https://doi.org/10.24095/hpcdp.40.1.02

Original quantitative research

Adoption of municipal bylaw legislating mandatory helmet use for cyclists under the age of 18: impact on cycling and helmet use

Aurélie Maurice, FRCPC (1); Michel Lavoie, MD (2); Denis Hamel, MSc (3); Mylène Riva, PhD (4)

This article has been peer reviewed.

Abstract

Introduction: Bicycle helmet use is recognized as an effective way to prevent head injuries in cyclists. A number of countries have introduced legislation to make helmets mandatory, but many object to this type of measure for fear that it could discourage people, particularly teenagers, from cycling. In 2011, the City of Sherbrooke adopted a bylaw requiring minors to wear a bicycle helmet. The objective of this study was to assess the impact of this bylaw on cycling and bicycle helmet use.

Methods: The impact of the bylaw was measured by comparing the evolution of bicycle helmet use among youth aged 12 to 17 years in the Sherbrooke area (n = 248) and in three control regions (n = 767), through the use of logistic regression analyses.

Results: Cycling rates remained stable in the Sherbrooke area (going from 49.9% to 53.8%) but decreased in the control regions (going from 59.1% to 46.3%). This difference in evolution shows that cycling rates increased in the Sherbrooke area after the adoption of the bylaw, compared to the control regions (odds ratio [OR] of the interaction term: 2.32; 95% confidence interval [CI]: 1.01–5.35). With respect to helmet use, a non–statistically significant upward trend was observed in the Sherbrooke area (going from 43.5% to 60.6%). This figure remained stable in the control regions (going from 41.5% to 41.9%). No significant difference was observed in the evolution of helmet use between the two groups (OR of the interaction term of 2.70; 95% CI: 0.67–10.83).

Conclusion: After the bylaw was adopted, bicycle use among youth aged 12 to 17 years in the Sherbrooke area remained stable and helmet used increased, though not significantly.

Keywords: *legislation, helmet use, cycling, youth*

Highlights

- A municipal bylaw requiring cyclists under the age of 18 years to wear a bicycle helmet has not been associated with a decrease in cycling among youth aged 12 to 17 years.
- These results are not necessarily generalizable to a province or country because it is not certain that the promotional activities that accompanied the bylaw can be carried out with the same intensity in those regions as at the municipal level.

Introduction

Cycling is encouraged for its health benefits.[1] However, cycling is also associated with a risk of serious injury, in particular to the head.[2-4] Bicycle helmets are known to be effective in preventing head injuries, especially among young people, both in the event of a fall and in the event of a collision with a motor vehicle.[5-7] In Quebec, in 2014, just 34.5% of cyclists over the age of 12 reported having always worn a bicycle helmet in the previous 12 months.[8]

A few countries, including Australia and New Zealand, some American states and several Canadian provinces have made bicycle helmets mandatory in order to increase helmet use. In Canada, bicycle helmets are mandatory in eight provinces, either for all cyclists (Nova Scotia, New Brunswick, Prince Edward Island, Newfoundland and Labrador and British Columbia) or for minors only (Ontario, Manitoba and Alberta).[9] In Quebec, the use of bicycle helmets is voluntary, except in the City of Sherbrooke, where a municipal bylaw has required cyclists under the age of 18 to wear helmets since March 2011. Three parliamentary committees in Quebec had heated debates on whether bicycle helmets should be mandatory throughout Quebec (in 1996, 2000 and 2010) but this measure was rejected each time. The main argument used by opponents was that this measure could have an overall negative health impact, by reducing cycling rates.[10,11]

Around 10 studies have been carried out in Australia,[11-14] New Zealand,[15] the United States[16] and Canada[9,17-19] to assess the impact of mandatory bicycle helmet measures on cycling rates. The results observed in the majority of these studies show that this type of measure is associated with

Author references:

1. Direction de santé publique, Centre intégré universitaire de santé et de services sociaux de la Capitale-Nationale, Québec City, Quebec, Canada
2. Direction du développement des individus et des communautés, Institut national de santé publique du Québec, Québec City, Quebec, Canada
3. Bureau d'évaluation et d'études en santé des populations, Institut national de santé publique du Québec, Québec City, Quebec, Canada
4. Institute for Health and Social Policy and Department of Geography, McGill University, Montréal, Quebec, Canada

