Evidence Brief: Driving Under the Influence of Cannabis and Risk of Motor Vehicle Collision

Key Messages

- According to the Canadian Alcohol and Drug Use Monitoring survey, 2.5% of Canadian drivers reported driving under the influence of cannabis (DUIC) in 2012.
- Five studies assessed the impact of cannabis legislation on driving-related outcomes, with mixed results. No study directly assessed the impact of cannabis legalization on the prevalence of DUIC.
- Four meta-analyses concluded that DUIC significantly but moderately increased the risk of motor vehicle collision compared to driving unimpaired.

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Background

The term cannabis refers to the cannabis plant, *Cannabis sativa*, and its products.[1] The main psychoactive ingredient in cannabis is delta-9-tetrahydrocannabinol (THC).[2] Acute intoxication with cannabis has effects that include euphoria, changes in perception and attention, and impaired motor functioning.[1]

Cannabis is the most widely-used psychoactive drug in Canada, after alcohol and tobacco.[1] According to the 2012 Canadian Alcohol and Drug Use Monitoring Survey (CADUMS), 41.5% of Canadian adults used cannabis at least once *in their lifetime*.[3] According to the 2015 Canadian Tobacco, Alcohol and Drugs Survey (CTADS), 12% of Canadians reported having used cannabis at least once *in the past year*.[4]

Cannabis legalization

The Government of Canada introduced legislation on the legalization and regulation of cannabis on April 13, 2017, and aims to implement regulated access to cannabis no later than July 2018.[5] During this process, the federal government will work with provinces on key implementation issues, such as preventing

drug-impaired driving. Whereas driving under the influence of cannabis (DUIC) is not a new phenomenon in Canada, cannabis legalization has the potential to increase cannabis use and DUIC.

Effects of cannabis intoxication on driving: evidence from experimental studies

Experimental studies, as well as simulated and on-road driving experiments, have shown that acute cannabis intoxication is associated with performance deficits on several cognitive and motor tasks relevant to driving,[1] changes in driving performance,[6] and a reduction in the ability to handle unexpected events.[1,6] The use of cannabis and alcohol in combination produce increased effects on impairment[6] and driving skills.[1]

As experimental conditions only provide indirect evidence about the real-life risk of motor vehicle collision (MVC) from driving under the influence of cannabis (DUIC),[1] evidence from epidemiological studies will be summarized in this Evidence Brief.

DUIC: legislation and enforcement

Driving under the influence (DUI) refers to the operation of a motor vehicle while one's ability is adversely affected by psychoactive substances such as alcohol or drugs,[1] and is a criminal offence in Canada.[1]

At present, enforcement of drug-impaired driving legislation is based on the assessment of functional impairment using a Standardized Field Sobriety Test (SFST).[1] Drivers who demonstrate impaired performance must undergo evaluation by an officer trained in the Drug Evaluation and Classification (DEC) program.[1] The validity and reliability of current methods for assessing functional impairment from cannabis use are the subject of discussion.[7]

Measuring cannabis intoxication using THC concentration in body fluids

Measurement of cannabis intoxication using body fluids presents challenges not encountered with alcohol and can lead to false positive and false negative results.[1]

Impairment from alcohol closely mirrors blood alcohol level, as alcohol dissolves readily in blood. In contrast, experimental studies have shown that functional impairment from cannabis (which binds to fats) lags behind THC blood level, which begins to decline prior to peak intoxication (Figure 2).[6] Additionally, low levels of cannabis may be detected for days to weeks after the period of intoxication has ended.

Further measurement challenges are introduced due to additional routes of exposure for cannabis, such as inhalation and ingestion, where timing of peak levels and intoxication varies.[7] Tolerance to cannabis among those who use it frequently also complicates the use of body fluids to predict intoxication. [6]

Establishment of fixed legal limits for THC in body fluids

Fixed legal limits, often known as '*per se* laws', facilitate the enforcement of impaired driving legislation: any driver in whom the concentration of a particular substance reaches or exceeds the legal limit is considered to have broken the law without there being a need to demonstrate any further signs of impairment.[8]

To date, only a few jurisdictions such as Norway,[9] Denmark,[10] and the State of Washington,[11] have passed legislation specifying a legal limit for THC. Development of *per se* limits were recommended by the Task Force on Cannabis Legalization and Regulation.[12]

Issue and Research Question

To inform the public health response to cannabis-impaired driving, this Evidence Brief addresses three questions:

1. What is the prevalence of DUIC in Ontario and Canada? How has it changed over time?

2. In jurisdictions where new cannabis legislation was introduced, did the prevalence of DUIC change following the change in legislation?

