased significantly from 11.4% (1990) to 37.5% (1991) ($p < .0001$).[79]

Helmet Ownership and Law Awareness

The self-reported survey also examined self-reported helmet ownership and awareness of the law. They found that helmet ownership among middle school children in Howard County was significantly higher than ownership in Montgomery and Baltimore Counties ($p<0.0001$) where no helmet legislation existed.[79] The survey also suggested that 87% of respondents in Howard County thought there was a law while 4% did not think there was a law and 10% reported that they 'did not know'.[79]

Cost-effectiveness

Hatziandreu et al., (1995), assessed the cost effectiveness of 1) the Howard County bike helmet law, 2) community wide programs and 3) school-based programs to promoting helmet use.[80] Using only direct costs and a four year follow-up period, a societal perspective was used to estimate the cost effectiveness of each of the three programs. Their results indicated that the costs per head injury avoided, costs per death avoided and costs per year life saved were lowest for the legislative program compared to the community and school-based programs.[80] Costs of the legislation were $36 643 per head injury avoided, $17 935 341 per death avoided, and $934 909 per year of life saved.[80] Benefit cost ratios were greater than 1 for head injuries (24.7), about 1 for years of life saved (1.04) and below 1 for deaths avoided (0.05).[80]

Summary

Together, comparison studies examining the effectiveness of the Howard County helmet law suggest that the law helped to increase helmet use and helmet ownership compared jurisdictions that had either an education campaign or no helmet related programs or laws. The law was also associated with lower costs (per death avoided or life saved) compared with community or school-based programs.

Oregon, USA (Child Law, 1994)

Context

On July 1, 1994, one month after the New York state law, Oregon passed a law requiring all children under the age of 16 to wear a helmet while riding on public property.[81] A $25 fine was issued to those not complying with the law.[81]

Effectiveness of Helmet Legislation in Oregon, USA

To evaluate the effectiveness of the Oregon helmet law, Ni et al., (1997), conducted four pre-law and post-law statewide helmet use surveys examining residents' opinions about and knowledge of the law as well as their helmet use and ownership.[81]

Helmet Use

Statewide observations at 13 metropolitan and rural areas demonstrated an increase in children's helmet use from 24.5% in 1993 (pre-law) to 49.3% in 1994 (first three months post-law).[81] Observations taken at 33 middle schools in Oregon found similar increases between 20.4% (pre-law) to 56.1% post-law and classroom surveys of these children indicated that the percentage of children 'always' using a helmet increased from 14.7% pre-law to 39.4% post-law.[81] According to a statewide adult telephone survey of parents asking about their children's riding habits 36.8% of parents reported that their children always wore a helmet pre-law compared with 65.7% post-law.[81]

Helmet Ownership

The same surveys also assessed helmet ownership. The self-report survey among middle school children indicated a 24% increase in helmet ownership following the introduction of the law (from 51.5% pre-law to 75.5% post law), while surveys of parents suggested a smaller increase in child helmet ownership (from 36.8% pre-law to 65.7% post-law).

Law Awareness and Opinion

In the self-reported survey among middle school students, respondents were asked whether they knew of a law in Oregon which requires people younger than 16 years to wear a helmet at all times while riding a bicycle and whether they thought the law was a good idea.[81] Children's knowledge of the law increased slightly (from 1% to 5% from pre- to post-law), while the percentage of students who thought the law was a good idea increased from 8% to 20% in the same time frame.[81]

Summary

Overall, the Oregon child helmet law increased both helmet use and ownership among children with slight increases in knowledge of the law and support for it.

Georgia, USA (Child Law, 1993)

Context

As of July 1, 1993, all bicyclists younger than 16 years of age were required to wear a bicycle helmet while riding a bicycle in Georgia.[82] There was a $25 fine for not wearing a helmet; however enforcement appeared negligible.[82]

Effectiveness of Helmet Legislation in Georgia, USA

Schieber et al., (1996) conducted a multi-stage cluster random digit telephone survey to evaluate the effect of the Georgia state law on reported bicycle helmet use and ownership among child cyclists between four to 15 years old.[82]

Helmet Use

The telephone survey of parents, conducted one month prior to and four months following introduction of the law indicated a significant ($p<0.05$) 58% increase in reported child helmet use following the introduction of the law.[82] Seven percent of riders changed their status from 'never-wearing' a helmet to 'always-wearing a helmet'.

Helmet Ownership

Respondents of the same survey also indicated a 46% increase in helmet ownership, with 39% of respondents reporting that their child owned a helmet one month prior to the law and 57% following the law ($p= 0.06$).[82] Reported ownership was inversely related to rider age and directly related to household income with race modifying the results. Parent knowledge of the law was highly associated with helmet ownership among black riders, while age and income were significantly associated with ownership among white riders.[82]

Summary

Results from Schrieber et als., (1996) survey suggest that the Georgia's state helmet law was effective at increasing both helmet use and ownership particularly among households with younger children and a higher income.

Beachwood, Ohio, USA (Child Law, 1990)

Context

On December 4, 1990, Beachwood, Ohio passed a law mandating that all children under 16 years of age wear a standard approved helmet while riding a two-wheeled bicycle off the property of their residence.[83] First violations resulted in a verbal warning for children and a written notice to their parents, while subsequent violations resulted in a $25 fine for parents of un-helmeted children.[83]

Additionally, Beachwood, Ohio implemented an educational program promoting helmet use for children up to grade six.[83] The program involved bicycle safety videos, slide shows, and letters for parents discussing the importance of helmets. Discounted helmets were available for purchase through the Parent Teacher Association and were provided to students who could not afford to buy them. Schools conducted poster and essay contests and food coupons were awarded to children 'caught' wearing a helmet. The program was also complimented by some brief television and media coverage.[83]

Effectiveness of Helmet Legislation in Ohio, USA

Helmet Use

To determine the association between bicycle helmet legislation, bicycle safety education and helmet use in children, Macknin et al., (1994) conducted anonymous self-reported surveys and direct observations of helmet use of elementary school children in four suburbs of Ohio.[83] They compared suburbs with helmet legislation and safety education with those that did not. Beachwood County had both helmet legislation targeting children as well as an educational program; Orange county had a law only, while Morland Hills and Pepper Pike counties had neither a law or educational programs.[83] Results from the self-reported child surveys demonstrated that child helmet use was greater among Beachwood County (67.6%) (which had both legislation and an educational program) compared with Orange County (37.2%) (which had only legislation); both of these communities had greater self-reported helmet use than the two counties with neither a law nor education program (Morland Hills 17.9% and Pepper Pike 21.5%).[83] Observational surveys indicated that helmet use in counties with a helmet law was significantly greater than in counties without a law (ps<0.001).[83]

Summary

Overall, Makin et al., (1994), demonstrated that combining helmet laws with educational programs was more effective at increasing helmet use than legislation alone. Legislation alone increased helmet use compared to no legislation.

