Bicycling injuries, helmets, & helmet legislation

Prepared by Kay Teschke

January 2012

Prepared as expert testimony for a Provincial Traffic Court case:

Regina vs. Van Der Eerden

Table of Contents

Appendix A Elvik R. Publication bias and time-trend bias in meta-analysis of bicycle helmet efficacy: a re-analysis of Attewell, Glase and McFadden, 2001. *Accident Analysis and Prevention* 2011;43:1245-51.

Appendix B Canadian Institute of Health Information. Cycling Injury Hospitalizations in Canada, 2009-2010. *Trauma Registries*. July 2011. http://www.cihi.ca/CIHI-ext-portal/pdf/internet/INFO_CYCLING_INJURY_09-10_EN Accessed December 18, 2011.

Appendix C Statistics Canada. *Commuting Patterns and Places of Work of Canadians, 2006 Census*. 2008. Catalogue no. 97-561-X http://www12.statcan.ca/census-recensement/2006/as-sa/97-561/tables-tableaux-notes-eng.cfm Accessed December 18, 2011.

Appendix D Transport Canada. *Canadian Motor Vehicle Traffic Collision Statistics: 2009*. 2011. TP 3322 http://www.tc.gc.ca/eng/roadsafety/tp-tp3322-2009-1173.htm Accessed December 18, 2011.

Appendix E Transport Canada. *Canadian Motor Vehicle Traffic Collision Statistics: 2004*. 2006. TP 3322 http://www.tc.gc.ca/eng/roadsafety/tp-tp3322-2004-menu-691.htm Accessed December 18, 2011.

Appendix F Transport Canada. *Canadian Motor Vehicle Traffic Collision Statistics: 2000*. 2002. TP 3322 http://www.ccmta.ca/english/pdf/collision_stats00_e.pdf Accessed December 18, 2011.

Appendix G Transport Canada. *Trends in Motor Vehicle Traffic Collision Statistics 1988 – 1997*. 2001. TP 13743 E.

http://www.tc.gc.ca/media/documents/roadsafety/Trends_88-97.pdf Accessed December 18, 2011.

Appendix H — Dennis J, Potter B, Ramsay T, Zarychanski R. The effects of provincial helmet legislation on helmet use and bicycle ridership in Canada. *Injury Prevention* 2010;16:219-224

Appendix I — Motor Vehicle Branch. *Traffic Collision Statistics. Police-attended injury and fatality collisions, British Columbia, 1995-97*. http://www.icbc.com/road-safety/safety-research/collisions-1997.pdf Accessed December 18, 2011.

Appendix J — Motor Vehicle Branch. *Traffic Collision Statistics. Police-attended injury and fatality collisions, British Columbia, 2005*. http://www.icbc.com/road-safety/safety-research/collisions-2005.pdf Accessed December 18, 2011.

Appendix K — Motor Vehicle Branch. *Traffic Collision Statistics. Police-attended injury and fatality collisions, British Columbia, 2006*. http://www.icbc.com/road-safety/safety-research/collisions-2006.pdf Accessed December 18, 2011.

Appendix L — Motor Vehicle Branch. *Traffic Collision Statistics. Police-attended injury and fatality collisions, British Columbia, 2007*. http://www.icbc.com/road-safety/safety-research/traffic-coll-stats-2007.pdf Accessed December 18, 2011.

Appendix M — Beck LF, Dellinger AM, O'Neil ME. Motor vehicle crash injury rates by mode of travel, United States: using exposure-based methods to quantify differences. *American Journal of Epidemiology* 2007;166:212-8

Appendix N — Pucher J, Buehler R. Making cycling irresistible: Lessons from the Netherlands, Denmark and Germany. *Transport Reviews* 2008;28:495-528

Appendix O — Mustel Group Market Research. *TransLink's 2008 Regional Trip Diary Survey: Final Report*. Mustel Group: Vancouver. February 2010

Appendix P — Jacobsen PL. Safety in numbers: more walkers and bicyclists, safer walking and bicycling. *Injury Prevention* 2003;9:205-209.

Appendix Q — Winters M, Davidson G, Kao D, Teschke K. Motivators and deterrents of bicycling: comparing influences on decisions to ride. *Transportation* 2011;38:153-168

Appendix R — Reynolds CCO, Harris MA, Teschke K, Cripton PA, Winters M. The impact of transportation infrastructure on bicycling injuries and crashes: A review of the literature. *Environmental Health* 2009;8:47

Appendix S — Lusk AC, Furth PG, Morency P, Miranda-Moreno LF, Willett WC, Dennerlein JT. 2011. Risk of injury for bicycling on cycle tracks versus in the street. *Injury Prevention* 2011;17:131-5

Appendix T — Winters M, Freisen MC, Koehoorn M, Teschke K. Utilitarian bicycling: A multilevel analysis of climate and personal influences. *American Journal of Preventive Medicine* 2007;32:52-58

Appendix U — Woodcock J, Edwards P, Tonne C, Armstrong B, Ashiru O, Banister D, et al. Public health benefits of strategies to reduce greenhouse-gas emissions: urban land transport. Lancet 2009;374:1930-43

Appendix V — Johan de Hartog J, Boogaard H, Nijland H, Hoek G. Do the health benefits of cycling outweigh the risks? *Environ Health Perspect* 2010;118:1109-16

Appendix W — Rabl A, Audrey de Nazelle A. Benefits of shift from car to active transport. *Transport Policy* 2012;19:121-131

Appendix X — Rojas-Rueda D, de Nazelle A, Tainio M, Nieuwenhuijsen MJ. The health risks and benefits of cycling in urban environments compared with car use: health impact assessment study. *BMJ* 2011;343:d4521. doi: 10.1136/bmj.d4521.

Bicycling injuries, helmets, & helmet legislation

1.0 Injuries and deaths prevented by helmets and helmet legislation

1.1 Research has demonstrated that helmet use results in head injury reductions

Many studies have examined associations between helmet use and injuries to cyclists, and a number of meta-analyses have summarized the results. They have concluded that helmets reduce injuries to the head and face, though they may increase injuries to the neck. The most recent meta-analysis is by Elvik (2011; Appendix A). It added new studies and answered criticisms of earlier meta-analyses (including one of his own) by adjusting for potential biases not taken into account previously. It came to the same conclusions, though it found somewhat weaker reductions in head injuries (estimated relative risks, in the form of odds ratios, ranging from 0.43 to 0.58, i.e., roughly a halving of risk compared to the reference value of 1.0) and face injuries (relative risks: 0.71 to 0.83), and confirmed an increase in neck injuries (relative risks: 1.28 to 1.32).[1]

1.2 The impact of helmet legislation is difficult to observe on a population basis

One way to understand the impact of helmet legislation on injury rates is to compare injury rates in provinces with and without legislation. The Canadian Institute of Health Information (CIHI) published data on hospitalizations resulting from cycling injuries in Canada from 2001/2 to 2009/10 (Appendix B).

Figure 1 shows one year of these data. Rates of hospital admissions for cycling injuries in Canadian provinces are grouped according to whether or not the provinces have helmet legislation and if so, whether it applies to all ages or only to children. The year 2006/7 was selected because by that year all provinces with helmet legislation had put it into effect, and because 2006 is a Census year for which there is some national data on cycling rates (the proportion of people who usually cycle to work[2], Appendix C). Two injury rates are shown:

- Injuries per 100,000 population (2006/7 data directly from the CIHI report, Appendix B).
- Injuries per 1,000 population who usually cycle, calculated by me (the proportion of people who usually cycle is assumed to be equal to the proportion who usually cycle to work, data from the 2006 Census of Canada, Appendix C).

