



## Full length article

# Estimating the harms and costs of cannabis-attributable collisions in the Canadian provinces



Ashley Wettlaufer<sup>a,b,\*</sup>, Roxana O. Florica<sup>b</sup>, Mark Asbridge<sup>c</sup>, Douglas Beirness<sup>a</sup>, Jeffrey Brubacher<sup>d</sup>, Russell Callaghan<sup>e</sup>, Benedikt Fischer<sup>b,f</sup>, Gerrit Gmel<sup>b,g</sup>, Sameer Imtiaz<sup>b</sup>, Robert E. Mann<sup>b</sup>, Anna McKiernan<sup>a</sup>, Jürgen Rehm<sup>b</sup>

<sup>a</sup> Canadian Centre on Substance Abuse, Canada

<sup>b</sup> Centre for Addiction and Mental Health, Canada

<sup>c</sup> Dalhousie University, Canada

<sup>d</sup> University of British Columbia, Canada

<sup>e</sup> University of Northern British Columbia, Canada

<sup>f</sup> Centre for Criminology and Sociolegal Studies, University of Toronto, Canada

<sup>g</sup> The University of New South Wales, Australia

## ARTICLE INFO

## Article history:

Received 28 October 2016

Received in revised form

23 December 2016

Accepted 24 December 2016

Available online 20 February 2017

## Keywords:

Cannabis

Costs

Harm

Canada

Traffic collision

## ABSTRACT

**Introduction:** In 2012, 10% of Canadians used cannabis and just under half of those who use cannabis were estimated to have driven under the influence of cannabis. Substantial evidence has accumulated to indicate that driving after cannabis use increases collision risk significantly; however, little is known about the extent and costs associated with cannabis-related traffic collisions. This study quantifies the costs of cannabis-related traffic collisions in the Canadian provinces.

**Methods:** Province and age specific cannabis-attributable fractions (CAFs) were calculated for traffic collisions of varying severity. The CAFs were applied to traffic collision data in order to estimate the total number of persons involved in cannabis-attributable fatal, injury and property damage only collisions. Social cost values, based on willingness-to-pay and direct costs, were applied to estimate the costs associated with cannabis-related traffic collisions. The 95% confidence intervals were calculated using Monte Carlo methodology.

**Results:** Cannabis-attributable traffic collisions were estimated to have caused 75 deaths (95% CI: 0–213), 4407 injuries (95% CI: 20–11,549) and 7794 people (95% CI: 3107–13,086) were involved in property damage only collisions in Canada in 2012, totalling \$1,094,972,062 (95% CI: 37,069,392–2,934,108,175) with costs being highest among younger people.

**Discussion:** The cannabis-attributable driving harms and costs are substantial. The harm and cost of cannabis-related collisions is an important factor to consider as Canada looks to legalize and regulate the sale of cannabis. This analysis provides evidence to help inform Canadian policy to reduce the human and economic costs of drug-impaired driving.

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## 1. Introduction

Globally, cannabis is the most commonly used illicit drug and the prevalence of use in North America is higher than the global average (United Nations Office on Drugs and Crime, 2015). In 2012, the prevalence of past year cannabis use in Canada was 10% (Health Canada, 2012), with highest rates among youth aged 15–19 (22.4%)

and young adults aged 20–24 (26.2%) (Statistics Canada, 2012). Youth often initiate use of cannabis at a young age, aligning the age of initiation of cannabis use with the driving age in many provinces (Statistics Canada, 2013).

Recent roadside and self-report survey data indicate that between 2.5% and 5.5% of licensed drivers in Canada have driven under the influence of cannabis (Beasley et al., 2013; Health Canada, 2012), again with higher rates among younger drivers (Health Canada, 2012; Pashley et al., 2014; Solomon et al., 2015; Walsh and Mann, 1999; Young et al., 2011). To coincide with this, substantial evidence points to the role of cannabis use in elevating crash involvement (e.g., (Asbridge, 2014; Asbridge et al., 2012, 2014,

\* Corresponding author at: Canadian Centre on Substance Abuse, 500–75 Albert Street, Ottawa, ON K1P 5E7, Canada.