Correspondence: Aurélie Maurice, Direction de santé publique, Centre intégré universitaire de santé et de services sociaux de la Capitale-Nationale, 2400 avenue D'Estimauville, Québec City, QC G1E 7G9; Tel: 418-666-7000; Email: aurelie.maurice.ciussscn@ssss.gouv.qc.ca

reduced cycling rates, particularly among youth.[11-14,16] However, most of these studies have significant methodological limitations (e.g. lack of a control group; a single measure before or after the law; or failure to control the effect of confounding variables, such as weather or changes in cycling infrastructure), which make it more difficult to interpret the observed results. Although it is not certain that legislation requiring cyclists to wear helmets would reduce cycling rates, this risk remains a public health concern, particularly for youth. In addition, a lack of helmet use is worrisome, considering that helmets can prevent between 50% and 69% of head injuries among cyclists.[6]

The objective of this study was to assess how a City of Sherbrooke bylaw legislating mandatory helmet use for cyclists under the age of 18 has affected cycling rates and bicycle helmet use. This article is based on the results of a Master of Public Health degree thesis on this topic.[20]

Methods

Intervention description

The City of Sherbrooke, with a population of around 140 000,[21] adopted a bylaw requiring cyclists under the age of 18 to wear a bicycle helmet. This bylaw has been in effect since March 1, 2011. Violations come with a $30 fine, but a non-punitive approach has been the preferred choice. Instead of issuing the fine, patrol officers inform cyclists who are not wearing a helmet that it is important to wear a helmet. Officers may even provide a helmet to cyclists who do not have one. Other types of activities were carried out in the community, particularly in schools, businesses and the health sector, before and after this bylaw came into force, to promote cycling and helmet use among youth (e.g. helmet donations, low-cost bicycles, expansion of cycling network, media campaign).

Study specifications and parameters

This study compared the evolution of cycling and helmet use (after the implementation of the bylaw vs. before) among young people subject to this bylaw, compared to a control group of young people who were not subject to this bylaw.

Data source

Data on cycling and helmet use are from the Canadian Community Health Survey (CCHS), a cross-sectional survey administered by Statistics Canada and conducted on an ongoing basis. Data for this survey are collected using surveys administered in person or by telephone to a representative sample of the Canadian population aged 12 years and over. This sample varies from one cycle to the next.[22] The use of random sample selection and survey weights allows the sample results to be inferred from regional populations. The data on cycling come from four survey cycles: two cycles before (2007–08 and 2009–10) and two cycles after (2011–12 and 2013–14) the adoption of the bylaws. For helmet use, only one survey cycle was used before (2009–10) and one after (2013–14) the adoption of these bylaws, since the data were not available prior to 2009–10 and were collected only every other cycle.

Exposed group

The exposed group consisted of the 248 youth aged 12 to 17 years who participated in one of the four CCHS cycles conducted in the Sherbrooke Census Metropolitan Area (CMA). The age limit of 12 years was determined based on the minimum age of the CCHS participants, and the age limit of 17 years was determined based on the maximum age of the persons covered by the bylaw. The Sherbrooke CMA encompasses a number of census subdivisions, and 77% of youth aged 12 to 17 residing in the CMA live in the City of Sherbrooke.

Unexposed group

The unexposed group consisted of the 767 youth aged 12 to 17 years who participated in one of the four CCHS cycles conducted in the Gatineau (n = 335), Trois-Rivières (n = 192) and Saguenay (n = 240) CMAs between 2009 and 2014. These three CMAs were selected because of their similarities to the Sherbrooke CMA in terms of the main factors influencing cycling, namely, the size of the population,[23] the topography of the land,[24] the climate and the size of the cycling network.[25]

Cycling

Cycling rates were measured using CCHS data on recreational and utility cycling. In this survey, recreational cycling was measured by the question, "In the past three months…have you done any of the following activities [including cycling]?" Utility cycling was measured by the question, "In the past three months…[did you bicycle] to and from work or school?" Anyone who answered yes to at least one of these two questions was considered to be a cyclist, and anyone who answered no to these questions was considered a non-cyclist. We chose to use a dichotomous variable to maintain statistical power and to reduce the risk of recall bias, which is more likely with a frequency variable.