Neither measure demonstrates a pattern of lower hospital admission rates for cycling injuries in provinces with helmet legislation.

There are several reasons that might explain why provinces with helmet legislation do not

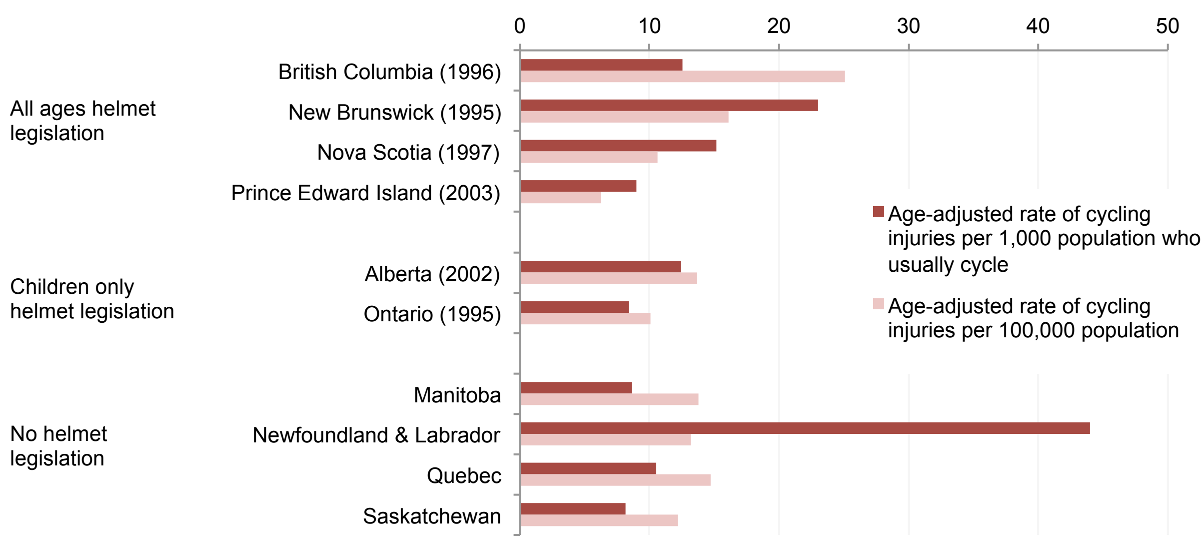
[1] Note that the types of injuries can range from mild to severe, including bruising, muscle strains, lacerations, concussions, bone fractures, nerve damage, or death.

[2] In Canada there is no national trip diary survey documenting the proportions of *all* trips made by the various modes of travel ("modal share"). Since 1996, the long-form Census has included a question asking employed persons about their usual mode of travel to *work*.

demonstrate lower cycling injury rates:

- The difference in overall injury rates achieved with helmet use is small.
- The CIHI data include injuries to areas of the body that are not protected by helmets. Helmets protect against injuries to the head, and head injuries represent less than a quarter of all cycling injuries resulting in hospitalization (21.5% in 2006/7, Appendix B).
- The CIHI data include injuries to children, adults who do not work, as well as non-commuting injuries among those who do work. Overall cycling rates were not measured in the Census and may or may not be correlated with rates of cycling to work.
- The CIHI data include all kinds of cycling injuries, including those during off-road recreational cycling. Off-road cycling patterns may differ across provinces. For example, there may be more mountain biking in British Columbia and Alberta, and this may have contributed to their higher injury rates compared to many other provinces. Mountain biking injuries are likely not relevant to helmet requirements under motor vehicle legislation.

Figure 1. Age-adjusted[3] rates of cycling injuries that resulted in hospital admission, per 100,000 population and per 1,000 population who usually cycle, by province, in 2006/7. Year helmet legislation took effect in brackets. Data sources: Appendices B,C



1.3 Deaths may be prevented by helmet legislation in Canada

The following sections of this report use data on traffic collisions involving cyclists, since these data are systematically compiled nationwide by Transport Canada and, within British Columbia, by the Motor Vehicle Branch. Such injuries are relevant to helmet requirements under motor vehicle legislation.

Table 1 presents motor vehicle collision fatality data over a 22-year period for the country as a whole. The same data are presented in Figures 2a and 2b. The data were abstracted from

[3] Adjusting for age means that the same age distribution was assigned to the population of each province. If age adjustment was not done, provinces with older populations could appear to have higher hospitalization rates, not as a result of the factor of interest (bicycling), but because older people are more likely to be hospitalized.

the following Transport Canada publications: Canadian Motor Vehicle Traffic Collision Statistics, 2009 (Appendix D); Canadian Motor Vehicle Traffic Collision Statistics, 2004 (Appendix E); Canadian Motor Vehicle Traffic Collision Statistics, 2000 (Appendix F); and Trends in Motor Vehicle Traffic Collision Statistics 1988-1997 (Appendix G).

Table 1. Traffic collision fatalities in Canada by road user class, 1988 to 2009.

	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998
Drivers & Passengers	3105	3177	2975	2790	2757	2817	2541	2661	2411	2422	2167
Pedestrians	586	503	584	533	440	479	429	416	465	402	402
Bicyclists	125	96	106	102	75	81	86	64	60	67	77
Total (including motorcyclists & others)	4154	4083	3962	3690	3501	3615	3263	3351	3091	3064	2934

	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Drivers & Passengers	2273	2216	2097	2227	2076	2076	2180	2125	2023	1774	1605
Pedestrians	414	372	335	368	379	366	342	376	376	299	307
Bicyclists	69	40	60	63	44	56	52	73	65	42	41
Total (including motorcyclists & others)	2969	2927	2781	2931	2766	2730	2898	2884	2761	2419	2209

Data sources: Appendices D,E,F,G

Figure 2a. Traffic collision fatalities in Canada by road user class, 1988 to 2009. Data from Table 1.

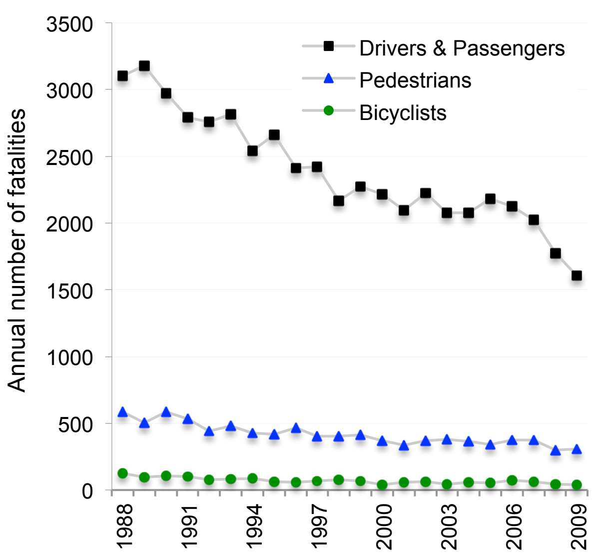
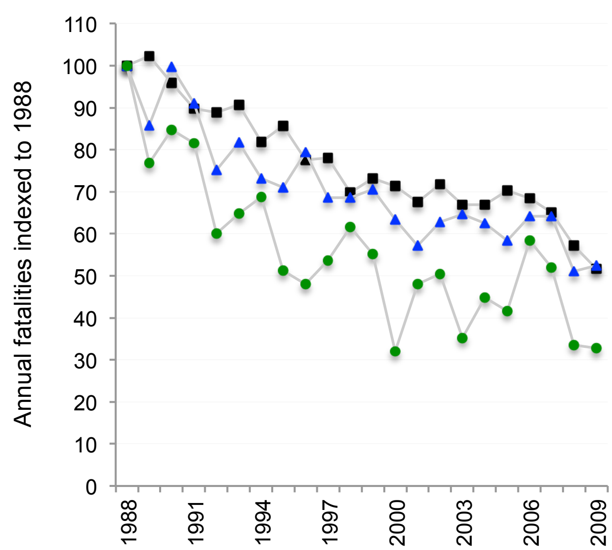


Figure 2b. Trend in number of traffic collision fatalities in Canada indexed to 1988 (assigned 100), by road user class, 1988 to 2009. Data from Table 1.