3. Does DUIC increase the risk of motor vehicle collision as compared to driving sober? By how much?

A related Evidence Brief, *Driving Under the Influence of Cannabis – Risk Factors and Preventive Interventions,* examines the risk and protective factors for DUIC as well as effective interventions for reducing DUIC. A review of the evidence quantifying the burden of harms from DUIC in Canada was not in scope for this Evidence Brief.

Methods

Literature search

We searched four databases (MEDLINE, EMBASE, CINAHL, PsychINFO) with the assistance of a PHO Library Information Specialist on January 27, 2017 for articles published between 2006-2017; this search was updated on June 5, 2017. The following search terms were used: "cannabis", "marijuana", "THC" and related terms, in combination with terms related to "driving". The full search strategy is available from PHO on request. References within the included articles were hand searched for additional relevant studies. For research question #1 on DUIC prevalence in Ontario and Canada, we conducted a targeted search of grey literature relevant sources: the Canadian Alcohol and Drug Use Monitoring Survey (CADUMS), the Road Safety Monitor (RSM) road-side survey conducted by the Traffic Injury Research Foundation (TIRF), and the Ontario Student Drug Use and Health Survey (OSDUHS).

Eligibility criteria

Studies were eligible for inclusion if they were published in English or French, between 2006 and 2017.

For research question #1:

Eligible studies reported the population prevalence of DUIC for anywhere in Canada.

For research question #2:

Eligible study designs included pre-post repeat cross-sectional studies, interrupted time series, and natural experiments; the intervention/exposure was a change in cannabis legislation; the outcome was the prevalence of DUIC or a proxy measure of this; and the study setting was a country similar to Canada, i.e., a member-country of the Organisation for Economic Co-operation and Development (OECD).[13]

For research question #3:

Eligible study designs included systematic reviews and meta-analyses, as well as any observational studies published after the latest meta-analysis literature search period (after 2015); the exposure was cannabis-impaired driving; the comparison was unimpaired driving; and the outcome was motor-vehicle collision.

Article screening, data extraction, and quality appraisal

Two reviewers independently screened titles and abstracts for eligibility using DistillerSR software from Evidence Partners (Ottawa, Canada). Two independent reviewers then used DistillerSR to review full-text articles for eligibility. One reviewer extracted relevant information from all included studies and 20% were verified by a second reviewer. Both reviewers independently appraised the quality of the included studies using a tool appropriate for the study's design (AMSTAR[14] for meta-analyses and systematic reviews, the

Newcastle-Ottawa scale for case-control studies,[15] the Newcastle-Ottawa scale modified for cross-sectional studies,[16] and the EPHPP[17] for natural experiments and interrupted time-series). Discrepancies in quality appraisal outcomes between the reviewers were resolved by consensus. More information on quality appraisal is available upon request.

Main Findings

The literature search identified 1,354 unique articles. A total of 124 articles underwent full-text screening. Four published articles[18-21] and three grey literature reports[3,22,23] were included to answer research question #1 on the prevalence of DUIC in Ontario and Canada. Five articles[2,11,24-26] were included to answer research question #2 about the impact of changes in cannabis legislation on DUIC prevalence. For question #3 on the risk of MVC due to DUIC, 19 articles were identified, but this Evidence Brief focuses on the four meta-analyses[27-30] as well as one primary research study[31] published after the latest meta-analysis.

1. DUIC prevalence in Ontario and Canada

Studies of DUIC prevalence in Canada used one of two approaches for measuring DUIC: self-report of cannabis use prior to driving or roadside testing of driver's oral fluid.