E-mail address: [AWettlaufer@ccsa.ca](mailto:AWettlaufer@ccsa.ca) (A. Wettlaufer).

2005; Beasley et al., 2013; Bédard et al., 2007; Beirness and Porath-Waller, 2015; Hall and Degenhardt, 2009; Mann et al., 2007, 2010; Mura et al., 2003; Poulin et al., 2007)). Four recent meta-analyses have concluded that cannabis use increases collision risk, with odds ratio estimates ranging from 1.10 to 2.79 (Asbridge et al., 2012; Elvik, 2013; Li et al., 2012; Rozeberg and Elvik, 2016). Although more research on how the drug affects collision risk is needed — for example, evidence on how collision risk varies with dose or blood THC levels (Asbridge et al., 2012).

While there is growing evidence that cannabis impairs the skills necessary for safe driving and increases collision risk (Burston et al., 2015), less is known about the larger social and economic impact of driving under the influence of cannabis (DUIIC). Studies have demonstrated the health and economic burden of motor vehicle collisions (Vodden et al., 2007) and, more specifically, the impact of alcohol-involved collisions (Rehm et al., 2006). To date, the health, social and economic costs linked to DUIIC-related collisions have yet to be estimated. Two recent studies, using different methodologies, estimated the numbers of traffic collision fatalities and injuries caused by cannabis in Canada (Fischer et al., 2015; Imtiaz et al., 2015). This study extends those methods and seeks to estimate the prevalence of DUIIC by age and province in order to calculate the numbers of people involved in fatal, injury and property damage only (PDO) collisions.

Additionally, this information will be used to estimate the social costs of cannabis-attributable traffic collisions across the Canadian provinces.

## 2. Methods

First, information on the prevalence of cannabis use in Canada's ten provinces was obtained and the prevalence of DUIIC was calculated. Next, information on the number of traffic collision fatalities, injuries and PDO victims for each province was collected. Then, the relative risk of collision involvement associated with DUIIC was obtained. This information permitted the estimation of population-attributable fractions which were used to determine the number of people involved in traffic collisions resulting in death, injury and PDO caused by cannabis in each province. Finally, estimates of the direct costs and human consequences associated with a collision fatality, injury and PDO collision were applied to estimate costs of DUIIC-attributable traffic collisions in Canada. These figures were estimated for 2012, which was the most recent year in which data were available. Estimates were not calculated for the territories due to a lack of available data.

### 2.1. Exposure data

The 2012 Canadian Alcohol and Drug Use Monitoring Survey (CADUMS) was used to obtain provincially representative estimates of past-year cannabis use by age group (Health Canada, 2012). To address the issue of small cell sizes, the marginal distributions were used to estimate the provincial prevalence rates by age group. The prevalence of DUIIC was obtained from a roadside survey of randomly selected drivers in British Columbia (B.C.). This survey tested oral fluids collected by the Quantisal® (Immunalysis Corporation, Pomona, CA) oral fluid collection kit to measure cannabis use. Laboratory testing of the samples used a cut off value of 5 ng/mL in oral fluid (personal communication, Beirness, 2015), which corresponds with the limit of detection for THC in whole blood (0.2 ng/mL) (Brubacher et al., 2016; Karschner et al., 2009). Due to the lack of provincial level data, the prevalence rates of DUIIC from B.C. were used as a basis to derive comparable estimates for the other provinces. These estimates were derived by incorporating variations in age specific self-reported prevalence rates of cannabis

use based on survey data to the BC roadside DUIIC data in order to estimate the prevalence of DUIIC among the other nine Canadian provinces.

### 2.2. Traffic collision outcome data

Provincial data on the number of persons involved in a traffic collision according to severity (fatality, injury, and property damage only), age group (16–19; 20–24; 25–34; 35–44; 45–54; 55–64; 65–74 and 75+) and road user type (motor vehicle driver, motorcyclist or moped rider, bicyclist, motor vehicle passenger and pedestrian) were provided by Transport Canada from the National Collision Database. Saskatchewan does not record age or road user information for all PDO collisions, and as such Saskatchewan PDO information was derived based on that observed in adjoining provinces (Alberta and Manitoba).