Helmet use

Helmet use was measured based on data collected from CCHS participants who reported riding a recreational or utility bicycle at least once in the previous three months. In this survey, helmet use was measured by the question, "When riding a bicycle, how often do you wear a helmet?" Respondents who reported wearing a helmet most of the time or always were considered helmet users, and those who reported wearing a helmet rarely or never were considered non-users.

Adjustment variables

The following variables were considered as adjustment variables in the statistical models: age, gender, season, level of material deprivation (proportion of people with less than high school graduation, employment/population ratio and average personal income) and level of social deprivation (proportion of people who are separated, divorced or widowed; proportion of people living alone; and proportion of single-parent families).[26] The "season" variable was created to ensure that the regions were balanced with respect to the seasons. The season was determined based on the month of the study, considering the fact that the respondent was providing answers corresponding to the three months prior to the study. Respondents who answered the survey from August to October were assigned the summer variable, fall was assigned to November to January, winter was assigned to February to April and spring was assigned to May to July.

Statistical analyses

The 1015 participants in the study were divided based on the survey cycles conducted before and after the bylaw came into force and compared for each of the adjustment variables using a Chi-square test at a 5% significance level. Analyses were then conducted to calculate the prevalence of cycling and helmet use in the

Sherbrooke CMA and the control CMAs, before and after the adoption of the bylaw, with 95% confidence intervals (CI). The prevalence of cycling was calculated by adjusting for the season. Logistic regression analyses were conducted to compare the evolution of cycling and helmet use before and after the adoption of the regulation in the Sherbrooke CMA and the control CMAs by transforming the results obtained into an odds ratio (OR). The impact of the bylaw on cycling and helmet use in the Sherbrooke CMA was measured by adding to the regression model a term of interaction between the Time variable (before vs. after the bylaw) and the CMA variable (Sherbrooke CMA vs. control CMAs). The presence of interaction signifies that the change observed before versus after the implementation of the bylaw differs in the two groups of CMAs, which shows the impact of the bylaw. The regression analyses were all done by controlling for the effect of potentially confounding variables present in the databases.

Table 1 shows the OR calculation of the dependent variable before and after the adoption of the bylaw in the Sherbrooke CMA and in the other CMAs, the gap observed between these two periods in the Sherbrooke CMA and the other CMAs ("difference"), and the gap observed between these two groups ("difference in the difference"). The OR is calculated by taking the exponential of β calculated by the regression model (e.g. $e^{\beta 1}$ = OR of the dependent variable in the Sherbrooke CMA before the adoption of the bylaw). The reference group corresponds to the other CMAs before the bylaw, which is why the OR equals 1 ($e^0 = 1$) for this group in the regression model. The other ORs refer to this value. The value of an OR may be equal to 1 (probability unchanged), less than 1 (decreased probability) or greater than 1 (increased probability). We calculated a 95% CI for the ORs and set the statistical significance threshold at .05 (*p*-value of β coefficients). The OR is therefore statistically significant when the CI does not include the value 1 for a significance threshold at .05.

In addition, in order to ensure that the results of the analyses are representative of the population of each CMA and not of the sample used in this study, a weighting factor adapted to the scale of the CMAs was included in the statistical analyses.[22] Lastly, in accordance with Statistics Canada recommendations,[22] bootstrapping was used to estimate the variance of the model parameters. The statistical analyses were performed using SAS 9.4 (SAS Institute Inc., Cary, NC, USA) and SPSS 22.0 (IBM, Chicago, IL, USA).

Results

The results presented in Table 2 show that the sample is equally distributed before and after the coming into force of the bylaw for gender, season, material deprivation and social deprivation. However, the sample distribution differs for the CMAs, likely due to the decrease in the number of participants in the Trois-Rivières CMA after the coming into force of the regulation compared to before. A difference was observed for the age distribution of the sample, but this result is not statistically significant.