DUIC prevalence based on self-report

Four published articles[18-21] and three grey literature reports[3,22,23] assessed DUIC prevalence based on self-report. Three published studies[18,19,21] scored 3/5 on the Newcastle-Ottawa scale modified for cross-sectional studies, and one scored 4/5[20] on the same scale.[16]

Canadian Alcohol and Drug Use Monitoring Survey (CADUMS): The CADUMS was an annual general population survey of alcohol and drug use among Canadians aged 15 years and older conducted by Health Canada from 2008 to 2012.[3] The 2012 CADUMS found that 2.5% (95% confidence interval [CI]: 1.9-3.3%) of Canadian drivers[32] and 2.7% (95% CI: 1.5-4.9%) of Ontario drivers[33] admitted driving within two hours of using cannabis at least once in the previous 12 months. The prevalence of DUIC among Canadian drivers was higher for adolescents and young adults: 4.7% (95% CI: 2.8-7.8) among drivers aged 24 years or younger, as compared to 2.2% (95% CI: 1.5-3.1) among drivers aged 25 years or older.[33] The response rate for the 2012 CADUMS was 39.8%.

Road Safety Monitor (RSM): The RSM is a public opinion telephone and on-line survey of a random, representative sample of Canadian drivers conducted annually by Traffic Injury Research Foundation (TIRF).[23] The 2013 RSM found that 1.6% ± 2.8% of Canadian drivers said that they had driven a motor vehicle within two hours of using marijuana or hashish at least once during the previous 12 months.[23] The response rate for the 2013 RSM was not reported. One published article[19] also used RSM data from 2015 and reported that the proportion of self-reported driving within two hours of using cannabis in the past 12 months was 2.6% ± 2.8%.[19]

Canadian Student Tobacco, Alcohol and Drugs Survey (CSTADS): The CSTADS is a biennial, provincially-generalizable, paper-and-pencil, school-based survey administered to Canadian students.[21] A cross-sectional study using data from the 2014-2015 CSTADS found that prevalence of *ever* driving within 2 hours of using marijuana among grade 11-12 students was 7.2%, (95% CI: 5.8-8.6) in Ontario and 9.4%, (95% CI: 8.3-10.4) in Canada.[21] This study also found that the prevalence of DUIC *in the last 30 days* was 3.5%, (95% CI: 2.1-4.9) in Ontario and 4.7% (95% CI: 3.9-5.5) in Canada.[21]

Ontario Student Drug Use and Health Survey (OSDUHS): The OSDUHS is a self-administered, anonymous survey of students in grades 7-12 across Ontario conducted by the Centre for Addiction and Mental Health every two years since 1977.[22] The 2015 OSDUHS found that 9.8%, 95% CI (8.3-11.4%) of drivers in grade 10-12 reported driving a vehicle within one hour of using cannabis at least once during the past year.[22] Of note, the percentage of drivers in

grades 10–12 reporting driving after cannabis use (10%) was higher than the percentage reporting driving after drinking alcohol (5%).[22] In 2015, the OSDUHS response rate was 59%; however, an analysis found no evidence of non-response bias.[22]

Data from earlier time periods indicate that DUIC among grade 10-12 drivers decreased over the past decade. DUIC in this group was estimated at 20% in 2001-2005. One published article[18] used data from the 2009 OSDUHS; it reported that 16.3% of licensed students in Ontario reported DUIC in the past year (in 2009).

DUIC prevalence based on roadside testing of oral fluid

One cross-sectional study[20] assessed the prevalence of DUIC using roadside testing of drivers' oral fluid. The investigators tested a random sample of nighttime non-commercial drivers from 16 sites in 3 British Columbia cities in June 2008. Of the 1533 vehicles selected, 78% (N=1,199) provided a sample of oral fluid. Among participating drivers, 4.6 ± 1.8% tested positive for cannabis.

2. Impact of cannabis legislative changes on DUIC prevalence

A total of five studies[2,11,24-26] measured DUIC before and after a change in cannabis legislation; all were conducted in the U.S. In general, legislative changes consisted of decriminalization or legalization. The prevalence of DUIC was directly estimated in only one study.[24] The other four studies used 'proxy' measures of DUIC: two studies[2,11] assessed the proportion of DUI law enforcement cases that tested positive for cannabis, and two studies[25,26] assessed the proportion of fatal MVCs in which the driver tested positive for cannabis.