The data show that traffic collision fatalities have declined substantially for all road user classes over this period. Figure 2b suggests that the rate of decline has been very similar for motor vehicle occupants and pedestrians, but it appears to have been somewhat steeper for bicyclists, especially in the early years prior to 1996.

Legislation requiring bicycle helmets for children or all ages was implemented in two periods, 1995 to 1997 and 2002 to 2003 (Figure 1). There were no visually obvious sustained changes in cycling fatalities after these two periods (Figure 2b), but the data can be examined more quantitatively. To estimate the numbers of deaths per year that might have been prevented by helmet legislation, I calculated the average annual numbers of fatalities in the 7-year periods before (1988 to 1994) and after (2003 to 2009) helmet legislation (Table 2). Averages over these extended periods were used because cycling fatalities vary considerably from year to year. To estimate the impact of helmet legislation, I assumed the following:

- that bicyclists also benefitted from the factors that resulted in an overall trend of reduced fatalities among motor vehicle occupants and pedestrians during this period, independently of helmet legislation;
- that all helmet use was a consequence of legislation, not personal choice[4]; and
- that the entire difference in the rate of decline in fatalities between bicyclists and other road users was a result of helmet legislation.

Table 2. Average **annual** number of traffic collision fatalities in Canada over 7-year pre- and post-helmet-legislation periods, by road user class. Calculated from Table 1 data.

	Pre-helmet legislation 1988-1994	Post-helmet legislation 2003-2009	Fatalities in post-legislation period as a percent of those in the pre-legislation period
Drivers & passengers	2880	1980	68.7%
Pedestrians	508	349	68.8%
Bicyclists	96	53	55.6%

The reduction in bicyclist fatalities in the post-legislation period compared to the pre-legislation period has two components:

- The first is the reduction from factors affecting all road users: fatalities in the 2003 to 2009 period were reduced to 68.7% of 1988 to 1994 levels. Therefore, if cyclists were affected only by the general temporal decline in traffic fatalities, there would have been 66 bicyclist fatalities on average per year in the later period (96 x 68.7%). This suggests that 30 bicyclist fatalities in Canada were prevented each year because of temporal trends in overall traffic collisions.
- The second is an additional reduction observed for cyclists, a reduction from 66 to 53 bicyclist fatalities. This suggests that helmet legislation may have prevented up to 13 deaths per year in Canada.

[4] This is unlikely to be true, since there is helmet use among those not required to do so. In the 2005 Canadian Community Health Survey, 26.9% of respondents wore helmets in a province with no legislation, and 40.6% did so in a province with legislation for children only (*vs.* 73.2% who did in a province with all ages helmet legislation). (Dennis *et al.* 2010, Appendix H)

There are limitations to this analysis.

- It does not account for any changes in the relative numbers of drivers and passengers, pedestrians, or cyclists over this time period. For example, if the number of cyclists declined over this period, this could account for some of the decline in the number of fatalities. Data on the proportion of trips to work by each mode (work trip "modal share") from the Census (Appendix C) suggest that there have been slight changes in the proportions of trips by each travel mode from 1996 to 2006, including slight increases in cycling to work. Unfortunately the Census data do not cover the entire 1988 to 2009 period and, as mentioned previously, tally only work trips not all types of trips.
- There were few cyclist fatalities each year, and the numbers fluctuate a great deal from year to year. Injury data would provide more stable numbers, but injuries were not reported in the same way in the periods before and after helmet legislation.
- Transport Canada did not report head injury fatalities separately, yet these are the injuries impacted by helmet use.
- Fatalities were not reported by both road user class and province, so it was not possible to determine whether the reductions in injuries to cyclists were consistent from province to province or varied by helmet legislation jurisdictions.

1.4 Head injuries and fatalities are prevented by helmet legislation in British Columbia

1.4.1 Comparison of head injuries and fatalities before and after helmet legislation took effect

Data specific to British Columbia are available from the Motor Vehicle Branch: Traffic Collisions Statistics, Police-attended Injury and Fatal Collisions. Table 3 summarizes the data on bicycling injuries and fatalities for the years 1995 to 1997 inclusive (Appendix I). All ages helmet legislation took effect in September 1996. These data allow an analysis similar to the one in section 1.3 above, but with a BC focus, with data on both fatalities and injuries, and with head injury data for cyclists.

To estimate the numbers of deaths and injuries prevented per year as a result of helmet legislation in British Columbia, I assumed that helmets only protect against head injuries. Some injuries of the upper face are also likely prevented, but the epidemiological evidence indicates that these are roughly balanced by increases in neck injuries.[5]

The simplest way to examine the impact of the helmet legislation is to subtract the number of bicyclist head injuries after the legislation from those before. The data in Table 3 indicate that there were 48 fewer head injuries reported in 1997 than in 1995 (165 - 117), and no fewer head injury fatalities (2 - 3).[6] However, as with the national data above, injuries for all road user classes decreased over this time period, so it is reasonable to adjust for these declines when examining cyclist head injuries.

- If the decline in driver and passenger injuries is adjusted for, it suggests that 13 cyclist head injuries may have been prevented by the legislation.

[5] Both face and neck injuries represent much smaller numbers of injuries than head injuries, for both helmeted and unhelmeted cyclists. Most injuries to cyclists are to the trunk, legs and arms.

[6] The small number of fatalities each year makes these numbers very unstable, so this result is not surprising. It would be better to compare the average of many years both before and after the legislation came into effect, but data before 1995 were not available.

- If the decline in pedestrian injuries is adjusted for, it suggests that 38 cyclist head injuries may have been prevented by the legislation.

However, an additional trend of interest over this period was the decline in all injuries to cyclists, not just head injuries. In fact the decline in all bicycling injuries was even stronger than the decline in head injuries and than the declines in injuries to other road user classes. This suggests that there were other factors changing at the same time. Two possibilities are a decline in the number of cycling trips and reduced recording of bicycling injuries. There is no data available on cycling rates in BC over these three years. There *was* a change in reporting policy that reduced police recording of minor injuries in *all* traffic collisions starting in 1996 and implemented more fully in 1997 (Appendix I). This explains at least in part the decline in all cycling injuries. Another odd feature of the data over these years is that head injuries as a proportion of all injuries increased over this period, the direction opposite to expectation given the new helmet legislation: 12.7% in 1995 vs. 13.8% in 1997. This may be because the minor injuries no longer being recorded were less often head injuries.

The strong decline in all reported bicycling injuries and the changes in injury reporting make it impossible to confidently interpret the injury data before and after implementation of helmet legislation in BC. This highlights a difficulty of before-after comparisons: concurrent temporal trends may be difficult to ascertain and it may not be possible to properly adjust for them.

Table 3. Injuries and fatalities in traffic collisions in British Columbia, by road user class, from 1995, the year before helmet legislation was implemented, to 1997, the year after it was implemented. Head injury data presented for bicyclists (not available for other road user classes).