### 2.3. Relative risk: the relationship between cannabis use and traffic collision outcomes

Risk relation (RR) functions for fatal (RR=2.17, 95% CI: 1.00–4.70) and injury (RR=1.80, 95% CI: 1.00–3.23) traffic collisions for THC positive drivers were obtained from Imtiaz et al. (2015). These RRs were derived based on pooled relative risk estimates from four North American studies as RTIs are co-determined by other regionally varying factors that likely interact with cannabis use (see, Imtiaz et al., 2015). Risk estimates for property damage only (RR=1.26, 95% CI: 1.10–1.44) traffic collision outcomes were obtained from Elvik (2013).

### 2.4. Population attributable fractions

To estimate the costs associated with DUIIC, the number of persons involved in cannabis-attributable traffic collisions was estimated using the population attributable fraction methodology. Province and age-specific cannabis-attributable fractions (CAFs) were calculated by traffic collision severity. The following formula was used to calculate the CAF:

$$\text{CAF} = \text{Pe}(\text{RRe}-1)/(1 + \text{Pe}(\text{RRe}-1))$$

where *Pe* = Prevalence of exposure; *RRe* = Relative risk of outcome due to exposure group.

The CAFs were then applied to traffic collision data from Transport Canada in order to estimate the total number of persons involved in cannabis-attributable traffic collisions. Age- and province-specific estimates were generated for cannabis-attributable traffic collisions by varying severity. A sensitivity analysis was conducted to estimate the number of PDO victims and the associated costs at different cannabis exposure parameters as the relative risk estimate from Elvik (2013) was based on both acute and past-year cannabis exposure. The 95% confidence intervals (CI) around the point estimates were computed using Monte Carlo simulations. Each parameter of the CAF was sampled 1 million times based on their error distribution giving 1 million CAF samples. The CIs were taken as 2.5% and 97.5% percentiles of the CAF samples.

### 2.5. Cost estimation

Traffic collision cost estimates for 2012 were provided by the Ministry of Transportation of Ontario (Haya, personal communication, 2016), and these Ontario cost values were applied to all provinces to estimate costs of cannabis-attributable traffic collisions. The 2012 Ontario cost estimates were based on Vodden et al. (2007), who utilized a willingness-to-pay (WTP) methodology. Updated cost values taking into account recent modifications to the

**Table 1**  
Estimated prevalence of DUIC by age and province.

Age	BC	AB	SK	MB	ON	QC	NB	NS	PEI	NL
16–19	7%	6%	5%	7%	5%	5%	5%	6%	6%	6%
20–24	7%	6%	5%	6%	4%	4%	4%	6%	5%	5%
25–34	7%	6%	5%	6%	4%	4%	4%	6%	5%	5%
35–44	5%	4%	4%	5%	3%	3%	3%	5%	4%	4%
45–54	5%	4%	3%	4%	3%	3%	3%	4%	4%	4%
55–64	3%	2%	2%	3%	2%	2%	2%	2%	2%	2%
65–74	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
75+	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%

Acronyms used: BC – British Columbia; AB – Alberta; SK – Saskatchewan; MB – Manitoba; ON – Ontario; QC – Quebec; NB – New Brunswick; NS – Nova Scotia; PEI – Prince Edward Island; NL – Newfoundland.

value of statistical life (VSL) fractions were employed in the present analyses (Miller and Lawrence, 2015). Individual cost values were provided for a collision fatality (\$8,532,200), injury (\$84,600) and PDO collision (\$10,700; these are direct costs only). To derive the cost of the average collision injury, the average VSL fraction for injuries was calculated based on the distribution of major, minor and minimal injuries in Ontario, and used to compute the value of a traffic collision injury. The social costs of traffic collisions used in the present analyses were based on median WTP cost values and direct costs (e.g., property damage, emergency and health services, courts, tow truck and traffic delay expenses). The individual social cost values were applied to the cannabis-attributable death, injury and PDO collision outcome estimates to calculate the total social costs associated with DUIC.