Cycling

Before the bylaw came into force, the prevalence of cycling among youth aged 12 to 17 years was 49.9% (95% CI: 40.7–59.1) in the Sherbrooke CMA and 59.1% (95% CI: 53.9–64.3) in the control CMAs (Table 3). After the adoption of the bylaw, the prevalence of cycling increased to 53.8% in the Sherbrooke CMA, but this increase was not statistically significant (OR: 1.25; 95% CI: 0.58–2.59). Conversely, there was a marked decrease to 46.3% in the prevalence of cycling in the control CMAs (OR: 0.54; 95% CI: 0.36–0.80). The value of the OR associated with the CMA*Time interaction term shows that the decline in cycling observed in the control CMAs was not observed in the Sherbrooke CMA, despite the adoption of the bylaw (OR interaction: 2.32; 95% CI: 1.01–5.35).

Helmet use

Before the bylaw came into force, the prevalence of bicycle helmet use among youth aged 12 to 17 years was 43.5% (95% CI: 24.6–64.0) in the Sherbrooke CMA and 41.5 % (95% CI: 32.8–50.2) in the control CMAs (Table 3). After the bylaw came into force, helmet use increased to 60.6% in the Sherbrooke CMA, but the impact measured by the OR was not statistically significant (OR: 2.61; 95% CI: 0.75–9.04). In the control CMAs, helmet use remained stable at 41.9% (OR: 0.97; 95% CI: 0.52–1.80). Analysis of the interaction results suggests an increase in helmet use in the Sherbrooke CMA compared to the control CMAs after the adoption of the bylaw versus before (OR interaction: 2.70; 95% CI: 0.67–10.83). The CI is high because of a lack of statistical power.

Discussion

Cycling

Cycling among youth aged 12 to 17 years remained stable in the Sherbrooke CMA in the period before and after the coming into force of the City of Sherbrooke bylaw, while cycling decreased in the control CMAs. This decrease is consistent with the results observed in Quebec as a whole as well as in the Estrie region, which includes the Sherbrooke CMA, for both youth aged 12 to 17 and adults aged 18 to 24.[20] As a result of this different evolution, cycling rates among youth aged 12 to 17 were higher in the Sherbrooke CMA than in the control CMAs after the coming into force of the bylaw compared to before.

This different evolution could be the result of two factors likely to have had a positive

TABLE 1
Probability of occurrence of the dependent variable (OR) before and after the coming into force of the mandatory helmet-use bylaw, based on place of residence

	Before	After	Difference	Difference in the difference[a]
Sherbrooke CMA	$e^{\beta 1}$	$e^{\beta 1 + \beta 2 + \beta 3}$	$e^{\beta 2 + \beta 3}$	$e^{\beta 3}$
Other CMAs	1	$e^{\beta 2}$	$e^{\beta 2}$	

Abbreviations: CMA, census metropolitan area; OR, odds ratio.

Note: e^{β} = OR.

[a] The difference in the difference corresponds to the net impact of the bylaw or to the term CMA*Time of the regression model.

TABLE 2
Sample distribution (n = 1015) before and after the bylaw came into force for the adjustment variables studied

Variables	Before		After		
	Percentage (%)	Respondents (n)	Percentage (%)	Respondents (n)	*p*-value[a]
Gender					.660
Boy	50.9	278	49.6	232	
Girl	49.1	268	50.5	237	
Age (years)					**.052**
12–14	50.0	272	43.9	205	
15–17	50.0	274	56.1	264	
Seasons					.606
Summer	27.8	152	27.2	127	
Fall	27.7	151	24.5	115	
Winter	21.9	119	24.4	114	
Spring	22.6	124	23.9	113	
Material deprivation					.379
Very privileged	27.5	150	31.5	147	
Privileged	25.1	137	21.0	98	
Neither privileged nor underprivileged	20.4	111	20.1	94	
Underprivileged[b]	27.1	148	27.4	130	
Social deprivation					.175
Very privileged	20.1	109	20.5	96	
Privileged	23.3	132	18.7	88	
Neither privileged nor underprivileged	24.8	135	23.2	109	
Underprivileged[b]	31.9	170	37.6	176	
CMA					**< .001**
Sherbrooke	23.6	129	25.4	119	
Trois-Rivières	23.3	127	13.9	65	
Gatineau	33.0	180	33.1	155	
Saguenay	20.2	110	27.7	130	

Abbreviation: CMA, census metropolitan area.