The only study[24] that directly estimated DUIC prevalence used a repeated road-side survey design to measure laboratory-confirmed DUIC before and after the decriminalization of cannabis in California (effective January 1, 2011). It reported no statistically significant change in the prevalence of THC-positive driving among weekend nighttime drivers (n = 894) in 2012 (9.2%; 95% CI: 6.3, 12.2) compared to 2010 (11.3%; 95% CI: 8.5, 14.0) or in the adjusted odds of testing positive for THC in 2012 compared to 2010 (adjusted odds ratio [AOR] = 0.96; 95% CI: 0.57, 1.60). This study's quality was rated as moderate using the EPHPP tool, primarily because of potential selection bias (participation rate <80%). No study directly assessed the impact of cannabis legalization on the prevalence of DUIC.

Two natural experiments[2,11] assessed the proportion of drivers suspected of DUI by law enforcement that tested positive for cannabis before and after cannabis legalization in December 2012 in Colorado and Washington State. The Colorado natural experiment[2] reported no change in cannabis screening test-positivity rate among drivers suspected of DUI from 2011-2014 (62% positive overall, range: 59–68% by year). However, the cannabis confirmation test-positivity rate (i.e., THC greater or equal to 2 ng/mL) increased significantly from 28% in 2011 to 65% in 2013. The natural experiment in Washington state[11] reported a statistically significant increase of 5.8% and 12.1% in suspected DUI drivers testing positive for THC and carboxy-THC, respectively, post-legalization (2013) compared with pre-legalization (2009-2012). The quality of both of these studies[2,11] was rated as weak using the EPHPP tool because of likely selection bias as well as confounding (in both studies, laboratory testing equipment and processes changed concurrently with the legislation change).

Two interrupted time series[25,26] used data from the Fatality Analysis Reporting System (FARS) to assess if the prevalence of cannabis among drivers involved in a fatal MVC increased after a change in cannabis legislation. One found an increase in the proportion of drivers involved in a fatal MVC who tested positive for cannabis in three of twelve states after medical marijuana legislation came into effect (ranging from 2.1 to 6.0% increase among drivers in all fatal crashes, and 4.6 to 9.6% among fatally-injured drivers depending on the state). The other found an

increase in the proportion of Colorado drivers involved in a fatal MVC who tested positive for cannabis increased after the widespread commercialization of legal medical marijuana in mid-2009 (change in trend, Beta=2.16 (SE=0.45), p<0.0001). The quality of both of these studies[25,26] was rated as moderate; both studies were subject to misclassification bias.

3. DUIC and the risk of MVC

Four meta-analyses,[27,29,30,34] and one case-control study[31] published after these reviews assessed the risk of MVC from DUIC. The quality of these studies was assessed using AMSTAR: scores ranged from 6-8/11 for the meta-analyses and the case-control study scored 3/9 on the Newcastle-Ottawa scale.

All four meta-analyses[27,29,30,34] reported that DUIC significantly increased the risk of MVC. However, the magnitude of the risk increase differed between the studies, ranging from OR=1.22 (95% CI: 1.1–1.36) in the most recent meta-analysis[27] to OR=2.66 (95% CI: 2.07–3.41) in the meta-analysis with the most methodological flaws based on our quality appraisal.[30]

A case-control study[31] published after the latest meta-analysis reported the risk of fatal MVC from DUIC (as compared to unimpaired driving) to be OR=1.54 (95% CI: 1.16-2.03); this risk is similar to that of latest meta-analysis.[27] This case-control study also estimated the magnitude of fatal MVC risk from drunk driving: OR=16.33 (95% CI: 14.23-18.75), as well as the combined risk of fatal MVC from alcohol and cannabis combined: OR=25.09 (95% CI: 17.97-35.03).[31]

Discussion and Conclusions

Overall, there was scant data on the prevalence of DUIC in Ontario and Canada, and the majority was based on self-report. The CADUMS[32] and RSM[23] estimated that 2.5% (95% CI: 1.9-3.3%) and 1.6% ± 2.8% of Canadian drivers self-reported DUIC in the previous year, respectively. The prevalence of DUIC among adult drivers was similar in Ontario and Canada.[33] In contrast, DUIC prevalence based on roadside testing of oral fluid among night drivers was approximately twice as high (4.6%).[20] Also, results from the CSTADS[21] and OSDUHS[22] suggest that self-reported DUIC is more common among younger drivers compared to the general population. Of note, the prevalence of DUIC among Ontario youth was lower than the Canadian average.[21]