Canada

ALL-AGE AND CHILD LAWS

Canadian Provinces (All-Age & Child Laws, 1995-2003)

Context

In Canada, between 1995 and 2003, six provinces enacted mandatory bicycle helmet legislation. Four provinces (New Brunswick, British Columbia, Nova Scotia and Prince Edward Island) implemented all-age legislation (in 1995, 1996, 1997 and 2003 respectively) while Ontario and Alberta implemented laws for children under 18 years of age in 1995 and 2002.[84-86] Fines for non-compliance ranged from $21 in New Brunswick to $100 in British Columbia, and $120 or a two hour safety seminar in Prince Edward Island.[85]

Most provinces promoted helmet use or the law with extensive media campaigns or programs. In the year prior to the law, British Columbia implemented a province-wide safe cycling program involving education, media, and helmet rebates.[85] Nova Scotia launched an extensive media campaign two months before its law was enacted while Ontario and Alberta implemented media public awareness campaigns and helmet promotion activities.[85]

Effectiveness of Helmet Legislation in Canadian Provinces

Three studies examined the effects of the provincial bicycle helmet laws in Canada by comparing effects in provinces with and without legislation.[84-86]

Helmet Use

Two studies by Dennis et al., (2010, 2013) reported helmet use in Canadian provinces and territories using data from national surveys.[84,85] Among provinces with data before and after helmet legislation (all except New Brunswick and PEI) helmet use increased. The increases reported were similar for provinces with all ages and child only laws: from 47% to 72% in BC; from 36% to 84% in Nova Scotia; from 44% to 66% among Ontario young people; and from 22% to 83% among Alberta young people.[85] Data from the 2005 Canadian Community Health Survey (CCHS) survey suggested that helmet use was greater (among youth and adults) in provinces with increasing comprehensiveness of helmet legislation.[84] Cyclists in Ontario with legislation for cyclists less than 18 years of age had 1.8 (95% CI 1.5 to 2.2) higher prevalence of helmet use compared to a province without legislation (i.e., Saskatchewan).[84] A province with all-age legislation (i.e., Nova Scotia) had 9 times (96% CI 6.9 to 12) greater prevalence of helmet use than Saskatchewan, suggesting that more comprehensive legislation may be beneficial.[84]

Injuries and Deaths

Two Canadian studies examined the effects of Canadian provincial helmet legislation on injuries and/or deaths.[85,86]

MacPherson et al. (2002) examined the effect of helmet laws adopted by four provinces in the period from 1994 to 1998 on cycling related hospitalizations of children.[86] They found reductions in head injuries and head injury rates (per 100,000 population) in provinces with and without legislation.

Reductions were significantly greater in legislation provinces (45% reduction) than provinces without legislation (27% reduction) ($p<0.001$).[86] Non-head injuries also declined in both legislation and non-legislation provinces, but no difference in these declines were observed ($p=.11$).[86]

Logistic regression analysis estimated the protective effect of legislation on head injuries of cyclists (odds ratio: 0.77; 95% CI:0.69–0.85).[86] The decrease in the ratio of head injuries to other (non-head) injuries was also greater among legislative provinces (38% decrease) compared with non-legislative provinces (8% decrease).[86] However, in a later critique of this study by Robinson (2003), it is suggested that these reductions in head injuries are likely not attributed to the legislation itself, but rather due to pre-existing trends.[106] Additionally, provinces with legislation had lower child cycling-related death rates (per one million children) than non-legislation provinces; however due to small numbers there was insufficient statistical power to test for trends.[86]

Dennis et al. (2013) examined the effect of child and all-age helmet laws adopted by six provinces in the period from 1994 to 2008.[85] Effects on cycling-related hospitalizations of children and adults were examined. Among the six provinces that had helmet legislation that applied to children, the rate of cycling-related head injuries among children declined between 1994 and 2008 in both helmet legislation and non-legislation provinces, with larger declines in provinces with legislation (54% decline: 15.9 to 7.3 / 100 000 person-years) than those without (33% decline: 19.1 to 12.9 per 100 000 person-years).[85] To examine the impact of helmet legislation, segmented regression analysis was conducted to determine if the rate of decline increased with legislation; no statistically significant effect of helmet legislation on hospital admissions for cycling-related head injuries among children was found.

Dennis et al. (2013) also examined the impact of legislation on adults. Four provinces had helmet legislation that applied to adults. The rate of cycling related head injuries in adults decreased between 1994 and 2003 in helmet legislation provinces (26% decrease: 3.0 to 2.2 / 100 000 person-years), and did not change in provinces without (2.7 vs. 2.8 / 100 000 person-years).[85] In the segmented regression analysis to determine if the rate of decline increased with adult helmet legislation, it was significantly associated with helmet legislation in one province (BC) and not in the other three.[85]

Cycling

Dennis et al., (2010) examined Canadian Community Health Survey (CCHS) data from 2000-07 to compare self-reported cycling in two provinces that introduced legislation in that period (Alberta – children and PEI – all ages) to three other Canadian provinces with no change in legislation in those years (Manitoba, Saskatchewan, BC) (83). In PEI, recreational bicycle use declined among youth in PEI between 2001 and 2003 (from 73.2% bicycle use in 2001 to 66.4% in 2003), but slightly increased among adults (from 16.6% in 2001 to 19% in 2003). In Alberta, prevalence cycling in youth and adults either remained unchanged or increased somewhat in this period.[84]

Summary

Results from Canadian studies indicated higher levels of helmet use where legislation was implemented. The data suggest that greater comprehensiveness of helmet legislation (i.e., no laws vs. child only laws vs. all-age laws) was associated with greater helmet use. Compared with provinces without legislation,

provinces with legislation had lower cycling-related head injury rates (population denominator) among adults and children. Data on bicycle use from a national survey did not show a significant change in cycling with legislation.

ALL-AGE LAWS

Nova Scotia, Canada (All-Age Law, 1997)

Context

Nova Scotia was the third province in Canada to implement an all-age helmet law on July 1, 1997.[87] Exemptions were made for those with applicable medical reasons, religious beliefs or head circumference greater than 64 cm.[87] Fines for non-compliance ranged from $25 for the first offence, $50 for the second and $100 for the third offence; enforcement began two months after the commencement of the legislation on September 1, 1997.

To inform the public about the law, an extensive media campaign was launched in July 1997 involving pamphlets, newspapers, radio and television. The campaign highlighted exemption terms, commencement of enforcement dates and the application of the law to all cyclists.[87] However, no media campaigns continued after 1997.

Effectiveness of Helmet Legislation in Nova Scotia, Canada

LeBlanc et al., (2002) examined the effect of the mandatory all-age bicycle helmet legislation on the use of bicycle helmets and injuries in Halifax using observational studies and hospital data records.[87]

Helmet Use

Observational studies of both children and adults in Halifax, Nova Scotia demonstrated that helmet use increased from 36% in 1995 to 84% in 1999, with a 35% increase among children, a 41% increase among adolescents and a 50% increase among adults.[87] The rates of helmet use rose rapidly immediately following the introduction of the legislation and increased rates were sustained in the following two years.[87]

Head Injuries

Data from the Emergency Department of a Halifax hospital were used to examine the proportion of cycling-related head injuries (to total cycle-related injuries) in the two pre-law years, the law implementation year, and the two post law years.[87] A decrease in the proportion of cycling-related head injuries was found (decreased from 3.6% in 1995-96 to 1.6% in 1998-99). There were 15 head injuries among 416 cycling injuries in 1995 and 1996, 3 head injuries among 222 cycling injuries in 1997, and 7 head injuries among 443 cycling injuries in 1998 and 1999 ($p = 0.06$).[87]

Summary

Nova Scotia's all-age helmet law was associated with increases in helmet use among both children and adults and a reduction in the proportion of cycling-related injuries that were head injuries.

British Columbia, Canada (All-Age Law, 1996)

In September 1996, British Columbia was one of the first Canadian provinces to enact mandatory bicycle helmet legislation requiring cyclists of all ages to wear a helmet when cycling on public roadways.[85,88] A $10 rebate program was introduced to help families purchase helmets for children, and fines of up to $100 were given to those not complying with the law.[85]

Although little effort was devoted to publicizing the law itself, a safe cycling program, funded by the government of Canada was implemented to provide elementary school children with safe-cycling practices, increase public awareness about bicycle safety and enhance cycling throughout the province.[88] The safe cycling program, called 'Bike Smarts" targeted children in grades three to seven and covered the rules of the road, the importance of helmets, bicycle handling skills and understanding traffic signals.[88]

Additionally, a public awareness campaign involving the media, schools, public forums and stakeholder groups such as the B.C. Injury Prevention Center and the B.C. Medical Association, was launched. Poster and newspaper advertisements promoting helmet use were also introduced a year before the introduction of the law.[88]

Effectiveness of Helmet Legislation in British Columbia, Canada

Foss et al., (2000) conducted an observational survey in 1995 (pre-law) and 1999 (three years post law) to examine helmet use and misuse among cyclists within various cities, towns, and municipalities in British Columbia.[88]

Helmet Use and Misuse

Between 1995 and 1999 following the implementation of the provincial all-age helmet law in British Columbia, observed helmet use increased among cyclists on both recreational and commuter routes as well as in metropolitan and non-metropolitan areas.[88] The greatest increase was observed among older adults (51 years and older) who were 8.85 times more likely to be wearing a helmet following the implementation of the legislation compared with pre-law rates.[88] Odds ratios for wearing a helmet in 1999 (post-law) compared with 1995 (pre-law) were 4.71 for children 1-5 years, 3.61 for children 6-15 years, 2.9 for adults 16-30 years, and 3.27 for adults 31-50 years.[88]

The percentage of individuals who wore their helmet correctly also increased.[88] Between 1995 and 1999 correct helmet use increased significantly among both males and females of all age groups. However, certain problems with helmet use (e.g., loose chinstrap, exposed forehead, non-approved helmet) remained among children; 33% of children 1 to 5 years old were observed with these problems.[88]

Summary

British Columbia's all-age helmet law was associated with increased helmet use, particularly among older adults and young children. The law also increased the percentage of riders who wore their helmet correctly. However, some helmet misuse remained among young children (1-5 years).