Note: Bolded values are statistically significant.

[a] The *p*-value is that of the likelihood ratio test of the Chi-square test.

[b] The "Underprivileged" category is a grouping of quintiles 4 and 5 of disadvantage.

TABLE 3
Prevalence (%) and odds ratios (OR) for cycling and helmet use among youth aged 12 to 17 years before and after the bylaw came into force, by place of residence

	Prevalence (%) Before the bylaw (95% CI)	Prevalence (%) After the bylaw (95% CI)	Adjusted OR (95% CI)[b]	OR interaction (95% CI)[c]
Cycling[a]				**2.32 (1.01–5.35)**
Sherbrooke CMA	49.9 (40.7–59.1)	53.8 (43.4–64.2)	1.25 (0.58–2.59)	
Other CMAs	59.1 (53.9–64.3)	46.3 (40.1–52.6)	**0.54 (0.36–0.80)**	
Helmet use				2.70 (0.67–10.83)
Sherbrooke CMA	43.5 (24.6–64.0)	60.6 (37.5–80.7)	2.61 (0.75–9.04)	
Other CMAs	41.5 (32.8–50.2)	41.9 (30.2–53.6)	0.97 (0.52–1.80)	

Abbreviations: CI, confidence interval; CMA, census metropolitan area; OR, odds ratio.

Note: Bolded values are statistically significant.

[a] The prevalence of cycling is adjusted for the season.

[b] This value corresponds to the difference in the measurement of the dependent variable (cycling or helmet use) after compared to before the coming into force of the bylaw. These ORs are adjusted for potentially confounding variables: age, sex, season and level of material and social deprivation.

[c] The interaction term (CMA*Time) is the net impact of bylaw. The latter corresponds to the difference in the difference in the measurement of the dependent variable (cycling or helmet use) after the bylaw came into force compared to before, in the Sherbrooke CMA versus the other CMAs.

influence on cycling in Sherbrooke. Information from key informants showed that, on the one hand, there was more, and more varied, promotion of cycling and helmet use before and after the adoption of the bylaw in the Sherbrooke CMA than in the control CMAs. On the other hand, the non-punitive approach used by City of Sherbrooke police officers to enforce the bylaw (e.g. giving a bicycle helmet to cyclists who did not have one instead of issuing a fine) had a positive impact. Analysis of the weather data shows that, during the period studied, the number of days with low temperatures (below 15°C) or high temperatures (above 28°C) and the number of days of rain (1 mm or more) were comparable in the three control CMAs and in the Sherbrooke CMA.[27]

The results of studies conducted in Australia,[11-14] New Zealand[15] and the United States[16] show that cycling rates decreased after bicycle helmets were made mandatory, in particular among young people. However, the results of the studies conducted in Australia and New Zealand should be interpreted with caution, given the presence of significant methodological limitations (lack of a control group; a single measure before or after the law; or failure to control the effect of confounding variables, such as weather or changes in cycling infrastructure). On the other hand, the results of the study conducted in the United States are of concern since it was much more methodologically rigorous than those conducted in Australia and New Zealand. The results observed in the three studies conducted in Canada are contradictory. The Karkaneh study[17,18] observed a reduction in cycling rates among youth in Alberta after the law, while those conducted by Macpherson et al.[19] in Ontario and by Dennis et al.[9] in Alberta and Prince Edward Island show no change in cycling. All of these studies were conducted at the territorial level of country or province, which may have masked the smaller-scale changes, for example, at the regional level. Moreover, none of the studies allow the results observed to be interpreted in the context of the implementation and enforcement of the law, due to the lack of information on the nature and type of activities carried out to strengthen bylaw enforcement or to promote cycling and helmet use.