### 3. Results

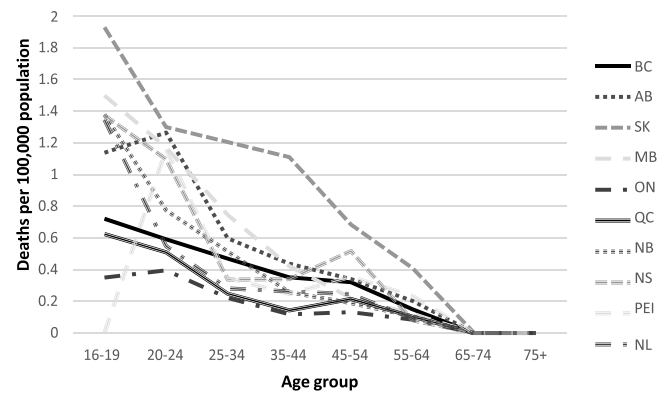
#### 3.1. The estimated prevalence of DUIC

In 2012, the estimated prevalence of DUIC in Canada was 4.1% and ranged from 3.4% to 5.5% across the provinces, with the highest rates found amongst those aged 16–19 and decreasing with age (Table 1). The CAFs computed for each age group and jurisdiction by traffic collision outcome severity are presented in Tables 1A–3A in the Appendix in Supplementary material.

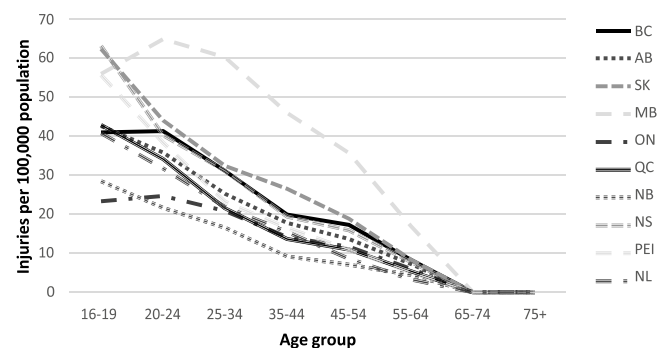
#### 3.2. The estimated cannabis-attributable traffic collision harms

The estimated number of traffic collision harms attributable to cannabis are presented in Table 2. Across all traffic collision outcomes, drivers appear to be most likely to be harmed. Using a second cannabis-exposure parameter (self-reported past year cannabis use) to test the robustness of the model for sensitivity purposes, up to 24,879 people were involved in a cannabis-attributable PDO collision, of which 21,856 (88%) were motor vehicle drivers. The rates of people involved in cannabis-attributable fatal, injury and PDO traffic collisions in 2012 are presented in Figs. 1–3.

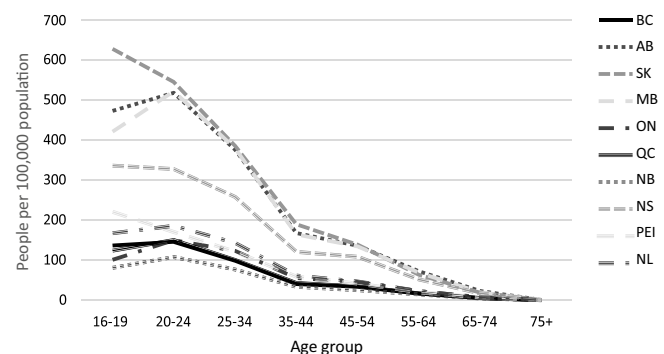
Cannabis-attributable fatalities, injuries and PDO collisions were particularly high among those ages 16–19, 20–24 and 25–34 years of age. While 16–34 year olds represented 32% of the adult population, they represented 61% of the cannabis-attributable fatalities, 59% of the cannabis-attributable injuries and 68% of the people involved in a cannabis-attributable PDO collisions. No cannabis-attributable deaths or injuries were estimated among those aged 65 years and older, and this age group represented just 1% of the proportion of people involved in cannabis-attributable PDO collisions. In examining the number of cannabis-attributable traffic collision outcomes across provinces, variation across jurisdictions was observed. For example, Saskatchewan had relatively high rates of cannabis-attributable traffic collision fatalities compared to other jurisdictions whereas Manitoba had



**Fig. 1.** Estimated cannabis-attributable traffic collision deaths per 100,000 population in 2012, by age and province.