CHILD LAWS

Alberta, Canada (Child Law, 2003)

Context

Based on the 2002 Highway Traffic Bicycle Safety Helmet Amendment Act, as of May 1, 2003, Alberta mandated helmet use for all bicyclists less than 18 years of age.[91] The penalty for not wearing a mandated helmet was a $69 fine; 188 tickets were issued in the province's two largest cities (Calgary and Edmonton) in the first six years of the law.[85,90,91] In the spring of 2004, public helmet awareness campaigns and targeted school health activities were implemented to complement the introduction of the law.[89]

Effectiveness of Helmet Legislation in Alberta, Canada

Three studies examined the effect of the Alberta helmet law on helmet use and head injuries by comparing observational survey data and health records both prior to and following the law.[89-91]

Helmet Use

Two studies, by Hagel et al., (2006) and Karkhaneh et al., (2011), observed cyclists in Calgary, Edmonton and eight surrounding communities to examine the impact of the child helmet law on the prevalence of helmet use among children and adults.[89,90] Both studies concluded that that there was a significant association between the helmet legislation and helmet use among children and limited change among adults (who were not targeted).[89,90]

Between 2000 (pre-law) and 2006 (post-law) children, adolescents and adults significantly increased their helmet use by 29%, 63%, and 14% respectively.[90] By 2004 (two years post legislation) children under 18 years of age were 3.69 times more likely to wear a helmet compared to 2000.[89] Adults (18 years and older) were only 1.17 times more likely to wear a helmet in 2004 compared to 2000.[89] The greater change in helmet use among children than adults, suggests that these changes were related to the law.[90]

Injuries

Karkhaneh et al., (2013) examined the proportion of head injuries to total injuries resulting in emergency department visits and hospitalizations among cyclists and pedestrians before and after helmet legislation in Alberta was implemented.[91] Cycling head injuries declined after the legislation. After adjusting for sex and rural or urban location, they found declines in the proportion of head injuries among cyclist emergency department visits in children and increases in adults.[91] They found declines in the proportion of head injuries among cyclist hospitalizations in all age groups.[91] There were no significant changes in the proportion of head injuries among pedestrian emergency department or hospitalizations were found suggesting that the decreases in head injuries among cyclist were likely due to the legislation.

Summary

Observational studies in Alberta suggest that the provincial child helmet law increased helmet use. Cycling-related head injuries as a proportion of all injuries requiring emergency department visits declined among children and increased among adults, and as a proportion of hospitalization declined among all age groups. However, limited change was seen among adults who were not targeted.

Ontario, Canada (Child-Law, 1995)

Context

Under Bill 124, an amendment to the Highway Traffic Act, legislation was enacted in 1995 mandating all cyclists less than 18 years of age to wear a helmet while riding on a public highway in Ontario.[93,94,96] Parents of children who were not wearing a helmet were subjected to $60 fine and 16 and 17 year olds who did not comply were subjected to a fine directly. Minimal levels of enforcement were reported.[96]

In the early 1990's prior to the introduction of the law, a number of province-wide and community specific health promotion initiatives took place to promote helmet use.[93,94] In 1989, a number of individuals and organizations in the community came together to form the Metropolitan Toronto Children's Bike Helmet Coalition which aimed to: 1) reduce the number of cycling deaths among children in Toronto by 50%, 2) increase helmet use by 100% per year to 40% by 1995, and 3) explore the feasibility of mandatory bike helmet use by 1995.[95]

The coalition actively campaigned to promote the use of helmets for children between 1990 and 1994. In the same year, they also developed a school program called Be Bike Smart week, for elementary schools in the metropolitan Toronto area.[95] The program involved a resource book along with posters which were distributed to schools and libraries throughout the city. Additional media events and news conferences took place and information on bike helmets was presented by the media and the Government of Ontario during this time.[95]

Effectiveness of Helmet Legislation in Ontario, Canada

Five studies examined the effects of Ontario's helmet law and helmet promotion campaigns on helmet use, cycling, deaths, head and non-head injuries.[92-96]

Helmet Use

Three studies examining the effectiveness of the child helmet law on helmet use by conducting observational studies of children under 15 years of age in East York, Ontario between 1994 (pre-law) and 1997 (post-law).[93-95] All studies demonstrated increases in observed helmet use from 42%-45% pre-law to 67%-68% post-law.[93-95] The greatest increase in helmet use post-legislation was in low- and middle-income areas, as children in high-income areas were already more likely to wear helmets.[94] Income areas were defined by census data and ranked according to average family income.[94] The initial increase in helmet use by all children was sustained over six years in the high income areas but declined in the low- and middle-income areas during this time.[93]

Head Injuries and Deaths

Wesson et al., (2000) examined data from the Ontario Trauma Registry of Hospital Discharges and coroners reports on causes of death of children 0-14 years of age in metropolitan Toronto over the period from 1989 to 1996 and noted a drop in bike-related head injury admissions from 71 in 1989 (pre-law) to 24 admissions in 1995 immediately following the introduction of the law.[95] They also noted no change in the number of bike-related hospital deaths among children during this time frame.[95]

In contrast, Wesson et al., (2008) examining bicycle-related mortality rates among children and adult cyclists in Ontario and found a slight reduction in fatalities among children following the introduction of the law.[96] Using data from the Chief Coroner Office of Ontario between 1991 and 2002, time series analyses revealed that the child helmet law (introduced in 1995) was found to be temporally associated with the reduction in fatalities (55% decrease in mortality rate per 100 000 person years, 52% decrease in average number of deaths per year; -0.59 in deaths per month, $p<0.001$). No significant change in mortality rates were observed for adults.[96]

Cycling

In East York, Ontario, MacPherson et al., (2001, 2006) reported observations of child cyclists at 111 locations (schools, parks, residential streets and intersections) conducted prior to and following legislation. The first paper reported observations from 1993 to 1999, the second added observations from 2001.[92,93] Cyclists observed per hour varied substantially from year to year both prior to and after legislation. No pattern of decrease in cycling rates was found following the implementation of the law.[92,93] In an observational study by Macpherson et al., (2006) between 1995 and 2001, there was no association between the introduction of legislation and the average number of cyclists observed per hour.[93] However, in an earlier study by Macpherson et al., (2001) also observing child cyclists in East York , cycling levels increased following the implementation of the law with 4.33 cyclists per hour observed pre-legislation in 1995 while 6.84 cyclists per hour were observed in 1996 (post law).[92] This increase was particularly prominent among children cycling in parks.[92]

Summary

Ontario's child helmet law was associated with increases in helmet use, (particularly among low and middle income communities). Decreases in cycling-related head injuries and fatalities were observed among children. However, no decrease in child cycling was observed following the implementation of helmet legislation.