	Pre-helmet legislation 1995	1996	Post-helmet legislation 1997	Ratio of injuries 1997 to 1995
Injuries				
Drivers & passengers	30,722	28,122	24,290	0.79
Pedestrians	2,140	1,992	2,004	0.94
Bicyclists	1,299	1,048	847	0.65
Head injuries	165	142	117	0.71
Fatalities				
Drivers & passengers	396	311	309	0.78
Pedestrians	56	61	45	0.80
Bicyclists	7	5	5	0.71
Head injuries	2	3	3	1.50

Data source: Appendix I

1.4.2 Comparisons of injuries and fatalities between helmeted and unhelmeted cyclists

Another way to examine the impact of helmets and helmet legislation is to compare injuries to helmeted and unhelmeted cyclists. This cannot be done during the transition period of 1995 to 1997, because the proportions of cyclists wearing helmets was changing (but not documented) at that time. Data from this transition period (Appendix I) show that the number of head injuries among helmeted cyclists increased over this period and the number of head injuries among unhelmeted cyclists decreased. This is almost certainly because more cyclists were wearing helmets and fewer were not.

Instead, the years 2005, 2006, and 2007 were selected for this analysis, for several reasons: these are the most recent years for which injury data are publicly available in BC; they are long after the implementation of helmet legislation, so helmet use patterns under the legislation should be established; they straddle the census year 2006 for which there are estimates of trips to work by various travel modes; and they are the years closest in time to a 2008 travel diary survey for the Metro Vancouver area which provides modal share data for all types of trips, not just work trips. Although the modal share data is not used in this analysis, this same injury data set is used again later in this report for analyses that do use it.

Table 4 summarizes Traffic Collisions Statistics, Police-attended Injury and Fatal Collisions on bicycling injuries and fatalities for 2005, 2006, and 2007 (Appendices J, K, L). It shows that bicyclists who did and did not wear a helmet suffered head injuries and deaths from head injuries. It also shows that head injuries and deaths from head injuries were more frequent among those who did not wear helmets. The ratio of the proportions of head injuries among those who wore and didn't wear helmets (11% *vs.* 19%, respectively) is in line with evidence from epidemiological studies about protection from helmets (summarized in Section 1.1 above), almost a halving of head injury risk.

To estimate the numbers of deaths and injuries prevented per year as a result of helmet legislation in British Columbia, I first calculated the numbers prevented by helmet use, then adjusted these estimates for helmet use attributable to helmet legislation. I made the following assumptions:

- that helmets only protect against head injuries;
- that if a head injury was prevented by a helmet, any remaining injury from the crash was so minor that it would not have been reportable;[7] and
- that the differences in the proportions of injured cyclists who had head injuries, between those who did and did not wear a helmet, were due only to helmet use.[8]

Table 4. Average annual number of bicyclists injured or killed in traffic collisions in British Columbia, stratified by helmet use, and type of injury, over the period from 2005 to 2007 inclusive.

	Helmet	% of all injuries	No helmet	% of all injuries	Total*
All injuries	436		368		982
Head injuries	48	11.0%	70	19.0%	136
Fatal injuries	3.7	0.85%	5.3	1.44%	9.7
Fatal head injuries	2.0	0.46%	3.0	0.82%	5.3

Data sources: Appendices J,K,L

* Total is greater than sum of those wearing and not wearing helmets, since helmet use was unknown for some people.

[7] This assumption means that in the formula at the top of page 72, additional prevented head injuries (x) were added to both the numerator and denominator. The opposite assumption is conceivable: that all crashes involving reportable head injuries also involve reportable injuries to other parts of the body. If this were the case, helmets would not have any impact on the total number of reportable injuries. The truth is likely to be intermediate between these two extremes. I used the assumption that maximizes the estimated benefit of helmets.

[8] This may not be the case, since a higher proportion of those who do not wear helmets are in demographic segments that are associated with higher injury rates in all road user classes: males and those in the age range 16 to 29 (Dennis *et al.* 2010, Appendix H; Beck *et al.* 2007, Appendix M).

I assumed that if no one wore helmets, the proportion of all injured cyclists who had head injuries would have been the same as for cyclists without helmets (i.e., 19.0%). If head injuries among all injured cyclists were the same proportion as among those without helmets, there would have been 62 additional bicyclist head injuries per year ($19\% = (x + 136)/(x + 982)$; where x = the additional head injuries incurred if no one wore a helmet). Therefore, without helmet use, there would have been 1044 (62 + 982) total injuries on average per year.

Similarly, I assumed that if no one wore a helmet, the proportion of all injured cyclists who had fatal head injuries would be the same as for cyclists without helmets (i.e., 0.82%). If head injury deaths among all injured cyclists were the same proportion as among those without helmets, there would have been 3.3 additional head injury deaths per year ($0.82\% = (y + 5.3)/1044$; where y = the additional head injury deaths if no one wore a helmet).

Thus, in the period from 2005 to 2007, helmet use likely prevented 62 head injuries and 3.3 head injury fatalities on average per year in British Columbia. To estimate the numbers saved by helmet legislation, the increase in helmet use attributable to legislation can be taken into account. Dennis *et al.* 2010 (Appendix H) analyzed data from a special module of the 2005 Canadian Community Health Survey completed in three provinces. Data from two provinces can be used to estimate the impact of helmet legislation on helmet use. In the province with no legislation (Saskatchewan), 26.9% of respondents wore helmets, and in the province with all ages helmet legislation (Nova Scotia), 73.2% wore helmets. This suggests that about 65% of helmet use is a result of legislation. This proportion can be used to estimate that 40 head injuries (65% of 62) and 2.1 head injury fatalities (65% of 3.3) per year were prevented as a result of helmet legislation.

These figures suggest that helmet *use* prevents about 6% of total potential injuries (62/1044) and helmet *legislation* prevents about 4% (40/1044).

There are limitations to this analysis.

- Reporting of bicycling fatalities is likely close to complete, but injuries are likely to be underreported.[9] The data source "Traffic Collisions Statistics, Police-attended Injury and Fatal Collisions" is less likely be complete for on-road bicycling injuries that do not involve motor vehicles and is unlikely to include off-road injuries. This means that the absolute number of injuries prevented by helmets is likely to be higher (by 6% of the unreported injuries). However, it also means that the absolute number of injuries *not* prevented by helmets is also likely to be higher (94% of the unreported injuries).
- Police-reported injuries include a wide range of injury severities, from those that may not need a visit to a hospital emergency department to hospitalizations and fatalities. Although the most severe (fatalities) were reported separately, there was no separate reporting to indicate intermediate injury severity (i.e., injuries requiring hospitalization). It is likely that some police-reported head injuries among helmeted cyclists would have been more severe had the cyclists not worn a helmet.
- Because data are not available on the numbers of trips made or distances travelled by BC cyclists who do and don't wear helmets, this analysis could not assess "exposure to risk" in each group.

[9] Studies have shown that higher severity injuries to bicyclists are associated with motor vehicle involvement (Reynolds et al., 2009, Appendix R). Injuries to cyclists involving motor vehicles are likely to be included in police-reported data.

1.5 Summary

In summary, British Columbia data from recent years, when helmet use and cycling rates under the legislation should be stable, and with information on head injuries and helmet use among injured cyclists, supports evidence from epidemiological studies that helmets and helmet legislation reduce head injuries. This benefit was difficult to observe in comparisons between provinces and over time, in part because data limitations impaired analysis and interpretation. Another reason the benefit was so difficult to discern is that the proportion of all injuries saved by helmets and helmet legislation is small. If helmets and helmet legislation had a profound effect on injuries and fatalities, then the epidemiological evidence would be much clearer in population level comparisons, such as the comparison between provinces with and without helmet legislation.