**Fig. 2.** Estimated cannabis-attributable traffic collision injuries per 100,000 population in 2012, by age and province.



**Fig. 3.** Estimated number of people per 100,000 population involved in a cannabis-attributable PDO in 2012, by age and province.

relatively high rates of cannabis-attributable traffic collision injuries. Saskatchewan, Alberta and Manitoba all demonstrated higher rates of PDO victims compared to other provinces.

#### 3.3. The estimated cannabis-attributable traffic collision costs

The total estimated cost of cannabis-attributable traffic collisions in Canada in 2012 was approximately \$1.09 billion, with drivers accounting for approximately \$643 million (59%) of these costs. Overall, fatalities accounted for 58% of the costs and injuries accounted for 34% of all cannabis-attributable costs (Table 3). Those aged 34 years and younger accounted for approximately \$658 million (60%) of the total traffic collision related costs attributable to cannabis use.

**Table 2**

Estimated cannabis-attributable traffic collision outcomes for the 10 provinces by level of severity, in 2012.

Cannabis-attributable traffic collision outcomes	Number of road users	Number of drivers (%)
Cannabis-attributable deaths	75 (95% CI: 0–213)	38 (95% CI: 0–109) (51%)
Cannabis-attributable injuries	4407 (95% CI: 20–11,549)	2856 (95% CI: 13–7486) (65%)
Cannabis-attributable PDO victims	7794 (95% CI: 3107–13,086)	6879 (95% CI: 2742–11,550) (88%)

**Table 3**

Cannabis-attributable costs for the 10 provinces by traffic collision outcome severity.

Cannabis-attributable traffic collision harms	All road user costs	95% CI
Cannabis-attributable death costs	\$638,776,532	(2,163,672–1,817,022,033)
Cannabis-attributable injury costs	\$372,797,626	(166,4133–977,071,132)
Cannabis-attributable PDO costs (acute cannabis use)	\$83,397,905	(33,241,586–266,203,832)
Cannabis-attributable PDO costs (past-12 month cannabis use)	(\$266,203,832)	–
<b>TOTAL COSTS</b>	<b>\$1,094,972,062 (\$1,277,777,990)</b>	<b>(37,069,392–2,934,108,175)</b>

## 4. Discussion

Cannabinoids are among the most common psychoactive substances found in dead and injured drivers in Canada (Beasley and Beirness, 2011; Brubacher et al., 2016) however, there is a common perception among some cannabis users that DUIC is a safe behaviour. This perception could be due to drivers believing that when they are driving under the influence of cannabis they are aware of their impairment and believe they are able to compensate for these effects (Fischer et al., 2006; Porath-Waller et al., 2013). However, in the past two decades several well-designed studies have demonstrated that cannabis impairment has clear impacts on collision risk (Asbridge, 2014; Asbridge et al., 2012, 2005; Bédard et al., 2007; Hall and Degenhardt, 2009; Mann et al., 2007, 2010; Mura et al., 2003; Poulin et al., 2007). This study uses that information to provide estimates of the numbers and social costs of cannabis-attributable collisions across the Canadian provinces. These estimates are of interest at a time when Federal and Provincial governments are considering cannabis-related policies, including those related to DUIC in Canada.