Appendix F: Law Context

Jurisdiction	Year Law Implemented	Type of Law	Fine for non-compliance	Other contextual factors (helmet promotion, rebate scheme etc.)
Victoria, Australia	July, 1990	All-age	Max $100 fine (rarely applied) $15 Bicycle Offence Penalty notices, or a Bicycle Offence report (no monetary penalty) sent to the parents of children not wearing a helmet	Rebate $10 helmet rebate for Australian-made helmet Education Bike-Ed for 9-13 year olds Helmet Promotion Decade of helmet promotion (education, mass media, organization support) prior to law Enforcement Low- to-moderate enforcement
Western Australia	January, 1992	All-age	$25 fine Infringement notices and fines were cancelled if the recipient provided proof of purchase of a helmet within 14 days	Rebate Helmet rebate scheme implemented between December 1987 to February 1994 in addition to a helmet subsidy scheme operating in schools between 1988 and 1990 Helmet Promotion Mass media campaign between December 1987 and 1988 (additional media campaigns continuing in 1991)
South Australia	July, 1991	All-age	$41 fine and a Traffic Infringement Notice. Parents responsible for paying fines of cyclists under the age of 16	Exemptions Postal workers and those wearing a turban for religious reasons exempt from legislation Rebate Rebate scheme introduced in 1989 providing a $10 rebate towards the purchase of an Australia Standards helmet for school children Helmet Promotion In 1984, a policy of public education and promotion created by the South Australian State Cabinet aimed at increasing helmet use and acceptance among cyclists was created Between 1985 and 1990 the promotion of voluntary bike helmet use continued with television and radio commercials, distribution of bike helmet information kits within schools and print media within bicycle shops and primary schools

Jurisdiction	Year Law Implemented	Type of Law	Fine for non-compliance	Other contextual factors (helmet promotion, rebate scheme etc.)
Northern Territory, Australia	January 1992 July, 1992	Adult (>17 years) All-Age	n/a	Rebate In 1991 a bike helmet subsidy scheme was introduced in Northern Territory primary schools and was later introduced in high schools in 1992. $10 subsidy was provided to students who purchased a Standard Australia approved helmet. In 1993 the scheme was later extended to toddlers with a $20 subsidy due the more expensive cost of toddler helmets. Helmet Promotion The Road Safety Council Field Officers created a large promotion program for students involving videos, demonstrations, pamphlets and newspaper articles highlighting the need to wear a helmet. Within schools, the Northern Territory Police Community Relation section ran a program in 1989 where students who obeyed safety rules (including wearing a helmet) were nominated by School-Based Constables to win monthly prizes through draws. There was promotion of voluntary helmet use prior to the law (1990-91) using public awareness campaigns involving radio, television and cinema advertisements including a Federal Office of Road Safety publicity campaign.
New South Wales, Australia	January, 1991 July, 1991	Adult (>16 years) Child (<16 years)	Fines issued to riders 15 years of age or older, and cautions or warnings given to parents of children up to 14 years of age	Exemptions Exemptions to the law were given for medical and religious purposes; however all exemptions were removed one year after the introduction of the law (January, 1992). Rebate In 1986 a helmet rebate scheme was introduced to increase voluntary helmet use and reduce the risk of head injuries to cyclists on the road prior to the introduction of the law[60]; however the scheme was unsuccessful as there were delays in processing and the $5 (10% discount) rebate was considered too low. In 1988 an additional rebate scheme of $12 (25% discount) was conducted with greater success. Helmet Promotion In December 1990, (month prior to adult law) Minister for Roads launched a media campaign to raise public awareness about the social and economic need for cyclists to wear a helmet. Campaign involved television, radio, cinema, and magazine advertisements. In June, 1991, (month prior to child helmet law), an advertising campaign along with school-based initiatives was launched. Campaign involved magazine, radio and newspaper ads along with brochures, posters, bookmarks, stickers, and pencils. Information resource kits with road safety teaching materials were provided to kindergarten to grade 12 teachers in all primary and secondary schools in the state.

Jurisdiction	Year Law Implemented	Type of Law	Fine for non-compliance	Other contextual factors (helmet promotion, rebate scheme etc.)
				Enforcement Police were engaged in activities to reinforce helmet wearing including the facilitation of bicycle education days, safety checks, and helmet adjustments.
New Zealand	January, 1994	All-age	$55-$150 fine	Helmet Promotion Campaign initiated by the Eastern Bay of Plenty Child Injury Prevention Trust between 1998-2002, involved the media, public meetings, and school principals to discourage children under nine years old from riding their bicycles to school to reduce collisions with motor vehicles .
California, USA	1994	Child (<18 years)	n/a	Enforcement No citations were issues in first year of law. Un-helmeted cyclists were given only warnings. In January, 1995, (one year post law) police began issuing written citations to those not complying.
Florida, USA	January, 1997	Child (<16 years)	$15-$27 fine	Helmet Promotion In the year prior to the law, a community wide educational campaign involving nurses working in emergency departments and pediatric referral trauma centers was implemented. The program involved visits to elementary schools by trauma service nurses who discussed safe biking and helmet use and risks of not wearing a helmet. They also provided information on the helmet law. This was complemented by fairs, school rodeos and print media campaigns. Within the emergency department, bicycle crash victims received helmet safety packets at discharge demonstrating how to wear helmets correctly and were shown a video about helmet safety. Educational packets were also given to parents containing tips on getting their children to wear a helmet. Children indicating that they would wear a helmet if they could afford one were provided with a helmet at no cost and discounted helmets were available for purchase. Community incentive programs took place involving police officers distributing toy and food coupons to any child they saw wearing a helmet while riding his or her bicycle, and giving away helmets to lower income children. Enforcement No fines were issued in the first year of the law; verbal warning and safety brochures were handed out to those not complying. After one year, fines were issued to violators of the law.
New York, USA	June, 1994 (Rockland	Child (<14 years)	$50 fine (fine waived if a helmet purchased after the	Rebate Cost subsidies were provided and some local bicycle shops agreed to honor a $10 discount coupon provided by

Jurisdiction	Year Law Implemented	Type of Law	Fine for non-compliance	Other contextual factors (helmet promotion, rebate scheme etc.)
	County, 1992)		first offence)	some promotional campaigns. Helmet Promotion Since 1990, the regional pediatric trauma center in Buffalo, New York conducted prevention programs involving community education and the distribution of helmets. In 1994, just prior to the New York state law, a bicycle helmet campaign was conducted and included the distribution of educational packets, prescriptions for bicycle helmets by local physicians, newspaper advertisements and a "Bicycle Helmet Day" at a local hospital. The educational packets contained information regarding the new law, fact sheets, and a $10 discount coupon towards the purchase of bicycle helmet.
Connecticut, USA	1993	Child (<12 years)	No fine	n/a
Maryland, USA (Howard County)	1990	Child (<16 years)	$25-$100 fine (fine waived if a helmet was purchased) Warning letters sent to parents of un-helmeted children after the first two offences; parents issued a citation after third offence	Helmet Promotion At the introduction of the law, an educational campaign was launched involving the distribution of safety handbooks to elementary and middle school students, a bicycle safety unit as part of health education within elementary school classes, and a bicycle safety curriculum in some middle schools. Local media coverage, bicycle rodeos and police officer visits to schools encouraging helmet use and promoting the law also took place.
Oregon, USA	July, 1994	Child (<16 years)	$25 fine	n/a
Georgia, USA	July, 1993	Child (<16 years)	$25 fine	Enforcement Appeared negligible.
Ohio, USA (Beachwood)	December, 1990	Child (<16 years)	First violations resulted in a verbal warning for children and a written notice to their parents Subsequent violations resulted in a $25 fine for parents of un-helmeted children	Rebate Discounted helmets were available for purchase through the Parent Teacher Association and were provided to students who could not afford to buy them. Helmet Promotion Beachwood, Ohio implemented an educational program promoting helmet use for children up to grade six. The program involved bicycle safety videos, slide shows, and letters for parents discussing the importance of helmets. Schools conducted poster and essay contests and food coupons were awarded to children 'caught' wearing a helmet. The program was also complimented by some brief television and media coverage.