2.0 Other methods of preventing cycling injuries and deaths

Although helmets prevent deaths and head injuries, the focus on helmets as the dominant prevention measure for injuries to bicyclists in North America has distracted public policy attention from the promotion and implementation of much more effective safety measures. This has likely cost many more fatalities and injuries than helmets and helmet legislation have prevented.

2.1 There are better prevention approaches than helmets and helmet legislation

Within public health, various classifications of disease and injury prevention measures have been described. In the traffic injury field, a matrix developed by a US physician, William Haddon, is most commonly used. It was developed about four decades ago to help understand the factors influencing motor vehicle crashes and their resulting injuries. One axis of the matrix describes three time-points when interventions can take place: pre-event prevention; during-event mitigation; and post-event treatment. Helmets act at the second stage, after the crash event has been initiated. Measures that act at the pre-event stage are preferable because they prevent all types of injuries, as well as the personal, medical, labour and capital costs of crashes.

Another classification system is used for preventing hazardous occupational exposures. It presents a hierarchy of controls: engineering measures; administrative measures; and personal protective devices. Personal protective devices are considered the least effective and therefore the last resort, because they usually protect against only one route of exposure, rely on the ongoing compliance of every exposed individual, and depend on the availability, maintenance, proper positioning, and fit of the protective device. This is true for helmets: they mitigate head and face injuries only; require individual decisions to use a helmet; and require good helmet condition, fit and quality to be maximally effective. In comparison, administrative measures (such as designation of quiet streets that restrict motor vehicle traffic and speeds) and engineering measures (such as physically separated bike lanes and traffic diverters) have the advantage of being population-based (protecting everyone), passive (not requiring repeated actions by cyclists or enforcement by authorities),[10] and preventing injury events before they occur and therefore protecting all parts of the body.

2.2 More deaths and injuries could be prevented using other approaches

One way to consider how many deaths could be prevented using other approaches would be to simply imagine we could prevent all injury events from occurring in the first place. The data presented in Table 4 show that in period from 2005 to 2007, the annual average number of cyclist fatalities was 9.7 and police-reported injuries was 982. Despite the fact that British Columbia has all-ages helmet legislation, there were many injuries of the type helmets are meant to protect against (amongst helmeted and unhelmeted cyclists): 136 head injuries and 5.3 head injury deaths per year. There were also over 800 injuries per year against which helmets offer no protection. These numbers dwarf the numbers of deaths and injuries prevented by helmets, and underscore the importance of implementing measures that

[10] Speed limits do need to be enforced, though streets can be designed to make speeding difficult.

prevent crash events from occurring in the first place.

It is fair to ask whether such measures are available. Northern European countries including the Netherlands, Denmark, and Germany have taken a much different approach to cycling safety (Pucher and Buehler 2008; Appendix N). Not only do they have no helmet laws, but helmet use is rare. The approach instead has been to construct bicycle-specific facilities, the design of which varies depending on motor vehicle traffic and speed. On major streets "cycle tracks" (i.e., specially designed bicycle lanes) are typically used to physically separate cyclists from motor vehicles and from pedestrians. On residential streets, motor vehicle traffic is restricted and kept slow, with speed limits of 30 km/h.

Pucher and Buehler (2008) calculated fatality and police-reported injury rates for these countries and for the United States. These are reported in Table 5. I calculated comparable rates for British Columbia (details presented in Section 5.2 of this report). The data for fatalities are expected to be good quality, since fatalities are well reported in all developed countries. The comparability of the police-reported injury data is less certain, but the size of the differences between the European and North American countries support confidence in the direction of effect.

If British Columbia injury and fatality rates were as low as those in Germany, Denmark and the Netherlands, more deaths and many more injuries would have been prevented than are with helmet legislation. Table 6 presents estimates of these savings: 3.4 to 5.6 deaths and 340 to 930 injuries. These numbers show the potential for major reductions in injuries in BC if a fully prevention-oriented approach, using a spectrum of engineering and administrative measures, were adopted here as they have been in the safer European countries.

Table 5. Comparison across jurisdictions of cyclist fatality rates and police-reported injury rates per 100 million km travelled

	British Columbia	United States	Germany	Denmark	Netherlands
Fatalities per 100 million km	2.6	5.8	1.7	1.5	1.1
Injuries per 100 million km	264	375	47	17	14

Data sources:
- Data for US, Germany, Denmark and the Netherlands (for 2002 to 2005) from Pucher and Buehler 2008 (Appendix N)
- I calculated British Columbia rates using injury and fatality data (for 2005 to 2007) from the Motor Vehicle Branch (Appendices J,K,L), with estimates of distance travelled per year from TransLink's 2008 Regional Trip Diary Survey: Final Report (Appendix O), and cycling modal share adjustment for BC using Statistics Canada 2006 data (Appendix C)

Table 6. Estimated annual deaths and injuries prevented if British Columbia fatality and injury rates were the same as those in Germany or the Netherlands

	Average annual number in BC	Ratio of German to BC rates	Estimated deaths / injuries prevented with German rate	Ratio of Dutch to BC rates	Estimated deaths / injuries prevented with Dutch rate
Deaths	9.7[a]	1.7 / 2.6	3.4	1.1 / 2.6	5.6
Injuries	982[a]	47 / 264	807	14 / 264	930
Injuries	982[a]	1.7 / 2.6[b]	340	1.1 / 2.6[b]	566

[a] Data from the Motor Vehicle Branch, 2005 to 2007 (Appendices J,K,L)

[b] Here the ratio of fatality rates is used, instead of the ratio of injury rates, since there is more uncertainty in the comparability of injury rates across jurisdictions. This provides a more conservative estimate of potential injuries prevented.

3.0 Helmets and ridership: what motivates cycling

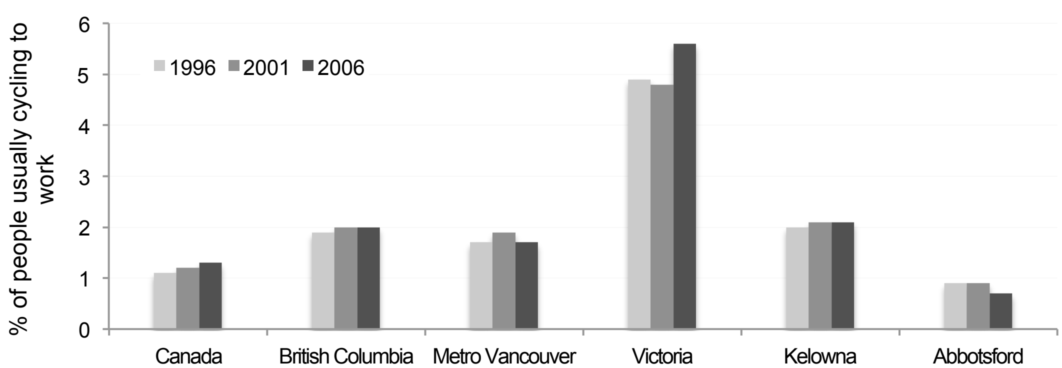
3.1 Helmet legislation does not make people feel safe and increase cycling

In addition to differences in cycling infrastructure, another major difference between Canada and northern European countries where cycling is safer is the proportion of trips made by bicycle, also known as the cycling modal share. There is evidence that there is "safety in numbers", that is, the greater the modal share the lower the injury rate per distance travelled or per trip. This effect has been shown consistently in a number of studies. The classic analysis was by Jacobsen (2003, Appendix P) using North American and European data. He examined the issue in several ways, comparing countries, cities and time periods within locations and found that injury and fatality rates declined as modal share increased.