Our results suggest that DUIC has a substantial impact on collision rates and attendant costs in Canada. Overall, we estimate 75 collision deaths, 4407 injuries and 7794 victims of PDO collisions attributable to cannabis use, amounting to \$1.09 billion in costs in 2012. Our estimate of 75 cannabis-attributable traffic collision deaths is somewhat less than the 94 deaths estimated by Imtiaz et al. (2015). This variation can be explained by the fact that Imtiaz et al. (2015) provided estimates based on national totals, while the current study calculated deaths, injuries and PDO victims for each province individually but were limited to the 10 provinces due to lack of comparable exposure data for the territories. Despite this difference, our estimates are similar and both fall within the 95% confidence intervals of the other.

Injuries are much more numerous than fatalities, and can range in severity up to those causing serious and permanent disability. Meanwhile, PDO collisions did not result in fatalities or injuries, but they reflect the social and economic burden of cannabis-caused collisions. We observed variation across provinces and age groups in the numbers and rates of deaths, injuries and collisions resulting from DUIC (summarized in Figs. 1–3). These variations are due to several factors, most notably differences between provinces, and age groups, in rates of cannabis use, DUIC and collision outcomes (Adlaf et al., 2003; Health Canada, 2012; Ialomiteanu et al., 2014). It is clear that the greatest burden is on young and novice drivers under the age of 34 which is concerning as young drivers are already at an increased crash risk regardless of impairment due to substances (Bates et al., 2014). The higher prevalence of DUIC among younger drivers also means that these cost estimates are likely to be conservative as the cost estimates applied in this study are based

on averaged cost estimates across all age groups. Costs resulting from deaths and injuries among younger road users are likely to be higher because they are associated with more years of life lost or living with a disability; these differential costs are not captured in this analysis. However, the increasingly common use of cannabis among older populations (Ialomiteanu et al., 2014), suggests that the cannabis-attributable collision harms, and the related costs, are likely to continue to increase (Salomonsen-Sautel et al., 2014).

In comparison, a Canadian Council of Motor Transport Administrators (CCMTA) report indicates that in 2012, 707 people died and 2314 drivers were involved in a serious injury alcohol-related collision across Canada, excluding British Columbia (Brown et al., 2015). Similar to the current findings, younger people were more likely to be killed or seriously injured in an alcohol-related collision. Of the 707 alcohol-related deaths and 2314 serious alcohol-related driver injuries over half (56% of deaths and 55.5% of serious driver injuries) occurred amongst people ages 35 and younger (Brown et al., 2015).

### 4.1. Implications for policy and practice

The present results suggest that the improved prevention of cannabis-related collisions would lead to important reductions in deaths, injuries and property damage, and in health, social and economic costs in Canada. The harm and cost of cannabis-related collisions is an important factor to consider as Canada looks to legalize and regulate the sale of cannabis (Philpott, 2016). This study may serve as a valuable benchmark estimate of the harms and costs associated with DUIC prior to the legalization of cannabis in Canada. Since specific efforts to prevent DUIC are relatively recent, little evidence on their effectiveness is available (Asbridge et al., 2016). Several jurisdictions in Australia, Europe and the United States have introduced *per se* laws modelled on those designed to prevent driving after drinking (Wong et al., 2014). A *per se* law is a law which stipulates that it is an offence to operate a vehicle with a concentration of alcohol or drugs in the body in excess of a specified threshold value (Canadian Centre on Substance Abuse, 2016). These laws have been coupled with the adoption of improved enforcement techniques that include the adoption of random roadside testing of drivers via oral fluid. These methods overcome many of the limitations of current enforcement approaches in Canada by allowing for the immediate assessment of recent drug use at the roadside, with a follow-up penalty (fine, suspension or criminal charge) for those who exceed the legal limit. Movement towards a similar approach in Canada could help to improve current enforcement efforts.

Additionally, youth prevention programs that are guided by psycho-social theories of behavior and target salient risk and protective factors may help address perceptions that DUIC is a safe behaviour (Griffin and Botvin, 2010; Robertson and Pashley, 2015). Cook et al. (2017) have observed that some restrictions in



graduated licensing programs appear to reduce DUI among young drivers (Cook et al., 2017). Also, evaluations of remedial programs for convicted impaired drivers suggest that these programs can successfully reduce use of cannabis, as well as alcohol and other drugs (Stoduto et al., 2014). It will be important to monitor and evaluate the success of DUI prevention efforts in order to most effectively reduce casualties and costs that result from this behaviour.