Jurisdiction	Year Law Implemented	Type of Law	Fine for non-compliance	Other contextual factors (helmet promotion, rebate scheme etc.)
Nova Scotia, Canada	July, 1997	All-age	$25 fine for the first offence $50 fine for the second offence $100 fine for the third offence	Helmet Promotion To inform the public about the law, an extensive media campaign was launched in July 1997 involving pamphlets, newspapers, radio and television. The campaign highlighted exemption terms, commencement of enforcement dates and the application of the law to all cyclists. However, no media campaigns continued after 1997. Enforcement Enforcement began two months after commencement of the legislation on September 1, 1997.
British Columbia, Canada	September, 1996	All-age	Fines of up to $100	Rebate A $10 rebate program was introduced to help families purchase helmets for children. Although little effort was devoted to publicizing the law itself, a safe cycling program, funded by the government of Canada was implemented to provide elementary school children with safe-cycling practices, increase public awareness about bicycle safety and enhance cycling throughout the province. Education The safe cycling program, called 'Bike Smarts" targeted children in grades three to seven and covered the rules of the road, the importance of helmets, bicycle handling skills and understanding traffic signals. Helmet Promotion A public awareness campaign involving the media, schools, public forums and stakeholder groups such as the B.C. Injury Prevention Center and the B.C. Medical Association, was launched. Poster and newspaper advertisements promoting helmet use were also introduced a year before the introduction of the law.
Alberta, Canada	May, 2003	Child (<18 years)	$69 fine	Helmet Promotion In the spring of 2004, public helmet awareness campaigns and targeted school health activities were implemented to complement the introduction of the law. Enforcement 188 tickets issued in the province's two largest cities (Calgary and Edmonton) in the first six years of the law.
Ontario, Canada	October, 1995	Child (<18 years)	$60 fine to parents of children not wearing a helmet 16 and 17 year olds who did not comply were	Helmet Promotion In the early 1990's prior to the introduction of the law, a number of province-wide and community specific health promotion initiatives took place to promote helmet use. Education

Jurisdiction	Year Law Implemented	Type of Law	Fine for non-compliance	Other contextual factors (helmet promotion, rebate scheme etc.)
			subjected to a fine directly	The coalition actively campaigned to promote the use of helmets for children between 1990 and 1994. In the same year, they also developed a school program called Be Bike Smart week, for elementary schools in the metropolitan Toronto area. The program involved a resource book along with posters which were distributed to schools and libraries throughout the city. Additional media events and news conferences took place and information on bike helmets was presented by the media and the Government of Ontario during this time. <u>Enforcement</u> Minimal enforcement levels reported.

Appendix G: Testing the Mechanisms

Reference	Jurisdiction	Cycling	Helmet Use	Head Injury	Non-Head Injury	Head to Non-Head Injury Ratio	Description	Supports Mechanism
Cameron et al., (1992)[41]	Victoria, Australia	↓ (Overall) ***↑ (Adults) **↓ (Children/ adolescents)	*↑	*,***↓	**, ***↓	n/a	**Cycling:** Between 1990 and 1991 there was a 15% decrease in cycling among children and a 44% decrease among adolescents. There was an overall decrease in cycling exposure: 6% decrease from 1991-92 (22.3 billion seconds per week) among all ages. Between 1977-98 and 1991 there was a 58% increase among adult bicycle use. **Helmet Use:** Helmet use increased from 31% in 1989-90 (pre-law) to 75% in 1990-91 (post-law). **Head Injuries:** From 1989-90 to 1990-91 the number of severely injured cyclist with head injuries decreased 40% (children), 64% (adolescents) and 38% (adults). **Non-head Injuries:** In the first year of the law non-head injury rates were 23% less than pre-law rates in 1989. Reductions were greatest among teenagers (35% decrease) followed by children (27%) and adults (11%).	*Supports mechanism 1 (increased helmet use) **Supports mechanism 2 (decreased ridership) ***Supports mechanism 3 (increased ridership)
Cameron et al., (1994)[42]	Victoria, Australia	***↑ (Overall) ***↑ (Adults) **↓ (Children/	*↑	*,***↓	**,***↓	n/a	**Cycling:** In the first year of the law, there was a 36% decrease in bicycle use among children, 43% decrease among adolescents and 44% increase among adults. Bicycle use across all age groups increased 9% from 1987-88 and 1991.	*Supports mechanism 1 (increased helmet use) **Supports mechanism 2

Reference	Jurisdiction	Cycling	Helmet Use	Head Injury	Non-Head Injury	Head to Non-Head Injury Ratio	Description	Supports Mechanism
		adolescents)					**Helmet Use:** Victoria-wide helmet-wearing rates significantly increased from 31% in 1990 to 75% in 1991 following introduction of the helmet-wearing law ($p<0.001$). **Head Injuries:** Head injury cases (from insurance TAC claims) decreased by 36% between 1989-90 (pre-law) and 1990-91 (post law). **Non-head Injuries:** In the first year of the law non-head injury rates were 23% less than pre-law rates in 1989 (pre-law).	(decreased ridership) ***Supports mechanism 3 (increased ridership)
Carr et al., (1995)[43]	Victoria, Australia	n/a	n/a	↓	n/a	n/a	**Head Injuries:** In the first four years after the introduction of the law there was a 39.5% ($p=0.0001$) reduction in the number of head injury admissions (all crashes) across Victoria.	Missing data
Finch et al., (1993)[44]	Victoria, Australia	↓ (Overall) ↑ (Adults) ↓ (Children/ adolescents)	↑	n/a	n/a	n/a	**Cycling:** Between 1990 and 1991 observational surveys indicated that there was a 24% reduction in the number of child cyclists (5-11 years) and a 46% reduction among adolescents. Overall, bicycle use (estimate of total cycling time in Melbourne metropolitan area over one week) for children and adolescents decreased 33% between 1990 and 1991 (a 36% decrease compared with pre-law levels). **Helmet Use:** Helmet wearing rates in all age-groups increased from 31% in 1989-90 (pre-law) to 75% in 1990-91 (post law).	Missing data
Finch et al., (1993)[45]	Victoria, Australia	***↑ (Overall)	*↑	*,***↓	**,***↓	n/a	**Cycling:** Between 1990 and 1992 bicycle use decreased 45% among adolescents, 11% among children (adults not measured).	*Supports mechanism 1 (increased

Reference	Jurisdiction	Cycling	Helmet Use	Head Injury	Non-Head Injury	Head to Non-Head Injury Ratio	Description	Supports Mechanism
		**↓ (Children/ adolescents)					Between 1987-88 and 1992 overall bicycle use (all ages) increased 12%. **Helmet Use:** Helmet use **i**ncreased from 31% in 1990 (pre law) to 75% in 1991 (post law). **Head Injuries:** The number head injury cases (from TAC claims) decreased by 70% from pre-law to two years post law. **Non-head Injuries:** Non-head injuries decreased 28% between 1989-90 (pre-law) and 1991-92 (post-law).	helmet use) **Supports mechanism 2 (decreased ridership) ***Supports mechanism 3 (increased ridership)
McDermott et al., (1995)[46]	Victoria, Australia	↓(Adolescents) ↑ (Overall) ↑ (Adults)	↑	n/a	n/a	n/a	**Cycling**: Adolescent cycling exposure decreased 40% after legislation; however adult exposure and total exposure continued to increase. **Helmet Use:** Helmet use increased from 18% in the year prior to legislation to 8% in the first year post-legislation.	Missing data
Newstead et al., (1994)[47]	Victoria, Australia	n/a	*↑	*↓	n/a	n/a	**Helmet Use:** Helmet use one year post-law was significantly higher than predicted pre-law trends ($p<0.0001$). **Head Injuries:** Post-law head injury rates were significantly lower than pre-law rates in the 3 years following the law. However this benefit was lost in the 3rd year post-law.	*Supports mechanism 1 (increased helmet use)
Ozanne-Smith et al., (1990)[48]	Victoria, Australia	n/a	*↑	*↓	n/a	n/a	**Helmet Use:** Helmet use increased among children, adolescents and adults in the first year post law. **Head Injuries:** Between 1989 (pre-law) and 1990, there was a 66% reduction in cyclists with head injuries.	*Supports mechanism 1 (increased helmet use)