Helmet use

The results of our study suggest that bicycle helmet use increased among youth aged 12 to 17 years in the Sherbrooke CMA after the bylaw came into effect, while it remained stable in the control CMAs. Although helmet use increased from 43.5% to 60.6% among young cyclists aged 12 to 17 in Sherbrooke after the bylaw came into effect, this increase is not significant, likely as a result of the small sample sizes available for the two cycles of the CCHS in question (50 and 39 respondents, respectively). The sample was small because just one measure was available both before and after the coming into force of the bylaw, and also because this measure applied only to those who reported having cycled in the previous three months. In our study, an OR of 2.6 can be detected with a statistical power of just 30%. For an OR of 2.6 to have been detected with a statistical power of 80%, the regression model would have to have been adjusted based on a sample of at least 280 respondents in total over the two cycles (before and after), which was not possible. That said, assuming that this increase in helmet use was real, this type of before-and-after change would be of clinical importance, given that helmet use is an effective way to prevent head injuries.[5-7] Furthermore, the measurement of bicycle helmet use may be overestimated in the Sherbrooke CMA, as it is possible that young Sherbrooke residents were more reluctant to report not always wearing a bike helmet, knowing that the use of this equipment was then mandatory in their municipality. However, the fact that the CCHS ensures the anonymity of respondents likely reduced the extent of this bias. Finally, we cannot exclude the possibility that helmet use increased independently of the regulations, as a result of the numerous promotional activities that were carried out.

The results of this study are consistent with those observed in the study by Cyr and Ouedrago,[28] which showed a significant increase in bike helmet use among young Sherbrooke residents after the bylaw came into force. According to this observational study, the extensive bicycle-safety awareness campaign (including the coming into force of the bylaw) helped increase helmet use. The results of this study showed that helmet use increased from 38% in 2006 to 92.9% in 2011 in cyclists aged 10 to 15, and from 12% to 57% for cyclists aged 16 to 18. A number of studies observed an increase in helmet use after it was made mandatory.[29-35] However, some authors attribute the proportional increase in helmet use to the decrease in the number of cyclists who do not use helmets (which leads to an artificial increase of the proportion of helmet users) instead of an increase in the number of helmet users (which involves a real increase in the proportion of helmet use).[36,37] In this study, the increase in the use of bicycle helmets cannot be attributed to a decrease in the number of cyclists not wearing a helmet, since cycling remained stable after the bylaw came into force in the Sherbrooke CMA.

Strengths and limitations

This study has several methodological characteristics that ensure the internal validity of the observed results: a before-and-after research design with an exposed group and a control group; the availability of two measures of cycling before and after the coming into force of the bylaw; documentation on the type of activities carried out to implement the bylaw; knowledge of the type of activities carried out in Sherbrooke and the three control CMAs to promote cycling and helmet use during this period; and knowledge of weather data in the regions concerned.

However, the research design of this study has some limitations. Our study does not make it possible to separate the specific impact that the bylaw had on cycling and helmet use from the impact of the awareness campaigns. To do so, it would have been necessary to have a control group from a region that had the same awareness campaigns as in Sherbrooke, which did not exist in Quebec. Also, in order to obtain sufficient statistical power, all youth in the Sherbrooke CMA were included in the exposed group, even though the bylaw applied only to the territory of the City of Sherbrooke. We obtained high ORs, but these figures remained insignificant. A larger sample size would have allowed us to verify the trends observed, especially for bicycle helmet use. Furthermore, we did not use the more sensitive variable of cycling frequency, but by using a dichotomous variable we observed an increase in cycling rates in the Sherbrooke CMA compared to the control CMAs (Table 3; interaction OR: 2.32; 95% CI: 1.01–5.35). Lastly, the results of this study are valid in an area in which a non-punitive approach was taken to enforce the bylaw.

Conclusion

The results of this study suggest that a municipal bylaw legislating mandatory

helmet use for cyclists under the age of 18 can be implemented without being associated with a decrease in cycling rates among youth aged 12 to 17, if the bylaw is implemented in a non-punitive manner and if cycling and helmet use are promoted. However, the study specifications and parameters do not exclude the possibility that such a bylaw could have reduced the impact of cycling promotional activities. Furthermore, these results cannot necessarily be applied at a provincial or national level because there is no guarantee that the awareness campaigns for the bylaw can be carried out to the same degree as at the municipal level.

Acknowledgements

We would like to thank the members of comité Communauté sécuritaire de l'organisme Sherbrooke Ville en santé, who graciously agreed to collaborate on this project by providing enlightening information on the specific context of cycling in Sherbrooke. We would also like to thank Dr. Pierre Maurice and Mathieu Gagné of the Institut national de santé publique du Québec for their help in revising the manuscript.