#### 4.2. Limitations

While the results reported here are of substantial interest, they are also subject to important limitations. First, estimates are restricted to a single year, 2012, and thus may not reflect changes in cannabis use and DUI, or in road safety policy and enforcement practices over time. Second, data on the population prevalence of cannabis use and DUI are limited; objective estimates of DUI were based on available data from British Columbia and might not reflect regional difference in this behaviour. Due to the lack of data on population prevalence of cannabis use in the territories they were not included in this analysis. Third, our estimates only include traffic collisions reported to police or requiring admission to hospital and thus under-represent minor collisions resulting in less severe injury and damages under a monetary threshold of \$1000–\$2000, depending on the province. Fourth, the estimate of risk derived from recent epidemiological assessments does not partition risk by level of THC in the body. Cannabis effects are dose-dependent, and it is reasonable to assume that its effects on collision risk would also increase with THC concentration (Ramaekers et al., 2004). Additionally, due to the lack of comparable cost estimates in other jurisdictions, traffic collision cost estimates from Ontario were applied to calculate the costs in each province and may not reflect provincial differences in collision costs. Finally, the 95% confidence intervals were quite broad and should be interpreted with caution. This is a product of the quality and variation in the data available.

#### 4.3. Conclusions and future research directions

Our results suggest that cannabis has a substantial impact on collision rates in Canada, and represents a substantial economic burden. Youth and young adults were over represented in all three levels of traffic collisions leading to higher cannabis-attributable harms and costs among this age group. Further research is needed to understand their patterns of cannabis use and DUI and effective means of prevention. Additional research is also needed to understand how the impact of cannabis on driving skills and collision risk is affected by dose, experience with the drug, driving experience and other factors. It is also important to understand jurisdiction-specific patterns of cannabis use and DUI. Roadside surveys see (Beasley et al., 2013) are an effective way of measuring DUI and should be extended to other provinces and territories.

#### Conflict of interest

This work was supported in part by a charitable donation made by State Farm Insurance to the Canadian Centre on Substance Abuse.

#### Role of funding source

This work was funded by the Canadian Centre on Substance Abuse. This work was supported in part by a charitable donation made by State Farm Insurance to the Canadian Centre on Substance Abuse to further research in the field of impaired driving. State Farm Insurance was not involved in the design of the project, collection,

analysis or interpretation of the data, the writing of this manuscript nor the decision to submit the manuscript for publication. Additionally, in-kind support was provided by co-investigators' respective organizations.

#### Author contributions

Ashley A. Wettlaufer, Roxana O. Florica, Mark Asbridge, Douglas Beirness, Jeffery Brubacher, Russel Callaghan, Benedikt Fischer, Sameer Imtiaz, Robert E. Mann, and Anna McKiernan were involved in the conceptualization of this project. Ashley A. Wettlaufer, Roxana O. Florica and Doug Beriness were responsible for the acquisition of data. Under the guidance of Jurgen Rehm and Sameer Imtiaz, Ashley A. Wettlaufer, Roxana O. Florica and Gerrit Gmel conducted the analysis. With guidance and input from all authors Ashley A. Wettlaufer, Roxana O. Florica and Robert E. Mann interpreted the data and co-wrote the first draft of the manuscript. All authors provided input on the content of several manuscript drafts and approved the final version before it was submitted.

#### Acknowledgments

We gratefully acknowledge the provinces and Transport Canada for the provision of Motor Vehicle Collision data, as well as Ministry of Transportation Ontario for providing the estimated cost values, that made this project possible. In addition, we acknowledge the charitable donation made by State Farm Insurance that, in part, supported this work along with the in-kind support provided by our co-investigators' organizations.

#### Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at <http://dx.doi.org/10.1016/j.drugalcdep.2016.12.024>.

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