Reference	Jurisdiction	Cycling	Helmet Use	Head Injury	Non-Head Injury	Head to Non-Head Injury Ratio	Description	Supports Mechanism
Sullivan et al., (1990)[49]	Victoria, Australia	↓ (Adults) ↓ (Children/ adolescents)	↑	n/a	n/a	n/a	**Cycling:** From pre- to post-legislation there was a 60% decrease in number of cyclists among adult commuters. Decreases among child and adolescent cyclist were found as well. **Helmet Use:** Between March 1990 (pre-law) and July 1990 (post-law) helmet use increased by 20% among children, 60% among adolescents and 45.5% among adults.	Missing data
Vulcan et al., (1992)[50]	Victoria, Australia	n/a	*↑	*↓	↓	n/a	**Helmet Use:** In the year following legislation helmet use increased to levels of 70-90% among children, adolescents and adults. **Head Injuries:** Between 1989 (pre-law) to 1990 (post law) there was a 46% decrease in the number of cyclists with head injuries. **Non-head Injuries:** Between 1989 (pre-law) and 1990 (post-law) there was a 30% decrease in non-head injuries.	*Supports mechanism 1 (increased helmet use)
Cooke et al., (1993)[51]	Western Australia, Australia	n/a	n/a	n/a	n/a	n/a	n/a	Missing data
Heathcote et al., (1993)[52]	Western Australia, Australia	↓ (Children) ↑ (Commuters) ↓ (Recreational cyclists)	*↑	*↓	n/a	n/a	**Cycling:** Since 1998, there was a steady decline in the number school children cycling to school and an increase among commuters. The rate of decline did not change between 1991-92 (post-law); however the was an accelerated drop in the number of recreational cyclists immediately post-law. **Helmet Use:** Overall helmet use increased 39%	*Supports mechanism 1 (increased helmet use)

Reference	Jurisdiction	Cycling	Helmet Use	Head Injury	Non-Head Injury	Head to Non-Head Injury Ratio	Description	Supports Mechanism
							in 1991 (pre-legislation), to 62% in 1992 (post-law) and 81% in 1993 (one year post legislation). **Head Injuries:** In 1992 (post-law) head injuries were 44% less than in 1991 (pre-law).	
Heathcote et al., (1994)[53]	Western Australia, Australia	↓ and ↑ (Mixed evidence)	n/a	n/a	n/a	n/a	**Cycling:** Self-reported cycling behaviour in the previous 12 months increased from 48% in 1989 (pre-law) to 51% in 1993 (post-law); however cycling frequency (weekly, monthly, and yearly) were similar between the two years. Telephone surveys indicated that the law may have been responsible for a small decrease in the frequency of cycling as 3.6-5% of respondents' indicated that they had stopped cycling because of the law, and 25%-28% reported that they would cycle more if they were not legally required to wear a helmet.	Missing data
Hendrie et al., (1999)[36]	Western Australia, Australia	n/a	n/a	↓	n/a	n/a	**Head Injuries:** The proportion of cyclists with head injuries was 16% less than the proportion of pedestrians with head injuries in the years following the law, compared with pre-law rates where the proportion of cyclists with head injuries was 6% greater than that of pedestrians with head injuries.	Missing data
Marshall et al., (1994)[54]	South Australia, Australia	**↓ (Children)	*↑	*↓	**↓	n/a	**Cycling:** Observational study indicated a 38% reduction in the number of children cycling to school. **Helmet Use:** Between 1990 (pre-law) and 1993 (post-law) significantly increased from 15% to 90.0% in children and from 41.6% to 85.5% in adults.	*Supports mechanism 1 (increased helmet use) **Supports mechanism 2 (decreased

Reference	Jurisdiction	Cycling	Helmet Use	Head Injury	Non-Head Injury	Head to Non-Head Injury Ratio	Description	Supports Mechanism
							Head Injuries: There was a 12.1% decrease one year post-law and a 24.7% decrease two years post-law in the number of cycling related hospital admissions that were preventable by use of helmet (i.e., head injuries) when compared with rates one and two years pre-law respectively. **Non- Head Injuries:** Non-preventable injuries (i.e. non-head injuries) decreased by 26.6% in the year after the law was introduced.	ridership)
Van Zyl et al., (1993)[55]	Northern Territory, Australia	= (Children) ↓ (Adolescents)	↑	n/a	n/a	n/a	**Cycling:** Number of primary school cyclists remained unchanged both prior to and following the introduction of the helmet law (from 987 cyclists observed in April 1992 to 995 in August 1992). However the number of secondary school children observed riding their bicycle to school dropped from 931 students in April 1992 to 595 students by August 1992. **Helmet Use:** Between 1991 (pre-law) and 1992 (post-law) primary school children increased their helmet use from 56% to 82%, secondary school children increased from 27% to 71% and adult commuters increased their helmet use from 40% to 85%.	Missing data
Olivier et al., (2013)[56]	New South Wales, Australia	n/a	n/a	↑	↑	↓	**Head Injuries:** Number of head injuries hospitalizations increased from 590 in 1991 to 1004 in 2006. **Non-head Injuries:** Number of non-head injuries hospitalizations increased from 590 in 1991 to	Missing data

Reference	Jurisdiction	Cycling	Helmet Use	Head Injury	Non-Head Injury	Head to Non-Head Injury Ratio	Description	Supports Mechanism
							1004 in 2006. **Head to Non-head Injury Ratio:** In 2006 rates of head injuries were 46% less than that of arm injuries compared with 19% fewer head than arm injuries immediately post-law.	
Voukelatos et al., (2010)[57]	New South Wales, Australia	n/a	*↑	*↓	n/a	*↓	**Helmet Use:** Observational surveys indicated that helmet use increased for all ages from approximately 18% to 78% three years after the introduction of the law. **Head Injuries:** Total head injuries declined from 702 in 1988-89 to 581 in 1999-2000, with the most marked decline among children (0-14 years). **Head to Non-head Injury Ratio:** The ratio of head-to-arm injuries was already declining prior to the introduction of the law; however the steepest decline took place between 1988-89 and 1990-91 at the same time that the legislation was.	*Supports mechanism 1 (increased helmet use)
Walker et al., (1992)[58]	New South Wales, Australia	↓ (Children) ↓ (Adults)	↑	n/a	n/a	n/a	**Cycling:** Observational surveys indicated that between 1990 and 1991 the number of child cyclists on the road decreased by 36% and adult cyclists decreased by 14%. **Helmet Use:** Helmet use increased 44.5% and 8% among children and adults respectively between pre- and post-law.	Missing data
Walter et al., (2011)[59]	New South Wales,	n/a	*↑	n/a	n/a	*↓	**Helmet Use:** Helmet use increased from approximately 20% to more than 60% among	*Supports mechanism 1

Reference	Jurisdiction	Cycling	Helmet Use	Head Injury	Non-Head Injury	Head to Non-Head Injury Ratio	Description	Supports Mechanism
	Australia						children and over 70% for adults within two months of the legislation coming into effect. **Head to Non-head Injury Ratio:** Among cyclists, there was a significant decrease in head injuries compared to arm injuries at the time of introduction of the legislation, while no significant effect was found among pedestrians.	(increased helmet use)
Williams et al., (1995)[60]	New South Wales, Australia	n/a	*↑	*↓	↓	n/a	**Helmet Use:** Between 1990 (pre-law) and 1993 (post-law) children under the age of 16 increased their helmet use from 12% to 74% while adults use increased from 26% to 83%. **Head Injuries:** Between 1988-89 and 1992-93 head injuries decreased 34% among children and 39% among adults. **Non-head Injuries:** Between 1988-89 and 1992-93 non-head injuries decreased 17% among children and 18% among adults.	*Supports mechanism 1 (increased helmet use)
Clarke et al., (2012)[61]	New Zealand	↓	n/a	n/a	n/a	n/a	**Cycling:** Survey data from the New Zealand Ministry of Transport indicated that between 1989-90 (pre-law) and 1997-98 (post-law), the average number of hours cycled per week decreased by 40%. The number of hours cycled per person decreased from 56hrs per person pre-law (1989-90) to 50hrs per person post-law (2006-09) representing a 51% decrease.	Missing data
Hansen et al., (1995)[62]	New Zealand	n/a	n/a	n/a	n/a	n/a	n/a	Missing data