Five studies[2,11,24-26] compared DUIC before and after various cannabis legislation changes in different U.S. states, with varying results. The only study[24] that directly measured DUIC prevalence using a road-side survey reported no significant change following cannabis *decriminalization* in California. The remaining four studies noted an increase in the THC test-positivity rate for suspected DUI cases[2,11] and fatal MVCs following various cannabis legislation changes.[25,26]

The included meta-analyses,[27,29,30,34] and recent case-control study[31] of the risk of MVC from DUIC agreed that, compared to driving unimpaired, DUIC significantly but moderately increases the risk of MVC. This is in keeping with the National Academies of Sciences, Engineering, and Medicine's recent report on the health effects of cannabis, which concluded that "there is substantial evidence of a statistical association between cannabis use and increased risk of motor vehicle crashes".[35] The latest included meta-analysis found that DUIC increased the risk of MVC by about 22% (OR=1.22; 95% CI: 1.10-1.36), compared to unimpaired driving.[27]

This evidence brief did not seek specifically to compare the risk of DIUC to alcohol-impaired driving. However, to provide additional context, based on other literature we note that the odds ratio of a fatal MVC differs for alcohol and cannabis: alcohol-impaired driving (BAC ≥0.08) ranged from 7.48 to 19.72, compared with 0.86 (95% CI 0.61-1.23) for cannabis.[36] This difference in the risk of MVC or fatal injury among impaired drivers arising from DUIC versus alcohol-impaired driving may be related to the different pattern of impairment

produced by each substance;[6] for example, alcohol-impaired driving has been associated with increased speeds, and DUIC with reduced speeds.[6] Alternatively, misclassification bias arising from challenges in measuring cannabis impairment would be expected to bias estimates of the risk of MVC from DUIC toward the null hypothesis (i.e., no increased risk). Further research using more rigorous study designs (e.g., case-crossover studies), more accurate measurement of cannabis impairment, and better control of confounding factors (e.g., alcohol, other drugs) would provide better estimates of the magnitude of the risk of MVC from DUIC, including relative to other risk factors.

Even though the risk of MVC from DUIC is lower than for drunk driving, the burden of DUIC-related harms in Canada is still considerable.[37] This is highlighted in a separate Evidence Brief, which also examines the risk and protective factors for DUIC as well as effective intervention for reducing DUIC.

Implications for Practice

The Ontario Public Health Standard (OPHS) on the 'Prevention of Injury and Substance Misuse' requires local Boards of Health to engage in assessment and surveillance, health protection, and health promotion and policy development activities related to road safety generally, and drunk (or drugged) driving specifically.[38] The evidence summarized in this Evidence Brief can help inform the public health response to DUIC.

In particular, this Evidence Brief highlights the need for continued assessment and surveillance of DUIC. Quantifying DUIC before and after cannabis legalization will be essential for evaluating the impact of this policy change. Research methods should account for secular trends in testing drivers for cannabis, as well as changes in the validity, reliability, and criteria for testing (e.g., the change from discretionary to universal testing when *per se* laws are implemented).

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Specifications and Limitations of Evidence Briefs

The purpose of this Evidence Brief is to investigate a research question in a timely manner to help inform decision making. The Evidence Brief presents key findings, based on a systematic search of the best available evidence near the time of publication, as well as systematic screening and extraction of the data from that evidence. It does not report the same level of detail as a full systematic review. Every attempt has been made to incorporate the highest level of evidence on the topic. There may be relevant individual studies that are not included; however, it is important to consider at the time of use of this brief whether individual studies would alter the conclusions drawn from the document.

Authors

Geneviève Cadieux, Public Health & Preventive Medicine Resident Physician, University of Toronto
Pamela Leece, Public Health Physician, Health Promotion, Chronic Disease and Injury Prevention

Contributors

Erin Berembaum, Research Coordinator, Health Promotion, Chronic Disease and Injury Prevention
Chetan Mistry, Research Assistant, Health Promotion, Chronic Disease and Injury Prevention

Reviewers

Heather Manson, Chief, Health Promotion, Chronic Disease and Injury Prevention
Benedikt Fischer, Senior Scientist, Centre for Addictions and Mental Health (CAMH)
Jason LeMar, Health Promotion Consultant, Health Promotion, Chronic Disease and Injury Prevention

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Knowledge Synthesis Services, Health Promotion, Chronic Disease and Injury Prevention
Email: hpcdip@oahpp.ca

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

For more information about PHO, visit www.publichealthontario.ca.

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