Because of this effect, there has been concern about the impact of helmet legislation on cycling modal share. It is possible that in some locations and among some demographic groups, helmet laws have reduced modal share. However, in my view, it is more important to note that helmet laws have not succeeded in making people feel safe enough to increase cycling rates.

Census data are available to examine time trends in cycling modal share. Figure 3 shows the proportion of people who usually cycled to work in Canada as a whole, in British Columbia, and in four BC municipalities for which data are available.[11] It shows that there was very little change in cycling modal share for work trips over the 10-year period after BC helmet legislation took effect in September 1996. It also shows that there are factors other than helmet legislation that do impact cycling modal share, given the differences between municipalities within BC. However, even the city with the highest share of people cycling to work, Victoria (approximately 5%), has a much lower cycling rate than those of safer European countries: Germany (10%), Denmark (18%), and the Netherlands (27%) (Pucher and Buehler, 2008, Appendix N).

Figure 3. Proportion of people who usually cycled to work in Canada, British Columbia, and selected BC cities, as reported in the 1996, 2001, and 2006 long-form Census. Data from Appendix C.



[11] The proportion of people who usually cycle to work may be a reasonable estimate of the proportion of *all trips* that are made by bicycle in BC. This measure for Metro Vancouver in 2006 was 1.7%, slightly higher than the 1.5% proportion of trips made by bicycle based on a detailed trip diary survey of all age groups and all trip types conducted in the same area by TransLink in 2008 (Appendix O).

Our research on motivators and deterrents of bicycling indicates that safety is one of the dominant concerns (Winters *et al*., 2011, Appendix Q). In a survey of 1402 current and potential cyclists in the Metro Vancouver area in 2006, we asked opinions about 73 potential motivators and deterrents. Four of the six strongest *deterrents* were concerns about interactions with motor vehicle traffic. In the same vein, routes away from traffic were the strongest *motivators*. In contrast, helmet legislation was a neutral factor for the majority of survey respondents; only 8 of the 73 factors had a more neutral average score for motivation to cycle.

Data from our survey and the Census show that helmet laws do not make British Columbians feel safer when cycling and have not resulted in increases in cycling modal share to levels experienced in safer northern European countries.

3.2 Other prevention approaches are safer and are associated with increased cycling

As described in section 2.2, European countries that are safer for cycling provide cycling-specific infrastructure (Pucher and Buehler 2008; Appendix N). Their focus on routes that separate cyclists from motor vehicle traffic jibes with the results of our survey: such routes are strong cycling motivators. Studies also show that bicycle-specific routes and physically separated bicycle routes are safer than roads with no cycling infrastructure (Reynolds *et al*., 2009; Lusk *et al*., 2011; Appendices R and S). Thus via both motivating cycling and direct impacts on safety, the northern European route design approach has been more successful as an injury prevention strategy than the North American focus on helmets, and legislation to enforce their use.

4.0 Helmets and equity: income and education

4.1 More people wear helmets where there is legislation, but some people still do not

Section 2.1 outlined some of the problems with helmets as an approach to bicycling safety. One issue is that they require individual decisions to buy a helmet and then repeated decisions to use the device on every trip. Therefore, it is important to understand what personal characteristics are associated with those decisions.

Dennis *et al.* (2010, Appendix H) used data from the 2005 Canadian Community Health Survey to examine helmet use in provinces with and without helmet legislation. They found that use was highest in provinces with all ages legislation (73.2%, Nova Scotia), lowest where there was no legislation (26.9%, Saskatchewan) and intermediate where there was legislation only for children (40.6%, Ontario). These findings show that helmets are used where there is no legislation. They also show that about 25% of cyclists do not wear helmets even where there is all ages legislation.

4.2 Helmet use decreases with lower levels of income and education

In their study, Dennis *et al.* (2010, Appendix H) examined personal characteristics associated with use of helmets and found that the following factors were the most important:

- *Education*: those who had completed high school were twice as likely to wear helmets as those who had not, and those with post-secondary education were three times as likely to wear helmets as those who had not completed high school;
- *Income*: those in the highest income quintile were more than twice as likely to wear a helmet as those in the lowest quintile, and there was a clear income gradient;
- *Age*: those 30 and older and those 15 or younger were about twice as likely to wear helmets as 16 to 29 year olds.

These data show that youth and those in the least educated and lowest income[12] strata of the population have not been as well protected by helmets and helmet legislation as those who are highly educated and high income. This underscores the fact that helmet legislation is not a population-based prevention approach that protects everyone equally.

4.3 People with lower levels of income and young people cycle more

This is unfortunate, because bicycling offers opportunities for independent travel to a wider demographic sphere than our dominant travel mode: driving. It is accessible to those too young to drive. It is one of the least expensive modes of transportation, so provides options for those with low incomes.

Our research shows that the poor and the young do cycle more than other groups, so the theoretical accessibility of bicycling is true in fact. We used data from the 2003 Canadian Community Health Survey to examine personal influences on bicycling for utilitarian purposes (Winters *et al.*, 2007, Appendix T). Youth from 12 to 19 years of age were three times more likely to cycle than adults, and those 20 to 29 were more likely to cycle than

---

[12] A search of the Mountain Equipment Co-op on-line store indicated that bicycle helmets have a large range in price: from $15 to $175. Although the minimum cost of helmets does not seem high, perhaps it is in the context of all household expenditures. (http://www.mec.ca/AST/ShopMEC/Cycling/HelmetsAndCovers.jsp)

those in every older age category. People with incomes less than $15,000 per year were almost twice as likely to cycle as those with incomes over $50,000.

5.0 Helmets and equity: motorists, pedestrians, and cyclists

5.1 All modes of travel involve injuries, including head injuries

Another question to consider is why injury prevention for cyclists has focused on helmet use, whereas this has not been the case for pedestrians or motor vehicle occupants.

Table 7 presents data on police-reported fatalities and injuries of motor vehicle drivers and passengers, pedestrians, and cyclists in British Columbia, again using the 2005 to 2007 Traffic Collision Statistics from the Motor Vehicle Branch (Appendices J, K, L). Of these groups, cyclists have the lowest absolute numbers of deaths, deaths from head injuries, injuries, and head injuries. Drivers and passengers have the most in all these categories, and pedestrians are intermediate. From the perspective of the *absolute* injury toll, cyclists do not merit special attention.

Table 7. Police-reported fatalities and injuries in traffic collisions in British Columbia over the period 2005 to 2007 inclusive, by road user class

	Average number of fatalities	Average number of head injury fatalities	Average number of injuries	Average number of head injuries
Drivers & passengers	300.7	98.7	22,274	3,303
Pedestrians	70.7	33.7	1,880	294
All bicyclists*	9.7	5.3	982	136
Helmet	3.7	2.0	436	48
No helmet	5.3	3.0	368	70
Total	430.0	155.3	26,316	3,882

Data sources: Appendices J,K,L
* Total is greater than sum of those wearing and not wearing helmets, since helmet use was unknown for some people.