Reference	Jurisdiction	Cycling	Helmet Use	Head Injury	Non-Head Injury	Head to Non-Head Injury Ratio	Description	Supports Mechanism
Moyes et al., (2007)[63]	New Zealand	n/a	n/a	= No change	n/a	n/a	**Head Injuries**: There was no significant reduction (p=0.87) in the number of head injuries per annum between 1982-86 and 1998-2005.	Missing data
Povey et al.,(1999)[64]	New Zealand	n/a	*↑	*↓	n/a	n/a	**Helmet Use:** Between 1990 and 1998 use increased from 65% to 98% among children, 41% to 97% among adolescents and from 30% to 97% among adults. **Head Injuries:** Using hospital records, the estimated reduction in head injuries among primary school children, secondary school children and adults was 24%, 32% and 28% respectively.	*Supports mechanism 1 (increased helmet use)
Scuffham et al., (2000)[65]	New Zealand	n/a	*↑	*↓	n/a	n/a	**Helmet Use:** Observational surveys indicated that helmet use (all ages) increased from 65% in 1993 to 98% In 1994. **Head Injuries:** Between 1994 and 1996 there was an overall 18.7% aversion rate of head injuries(difference between predicted and observed head injuries) among all age groups with 6.2% of head injuries averted among primary school children, 16.2% averted among secondary school children and 24.5% among adults.	*Supports mechanism 1 (increased helmet use)
Taylor et al., (2002)[66]	New Zealand	n/a	*↑	*↓	n/a	n/a	**Helmet Use:** Between 1993 (pre-law) and 1994 (post-law) and helmet use increased from 86.8% to 98.6% among children, 55.9% to 97.1% among adolescents and 38.9% to 92.9% among	*Supports mechanism 1 (increased helmet use)

Reference	Jurisdiction	Cycling	Helmet Use	Head Injury	Non-Head Injury	Head to Non-Head Injury Ratio	Description	Supports Mechanism
							adults. **Head Injuries:** In the first three years post law, there was an annual average reduction in head injuries of 4, 10.3, and 23.8 among children, adolescents and adults respectively.	
Chatterji et al., (2013)[67]	Various states in the USA	n/a	n/a	↓	↓	n/a	**Head Injuries and Non-head Injuries:** Bicycle helmet laws were associated with a 13.7% reduction in the number bicycle-related head injuries, 9% reduction in non-head bicycle related injuries.	Missing data
Castle et al., (2012)[68]	California, USA	n/a	n/a	= No change	↓	n/a	**Head Injuries:** Head injuries decreased slightly from: 67% pre-law to 65% post-law; however was not significant (p=0.35). **Non-head Injuries:** Non- head injuries such as intra-abdominal injuries decreased from 13% pre-law to 6% post law.	Missing data
Ji et al., (2006)[69]	California, USA	n/a	↑	= No change	n/a	n/a	**Helmet Use:** Between 1992 and 1996 there was a significant increase ($p<0.001$) in helmet use (from 13.2% pre-law to 31.7% post law) among adult and child residents in San Diego County. **Head Injuries:** Non-significant decreases in head injuries from pre- to post- law were found among children and adults (not targeted by the law).	Does not support mechanism 1 (increased helmet use)
Lee et al., (2005)[70]	California, USA	n/a	n/a	= No change (Adults)	↑	n/a	**Head Injuries:** When comparing pre- and post-legislation rates, there was an 18.2% (significant) reduction in the proportion of traumatic brain	Missing data

Reference	Jurisdiction	Cycling	Helmet Use	Head Injury	Non-Head Injury	Head to Non-Head Injury Ratio	Description	Supports Mechanism
				↓(Children)			injuries among youth. No significant change in the proportions of head injuries (when comparing pre to post legislation) among adults was found. **Non-head Injuries:** There was a 9% increase in the proportion of non-head injuries among children when comparing pre and post legislation rates, and no significant change in the proportions of non-head injuries among adults.	
Borglund et al., (1999)[71]	Florida, USA	n/a	*↑	*↓	n/a	n/a	**Helmet Use:** Significant increases in helmet use of 25% and 27% were seen among children 7-9 years and 10-12 years respectively. **Head Injuries:** There were slight decreases in the number of severe and minor head injuries post law.	*Supports mechanism 1 (increased helmet use)
Delamater et al., (2003)[72]	Florida, USA	n/a	↑	n/a	n/a	n/a	**Helmet Use:** Helmet use increased following the implementation of the law in both communities with and without an incentive program; however the community with the incentive program more than doubled their helmet use (from 5.8% to 12%) while helmet use in the other community remained low (from 1.5% to 2.4%).	Missing data
Kanny et al., (2001)[73]	Florida, USA	n/a	↑	n/a	n/a	n/a	**Helmet Use:** In an observational study of child cyclists at elementary schools there was a significant difference in helmet use between counties with state helmet law vs. those without (p= .001). Children living in counties with a law were 2.3x more likely to wear a bicycle helmet than	Missing Data

Reference	Jurisdiction	Cycling	Helmet Use	Head Injury	Non-Head Injury	Head to Non-Head Injury Ratio	Description	Supports Mechanism
							children in counties exempt from the (95 % CI: 2.1- 2.8).	
Liller et al., (2003)[74]	Florida, USA	n/a	↑	n/a	n/a	n/a	**Helmet Use:** Helmet use following the law was significantly greater than what would have been predicted from pre-law trends. Additionally, the odds of a child wearing a helmet in 1997 (year of law) was eight times greater than in the preceding year (OR 8.3; 95% CI 6.1 to 11.4). Between 1993 and 1998 helmet use among children (5-13 years) increased from 3.6% to 67%.	Missing data
Abularrage et al., (1997)[75]	New York, USA	n/a	↑ and =	n/a	n/a	n/a	**Helmet Use:** In Queens County, NY there (law + campaign) there was a significant increase ($p<0.001$) in helmet use following implementation of the law; however a non-significant decrease in helmet use was observed in Brooklyn (law only).	Missing data
Puder et al., (1999)[76]	Rockland, New York, USA New York, USA Connecticut, USA	n/a	n/a	n/a	n/a	n/a	n/a	Missing data
Shafi et al., (1998)[77]	New York, USA	n/a	↑	n/a	n/a	n/a	**Helmet Use:** There was a significant increase ($p<0.0001$) in helmet use from 2% pre-law to 26% post-law among children involved in	Missing data

Reference	Jurisdiction	Cycling	Helmet Use	Head Injury	Non-Head Injury	Head to Non-Head Injury Ratio	Description	Supports Mechanism
							crashes.	
Cote et al., (1992)[78]	Howard County, Maryland, USA	n/a	↑	n/a	n/a	n/a	**Helmet Use:** Helmet use in Howard country increased from 4% in 1990 (pre-law) to 47% in 1991 (post law).	Missing data
Dannenberg et al., (1993)[79]	Howard County, Maryland, USA	n/a	↑	n/a	n/a	n/a	**Helmet Use:** In Howard County, helmet legislation increased from 11.4% (past year) to 37.5% (past month) ($p < .0001$).	Missing data
Hatziandreu et al., (1995)[80]	Howard County, Maryland, USA	n/a	↑	n/a	n/a	n/a	**Helmet Use:** In Howard County, helmet use among children increased from 4%-47% from pre- to post-law.	Missing data
Ni et al., (1997)[81]	Oregon, USA	n/a	↑	n/a	n/a	n/a	**Helmet Use:** Statewide observations at 13 metropolitan and rural areas demonstrated a 24.8% increase in children's helmet use from 24.5% in 1993 (pre-law) to 49.3% in 1994 (first three months post-law). Observations taken at 33 middle schools in Oregon found between 20.4% (pre-law) to 56.1% (post-law) and classroom surveys of these children indicated that the percentage of children 'always' using a helmet increased from 14.7% pre-law to 39.4% post-law.	Missing data
Schieber et al., (1996)[82]	Georgia, USA	n/a	↑	n/a	n/a	n/a	**Helmet Use:** Telephone surveys of parents, conducted one month prior to and four months following introduction of the law indicated a	Missing data