Conflict of interest

The authors have no conflicts of interest to declare.

Authors' contributions and statement

All authors contributed to the preparation of the study specifications and parameters. DH provided expertise in statistical analysis. AM wrote the first version of the manuscript. All authors assisted in manuscript revision and have approved the final version.

The content and views expressed in this article are those of the authors and do not necessarily reflect those of the Government of Canada.

Ethics approval

This research project obtained the exemption of the Comités d'éthique de la recherche avec des êtres humains de l'Université Laval (CÉRUL) since it involved secondary analyses of individual CCHS data. Access to this data was granted following the evaluation of an analytical protocol submitted to the Social Sciences and Humanities Research Council of Canada (SSHRC). The analyses were conducted at the Centre interuniversitaire québécois de statistiques sociales (CIQSS) at Université Laval, which had secure access.

References

1. Vélo Québec. Cycling in Québec in 2015. Montréal (QC): Vélo Québec; 2015. 24 p.

2. Société de l'assurance automobile du Québec (SAAQ). Le traumatisme craniocérébral. Québec (QC): SAAQ; 2003. 65 p. Available from: http://publications.msss.gouv.qc.ca/msss/fichiers/2016/Traumatisme_FR.pdf

3. Meehan WP III, Lee LK, Fischer CM, Mannix RC. Bicycle helmet laws are associated with a lower fatality rate from bicycle-motor vehicle collisions. J Pediatr. 2013;163(3):726-9.

4. Sosin D, Sacks J, Webb K. Pediatric head injuries and deaths from bicycling in the United States. Pediatrics. 1996;98(5):868-70.

5. Attewell R, Glase K, McFadden M. Bicycle helmet efficacy: a meta-analysis. Accid Anal Prev. 2001; 33(3):345-52.

6. Thompson D, Rivara F, Thompson R. Helmets for preventing head and facial injuries in bicyclists. Cochrane Database Syst Rev. 2000;(2):CD001855. doi: 10.1002/14651858.CD001855.

7. Elvik R. 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. 2011;43(3):1245-51.

8. Statistics Canada. Cycling in Canada [Internet]. Table 2: Percentage who always wore helmet when cycling, by sex and selected characteristics, household population aged 12 or older who reported cycling in past 12 months, Canada, 2013/2014. Ottawa (ON): Statistics Canada; 2017. Available from: https://www150.statcan.gc.ca/n1/pub/82-003-x/2017004/article/14788/tbl/tbl02-eng.htm

9. 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.

10. Robinson DL. Safety in numbers in Australia: more walkers and bicyclists, safer walking and bicycling. Health Promot J Austr. 2005;16(1):47-51.

11. 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 Prev. 1994;26(3): 325-37.

12. Finch C, Heiman L, Neiger D. Bicycle use and helmet wearing rates in Melbourne, 1987 to 1992: the influence of the helmet wearing law. Clayton (AU): Monash University Accident Research Centre; 1993. 86 p. Available from: http://www.monash.edu.au/miri/research/reports/muarc045.pdf

13. Walker MB. Law compliance and helmet use among cyclists in New South Wales. Sydney (AU): Road Safety Bureau Consultants CR 6/90, for the Roads and Traffic Authority, NSW; 1990. 59 p.

14. Smith N, Milthorpe F. An observational survey of law compliance and helmet wearing by bicyclists in New South Wales. Sydney (AU): Institute of Transport Studies, University of Sydney; 1993. 51 p.

15. Clarke CF. Evaluation of New Zealand's bicycle helmet law. N Z Med J. 2012; 125(1349):60-69.

16. Carpenter CS, Stehr M. Intended and unintended consequences of youth bicycle helmet laws. J Law Econ. 2011;54(2):305-24. Available from: https://www.jstor.org/stable/10.1086/652902?seq=1-%20page_scan_tab_contents#page_scan_tab_contents

17. Karkhaneh M, Rowe B, Saunders L, et al. The association between bicycle helmet legislation and the rate of cycling in Alberta, Canada [abstract]. Can J Emerg Med. 2010;12(3):266.