5.2 Both pedestrians and cyclists are "vulnerable road users"

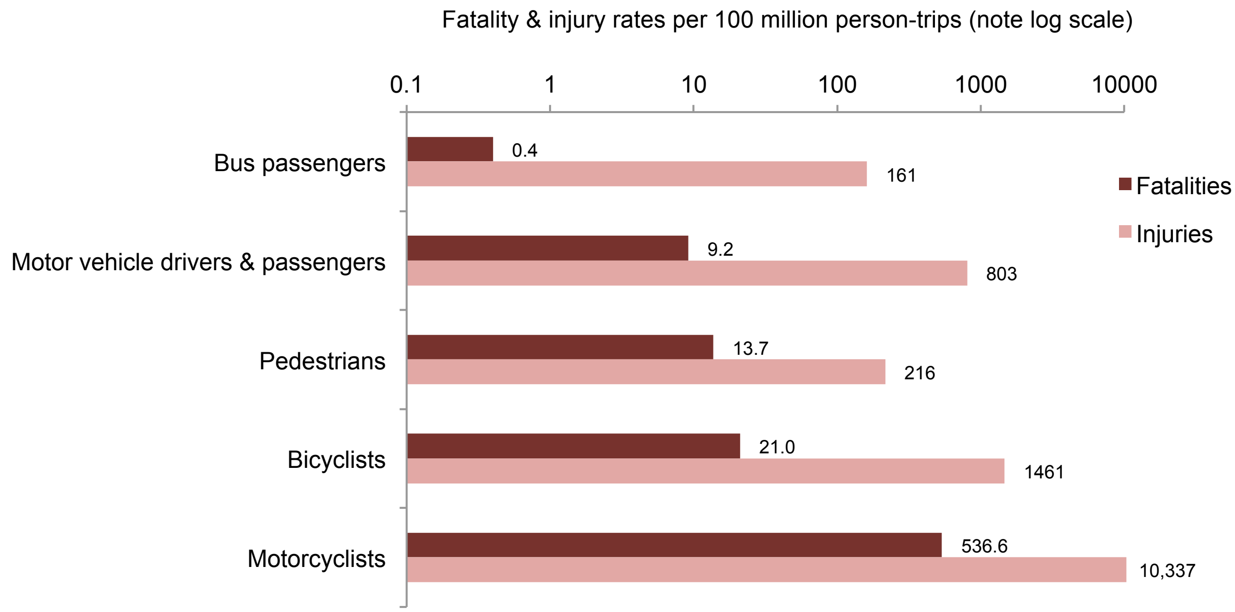
One reason that cyclists and pedestrians have fewer injuries and deaths than motorists is that there are fewer trips made by these modes. Comparisons of risk between travel modes are therefore best done by calculating an "exposure-based" injury rate, typically by dividing the number of injuries by one of two types of denominators: number of person-trips; or distance travelled. Trip duration could also be used as a denominator, though this is less common.

A team at the Centers for Disease Control and Prevention published a comparison of injury rates for various modes of travel in the United States over the period 1999-2003 inclusive (Beck *et al.*, 2007; Appendix M). Figure 4 and Table 8a summarize the injury and fatality rates they calculated per 100 million person-trips. Striking features of the results are that bus travel had a much lower fatality rate than any other mode (over 20 times lower), and that motorcycle travel had much higher fatality and injury rates than any other mode (over 25 and 7 times higher, respectively). Fatality and injury rates for drivers and passengers, pedestrians, and bicyclists were intermediate. Bicycling had the highest rates of these three modes, though the differences were not as striking, compared to at least one other mode. The cyclist fatality rate was about 1.5 times that of pedestrians, and the cyclist injury rate was about 1.8

times that of drivers and passengers.

Beck *et al.* (2007; Appendix M) conducted subanalyses by sex and age, and found that differences in rates for these three modes of travel were mainly among men. Fatality rates of female bicyclists, drivers and passengers, and pedestrians were nearly the same (7.2, 6.3, 8.0 per 100 million person-trips, respectively, *vs.* 27.6, 12.4, and 20.3 respectively, for males). Injury rates of female bicyclists were not significantly different from drivers and passengers (989 and 846 per 100 million person-trips, respectively) although those of male cyclists were (1,690 and 757, respectively). This suggests that the demographics of cycling (dominantly young males; e.g., Winters *et al.*, 2007, Appendix T) may in part explain apparent higher risks of cycling compared to driving and walking.

Figure 4. Traffic collision fatality and injury rates in the United States, 1999-2003, by road user class. Data from Beck *et al*., 2007; Appendix M.



For comparison purposes, I calculated rates using the same person-trip denominator for British Columbia (Table 8a), once again using the 2005 to 2007 Traffic Collision Statistics (Appendices J, K, L). Trips and modal shares were estimated using data from TransLink's 2008 Regional Trip Diary Survey (Appendix O), with modal share adjustments for the province as a whole using Statistics Canada 2006 Census data on trips to work (Appendix C). I also calculated rates per distance travelled, since this denominator has more commonly been used in international comparisons (as in section 2.2 above). The data for the denominators used in the BC rate calculations are outlined in Table 8b. BC data were not available to allow injury rate calculations for bus passengers or motorcyclists.

The BC fatality and injury rates per 100 million trips for drivers and passengers, pedestrians, and cyclists were very similar to the US rates (Table 8a). The BC fatality rates per 100 million person-trips were very similar for pedestrians and cyclists, but cyclists had a higher injury rate on a person-trip basis. Once average distances travelled by each mode were taken into account, pedestrians had a higher fatality rate than cyclists, and the injury rates were very similar. Using the distance denominator (per 100 million km travelled), both cyclists and pedestrians had higher fatality and injury rates than drivers and passengers, reinforcing their classification as "vulnerable road users". However, these data do not make clear why cyclists are treated differently from pedestrians with regard to helmet laws.

Table 8a. Traffic collision fatality and injury rates in the United States (1999-2003) and British Columbia (2005-2007), by road user class, using person-trips and distance travelled as denominators

	US fatalities per 100 million person-trips	US injuries per 100 million person-trips	BC fatalities per 100 million person-trips	BC injuries per 100 million person-trips	BC fatalities per 100 million km	BC injuries per 100 million km
Bus passengers	0.4	161	-	-	-	-
Drivers & passengers	9.2	803	9.6	713	0.97	72
Pedestrians	13.7	216	14.7	392	7.37	196
Bicyclists	21.0	1,461	13.8	1,398	2.60	264
Motorcyclists	536.6	10,337	-	-	-	-

US data source: Appendix M.
BC data sources: Appendices J,K,L and Table 8b.
- BC data not available to calculate rates for these road user classes.

Table 8b. Denominator data used to calculate British Columbia injury rates: Proportion of trips, annual number of trips, average distance travelled, and annual distance travelled, by road user class

	Proportion of all trips*	Annual number of trips†	Average individual trip distance (km)°	Annual distance travelled (km)
Drivers & passengers	78.6%	3,125,479,000	10.0	31,107,465,000
Pedestrians	12.1%	479,347,000	2.0	958,694,000
Bicyclists	1.76%	70,214,000	5.3	372,132,000

Data sources: Appendices C and O
* Proportion of all trips in British Columbia calculated as: 2006 Census data on % of BC working population usually using this mode to travel to work * TransLink's 2008 Regional Trip Diary Survey data for % of all Metro Vancouver trips by this mode (all age groups) / 2006 Census data on % of Metro Vancouver working population usually using this mode to travel to work.
† Population of British Columbia, 2006 Census = 4,113,487; average number of trips by all modes per person per day = 2.65, TransLink's 2008 Regional Trip Diary Survey
° From TransLink's 2008 Regional Trip Diary Survey