Reference	Jurisdiction	Cycling	Helmet Use	Head Injury	Non-Head Injury	Head to Non-Head Injury Ratio	Description	Supports Mechanism
							significant (p<0.05) 58% increase in reported child helmet use following the introduction of the law.	
Macknin et al., (1994)[83]	Beachwood, Ohio, USA Orange, Ohio, USA	n/a	↑	n/a	n/a	n/a	**Helmet Use:** Observational surveys indicated that helmet use among counties with a helmet law was significantly greater than those counties who did not have a law (ps<0.001).	Missing data
Dennis et al., (2010)[84]	British Columbia, Canada New Brunswick, Canada Nova Scotia, Canada Prince Edward Island, Canada Alberta, Canada Ontario, Canada	= No change	↑	n/a	n/a	n/a	**Cycling:** Regression analyses of the data from the 2000-07 Canadian Community Health Survey (CCHS) data indicated that helmet legislation was not associated with reduced cycling among Canadian provinces. **Helmet Use:** Data from the self-reported 2005 Canadian Community Health Survey (CCHS) survey indicated that residence in provinces with legislation less than 18 years of age (i.e., Ontario) had a 1.8 (95% CI 1.5 to 2.2) times greater prevalence of helmet use compared with provinces without legislation.	Missing data
Dennis et al., (2013)[85]	New Brunswick, Canada British Columbia, Canada Nova Scotia,	n/a	*↑	*↓ (Adults) *↓ (Children)	n/a	= No change (Children)	**Helmet Use:** Among provinces with helmet legislation (with the exception of New Brunswick and PEI in which no data was available) helmet use increased from 22% to 56% following the implementation of the helmet law. **Head Injuries:** Among the six provinces where	*Supports mechanism 1 (increased helmet use)

Reference	Jurisdiction	Cycling	Helmet Use	Head Injury	Non-Head Injury	Head to Non-Head Injury Ratio	Description	Supports Mechanism
	Canada Prince Edward Island, Canada Ontario, Canada Alberta, Canada						helmet legislation was implemented, the rate of cycling-related head injuries for youth between 1994 and 2008 decreased 54% (from 15.9 to 7.3 per 100 000 person years) in provinces with legislation compared with 33% (from 19.1 to 12.9 per 100 000 person years) in provinces and territories without. Among adults, there was a 26% reduction in the rate of admissions for head injuries in provinces who implemented helmet legislation, with no reduction in provinces without. **Head to non-head injury ratio**: Segmented regression analysis indicated no statistically significant effect of helmet legislation on hospital admissions for cycling-related head injuries (per total admissions for cycling) among children in the year after legislation was implemented.	
Macpherson et al., (2002)[86]	Ontario, Canada New Brunswick, Canada British Columbia, Canada Nova Scotia, Canada	n/a	n/a	↓	= No change	↓	**Head Injuries:** Reductions in head injury rates were significantly greater (45% reduction) than provinces without legislation (27% reduction) ($p<0.001$). **Non-head Injuries:** Helmet legislation had no benefit on non-head injury rates. No significant difference in the change over time in non-head injuries between legislative and non-legislative provinces was found ($p=.11$). **Head to non-head injury ratio:** The ratio of head injuries to other (non-head) injuries decreased from 0.67 in 1994 to 0.41 in 1998 in legislative	Missing data

Reference	Jurisdiction	Cycling	Helmet Use	Head Injury	Non-Head Injury	Head to Non-Head Injury Ratio	Description	Supports Mechanism
							provinces (38% decrease) and from 0.52 in 1994 to 0.48 in 1998 in non-legislative provinces (8% decrease).	
LeBlanc et al., (2002)[87]	Nova Scotia, Canada	n/a	*↑	n/a	n/a	*↓	**Helmet Use:** Helmet use increased from 36% in 1995 to 84% in 1999 with a 35% increase among children, 41% increase among adolescents and a 50% increase among adults. **Head to Non-head Injury Ratio:** Hospital data records in Halifax Nova Scotia suggested that the proportion cycling-related head injuries to total cycle-related injuries decreased substantially following legislation compared with pre-law rates (p = 0.06) (from 3.6% in 1995-96 to 1.6% in 1998-99).	*Supports mechanism 1 (increased helmet use)
Foss et al., (2000)[88]	British Columbia, Canada	n/a	↑	n/a	n/a	n/a	**Helmet Use:** Helmet use increased among children and adults. Odds ratios for wearing a helmet in 1999 (post-law) compared with 1995 (pre-law) were 4.71 for children 1-5 years, 3.61 for children 6-15 years, 2.9 for adults 16-30 years, and 3.27 for adults 31-50 year.	Missing data
Hagel et al., (2006)[89]	Alberta, Canada	n/a	↑	n/a	n/a	n/a	**Helmet Use:** By 2004 (two years post legislation) children under 18 years of age were 3.69 times more likely to wear a helmet compared to in 2000. Adults (18 years and older) were only 1.17 times more likely to wear a helmet in 2004 compared to 2000.	Missing data
Karkhaneh et	Alberta,	n/a	↑	n/a	n/a	n/a	**Helmet Use:** Between 2000 (pre-law) and 2006	Missing data

Reference	Jurisdiction	Cycling	Helmet Use	Head Injury	Non-Head Injury	Head to Non-Head Injury Ratio	Description	Supports Mechanism
al., (2011)[90]	Canada						(post-law) children, adolescents and adults significantly increased their helmet use by 29%, 63%, and 14% respectively.	
Karkhaneh et al., (2013)[91]	Alberta, Canada	n/a	n/a	↓(Childre n) = ↑(Adults)	n/a	n/a	**Head Injuries:** Declines in the proportion of emergency department cyclist head injuries (percentage of total injuries) among children were found (9% decrease); however increases were observed among adults.	Missing data
Macpherson et al., (2001)[92]	Ontario, Canada	↑ (Children)	n/a	n/a	n/a	n/a	**Cycling:** Observations of child cyclists in East York indicated that cycling increased following the implementation of the law with 4.33 cyclists per hour observed pre-legislation in 1995 while 6.84 cyclists per hour were observed in 1996 (post law).	Missing data
Macpherson et al., (2006)[93]	Ontario, Canada	= (No change children)	↑	n/a	n/a	n/a	**Cycling:** No association between the introduction of legislation and the average number of cyclists observed per hour was found.	Missing data
Parkin et al., (2003)[94]	Ontario, Canada	n/a	↑	n/a	n/a	n/a	**Helmet Use:** Child helmet use increased from 44% pre-law (1994) to 68% post-law (1996).	Missing data
Wesson et al., (2000)[95]	Ontario, Canada	n/a	*↑	*↓	n/a	n/a	**Helmet Use:** Observation studies indicated that helmet use increased from 42% in 1994 (pre-law) to 67% in 1996 (post-law). **Head Injuries:** The Ontario child helmet law was associated with a small decrease in bike related head injuries from 71 admissions in 1989 (pre-law) to 24 admissions in 1995 immediately following the introduction of the law.	*Supports mechanism 1 (increased helmet use)

Reference	Jurisdiction	Cycling	Helmet Use	Head Injury	Non-Head Injury	Head to Non-Head Injury Ratio	Description	Supports Mechanism
Wesson et al., (2008)[96]	Ontario, Canada	n/a	n/a	n/a	n/a	n/a	n/a	Missing data

Public Health Ontario
480 University Avenue, Suite 300,
Toronto, Ontario
M5G 1V2

647.260.7100
communications@oahpp.ca
www.publichealthontario.ca