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

19. Macpherson A, Parkin P, To T. Mandatory helmet legislation and children's exposure to cycling. Inj Prev. 2001;7(3):228-230.

20. Maurice A. Influence du règlement adopté à Sherbrooke pour obliger les moins de 18 ans à porter un casque à vélo sur la pratique du vélo et le port du casque [master's thesis]. Montréal (QC): Université Laval; 2017. 91 p. Available from: https://corpus.ulaval.ca/jspui/bitstream/20.500.11794/28258/1/33855.pdf

21. Statistics Canada. Census profile, 2016 census: Sherbrooke [Internet]. Ottawa (ON): Statistics Canada; 2017. [Catalogue no. 98-316-X2016001]. Available from: https://www12.statcan.gc.ca/census-recensement/2016/dp-pd/prof/details/page.cfm?Lang=E&Geo1=POPC&Code1=0758&Geo2=PR&Code2=24&Data=Count&SearchText=Sherbrooke&SearchType=Begins&SearchPR=01&B1=All&TABID=1

22. Statistics Canada. Canadian Community Health Survey – Annual Component (CCHS) 2015. Ottawa (ON): Statistics Canada; 2015. Available from: http://www23.statcan.gc.ca/imdb/p2SV.pl?Function=getSurvey&Id=238854

23. Institut de la statistique du Québec (ISQ). Estimations de la population des régions métropolitaines de recensement (RMR), 1er juillet 2006 à 2019 [Internet]. Québec City (QC): ISQ; 2019 [updated 2019 May 28]. Available from: https://www.stat.gouv.qc.ca/statistiques/population-demographie/structure/rmr-totaux.htm

24. Natural Resources Canada. The Atlas of Canada – Toporama. 2015 [Internet]. Ottawa (ON): Natural Resources Canada; 2015. Available from: http://atlas.nrcan.gc.ca/toporama/en/index.html

25. Transportation Association of Canada. Urban transportation indicators, fourth survey. Ottawa (ON): Transportation Association of Canada; 2010. 125 p. Available from: http://tac-atc.ca/sites/tac-atc.ca/files/site/doc/resources/report-uti-survey4.pdf

26. Pampalon R, Hamel D, Gamache P, Raymond G. A deprivation index for health planning in Canada. Chronic Dis Can. 2009;29(4):178-91.

27. Government of Canada. Historical climate data [Internet]. Ottawa (ON): Government of Canada; 2019. Available from: http://climat.meteo.gc.ca/index_e.html

28. Cyr C, Ouedraogo N. A safe community-based campaign to promote the use of bicycle helmets in children 2013. Paper presented at: American Academy of Pediatrics; 2013 Oct 26-29; Orlando, USA. Available from: https://aap.confex.com/aap/2013/webprogram/Paper20527.html

29. National Highway Traffic Safety Administration (NHTSA). Bicycle helmet use laws: lessons learned from selected sites. Washington (DC): NHTSA; 2005. 219 p.

30. Hagel BE, Rizkallah JW, Lamy A, 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.

31. Karkhaneh M, Rowe BH, Duncan Saunders L, Voaklander D, Hagel B. Bicycle helmet use after the introduction of all ages helmet legislation in an urban community in Alberta, Canada. Can J Pub Health. 2011; 102(2):134-8.

32. Macpherson A, Spinks A. Bicycle helmet legislation for the uptake of helmet use and prevention of head injuries. Cochrane Database Syst Rev. 2008;Jul 16(3):CD005401. doi: 10.1002/14651858.CD005401.pub3.

33. Karkhaneh M, Kalenga J, Hagel BE, Rowe BH. Effectiveness of bicycle helmet legislation to increase helmet use: a systematic review. Inj Prev. 2006; 12(2):76-82.

34. Lindsay H, Brussoni M. Injuries and helmet use related to non-motorized wheeled activities among pediatric patients. Chronic Dis Inj Can. 2014; 34(2-3):74-81.

35. Liller K, 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(2):177-9.

36. Markowitz S, Chatterji P. Effects of bicycle helmet laws on children's injuries. Health Econ. 2015;24(1):26-40.

37. Robinson DL. Head injuries and bicycle helmet laws. Accid Anal Prev. 1996;28(4):463-75.