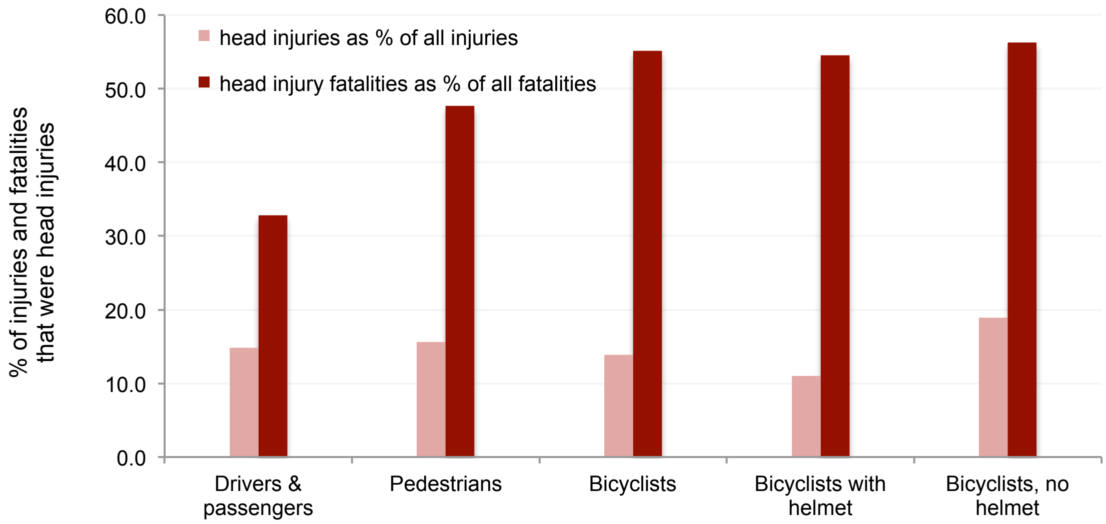
5.3 Differences in head injury risk do not explain why cyclists are subject to helmet legislation and pedestrians are not

Given that pedestrians and cyclists experience similar risk of death or injury (though each appears less safe with one type of denominator), are there other reasons why helmet legislation applies to bicyclists but not to pedestrians? Perhaps cyclists are more likely to have head injuries than pedestrians.

Figure 5 presents data calculated from Table 7 on the proportions of fatalities and injuries that are head injuries in each road user class. Data for unhelmeted cyclists are included for comparability to pedestrians and motorists, who do not wear helmets. These data show that unhelmeted cyclists when injured were more likely to have head injuries, but this difference was not large: 19.0% *vs.* 14.8% of motorists' injuries and 15.6% of pedestrians' injuries. The fatalities data shows some difference for motorists (32.8% involved head injuries), but little difference between pedestrians (47.6%) and unhelmeted cyclists (56.3%).

One interpretation of these data is that pedestrians too would benefit from helmets. Another is that both pedestrians and cyclists would benefit from population-based engineering and administrative measures that would prevent crashes and substantially reduce all types of injuries and fatalities.

Figure 5. Proportions of police-reported fatalities and injuries that were head injuries, by road user class, in traffic collisions in British Columbia over the period 2005 to 2007 inclusive. Calculated from Table 7 data.



6.0 Summary and concluding thoughts

This report reviews British Columbia data and provides estimates that helmets prevent about 60 head injuries and 3 deaths to cyclists per year in the province, and that helmet legislation may contribute about two-thirds of this reduction. The estimated proportion of all bicycling injuries prevented by helmets is about 6% and by helmet legislation about 4%.

Thus, even with helmet legislation that applies to both adults and children, large numbers of injuries to cyclists still take place. British Columbia cyclists incur about 1000 police-reported injuries per year on average, including about 140 head injuries and 10 fatalities. Cyclists continue to be injured because helmets do not prevent crashes from occurring, the head is not the only part of the body to sustain injuries, and helmets do not prevent all head injuries. Helmets are a post-crash, individual-based, injury mitigation measure.

Elsewhere in the world, there are success stories with a different approach to cyclist safety – one that aims to prevent crashes before they happen. These prevention efforts rely on population-based engineering and administrative measures, instead of helmets and helmet legislation. The Netherlands, Denmark, and Germany have focused on reducing interactions between motor vehicles and vulnerable road users, including cyclists. In cities such as Amsterdam and Copenhagen, cyclists ride on physically separated "cycle tracks" alongside major city streets or on "quiet streets" in residential neighbourhoods. This approach has resulted in much lower injury and fatality rates. If similar rates were achieved in British Columbia, I estimate there would be 3 to 6 fewer deaths and 300 to 900 fewer injuries per year. An interesting comparison is that the *cyclist* fatality rate in the Netherlands is almost identical to the *motorist* fatality rate in BC (1.1 vs. 0.97 per 100 million km travelled, respectively) and their cyclist injury rate is lower than our motorist injury rate (14 vs. 72 per 100 million km travelled, respectively), demonstrating the Dutch success in protecting vulnerable road users.

Separating cyclists from motor vehicle traffic and lowering traffic speeds are measures that also make people feel safer and motivate choice of cycling as a mode of transportation. Increasing bicycling has a number of public health benefits. One, outlined earlier in this report, is the increase in safety demonstrated with increased cycling modal share. Another potentially greater benefit is the reduction in premature mortality from chronic diseases including diabetes, heart disease and various cancers related to low levels of physical activity. The health benefits of cycling have been consistently estimated to greatly outweigh the injury risk, with estimated ratios of benefit to risk from 9:1 to 96:1 (Woodcock *et al.*, 2009; Johan de Hartog *et al.*, 2010; Rabl and de Nazelle, 2012; Rojas-Rueda *et al.*, 2011; Appendices U, V, W, X, respectively).

Our focus on helmets in British Columbia is associated with inequities. Cycling is an inexpensive mode of transportation that provides more travel options to youth and those with low incomes, but these are also demographic groups that are less likely to use helmets, even with helmet legislation.

Another inequity of helmet legislation is that it applies to bicyclists, but not to all road user classes, including one with much higher absolute numbers of injuries and one with similar fatality and injury rates. A reasonable public health approach is to address the overall injury *burden* by reducing the absolute numbers of injuries. This could be accomplished by promoting helmet use among motorists, since they suffer the largest numbers of head injuries from traffic collisions, more than an order of magnitude higher than pedestrians or cyclists. Suggesting helmet use by motorists may appear surprising, but race car drivers wear helmets, so it might be reasonable to suggest that helmet use migrate from car racers to ordinary motor vehicle users, in the same way that initial helmet use by bicycle racers was subsequently promoted for ordinary cyclists.

Another approach is to consider the *risk* of incurring an injury – per trip or per distance travelled. Here the classification of pedestrians and cyclists as vulnerable road users becomes clearer since in British Columbia their injury and fatality rates are, on the whole, higher than those of motorists. However the differences in rates between cyclists and pedestrians are not great, with fatality rates higher for pedestrians than cyclists, while the reverse is true of injury rates. The similarity in the injury and fatality rates of cyclists and pedestrians raises questions:

- Is the cyclist helmet law motivated by prevention of fatalities or injuries?
- As pedestrians have higher fatality rates than cyclists, how high would pedestrian fatality or injury rates need to be for pedestrians to be required to wear helmets?
- Alternatively, how low would cyclist fatality or injury rates need to be for the helmet law to be removed?
- Are helmet laws the right approach to injury reduction for either group?

In my view, given that the large majority of bicycling injuries remain despite helmet legislation, we have a responsibility to change our prevention focus from post-crash mitigation of head injuries towards measures that evidence shows us are much more effective at reducing all injuries to cyclists by preventing crashes before they occur.