ALCOHOL, MARIJUANA & DRIVING RISK

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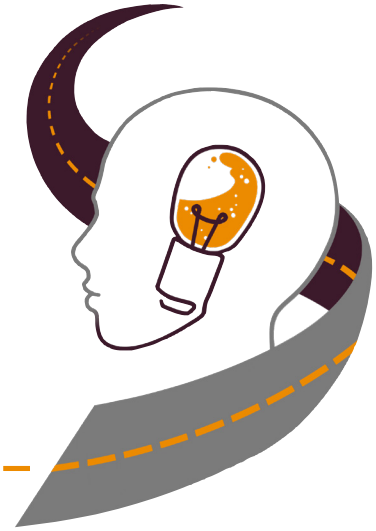
By Craig Lyon & Robyn D. Robertson

SoberSmartDriving.tirf.ca



Drug-impaired driving and notably, marijuana-impaired driving have been priority road safety issues in Canada for more than a decade. Concern is based on growing recognition that illicit and licit substances can impair driving skills to varying degrees. Marijuana, cocaine, amphetamines and a variety of prescription medications, particularly pain medications, as well as over-the-counter medications have been increasingly detected in drivers killed in road crashes. More concerning, the combination of marijuana and alcohol is prevalent among drivers self-reporting using drugs within two hours of driving and drivers killed in road crashes.

With the passage of Bill C-45 or the Marijuana Act by the Canadian Federal Government in October 2018, the possession, growing, selling, and consumption of marijuana was legalized. In tandem with this legislation, the Canadian Government also implemented Bill C-46 which comprised a major revision to Federal impaired driving legislation and several new provisions to drug-impaired driving were added specifically to mitigate road safety concerns.

As such, the prevalence of drug-impaired driving and the new legal status of marijuana makes it timely to review new research evidence about the impairing effects of alcohol and marijuana alone as well as combined. In particular, the emergence of edible marijuana products with much higher potency has raised questions about implications for impaired driving and many questions remain unanswered. For these reasons, it is imperative that Canadian legislators, police services and other criminal justice professionals, transportation officials and researchers understand the risks posed by the combined use of these substances. Perhaps more importantly, there is an equal need for heightened awareness among drivers on the road.

This fact sheet presents the latest data regarding the prevalence of alcohol and marijuana alone, and the combined use of these substances among Canadian drivers on the road, and drivers killed in road

crashes. It explains the dose-response relationship of alcohol as well as marijuana, and their respective impairing effects. It also summarizes the combined impairing effects of alcohol and marijuana on driving skills and crash risk. The attitudes and practices of drivers towards driving after using them are discussed along with enforcement issues and strategies to reduce recidivism.

Prevalence of alcohol in drivers and road crashes

Alcohol-impaired driving has been a leading contributor to road crashes in Canada for more than three decades. Dramatic progress reducing the number of alcohol-involved crashes resulting in fatal and serious injuries has been achieved during this period (Robertson et al., 2018). Today, less than 10% of Canadians self-report driving after drinking when they thought they were over the legal limit (Lyon et al., 2019) and fatal road crashes involving a drinking driver have decreased substantially, representing 28.8% of road deaths in 2016. The total number of persons killed in alcohol-related crashes has declined from 1,057 in 1995 to 480 deaths in 2016, according to the Traffic Injury Research Foundation (TIRF) National Fatality Database (Simpson et al., 1978). New research and greater knowledge of effective countermeasures have played a critical role in achieving these declines. But the number of deaths remains unacceptably high, and progress achieved to date should not lull Canadians into complacency.

Alcohol-impaired driving has been a leading contributor to road crashes in Canada for more than three decades.

Prevalence of marijuana in drivers and road crashes

While the prevalence of drugs in drivers is not yet fully understood, data available today indicate this topic most certainly merits concern. Results of a national public opinion poll, the *Road Safety Monitor 2019: Trends in Marijuana use among Canadian Drivers*, published by TIRF, revealed 7% of Canadian drivers admitted driving within two hours of using marijuana in 2019, and 3% used marijuana and alcohol (Woods-Fry et al., 2019). While these percentages may appear small, they are based on an estimated population of 24 million drivers. Likewise, these percentages represent substantial increases from the previous year (3.3% and 1.7%, respectively).

In addition, marijuana was the drug most often detected among drivers killed in road crashes. In 2016, among those drivers tested for drugs, 23.3% of fatally injured drivers tested positive for marijuana, representing a steady increase over previous years. Drivers aged 16 to 19 years and 20 to 34 years were most likely to test positive for this substance (Brown et al., 2019).

Marijuana was also detected in combination with other impairing substances. Between 2012 and 2016:

- Less than one-third of fatally injured drivers who tested positive for marijuana (31.1%) had only used that drug.
- More than two-fifths (43.4%) of these drivers tested positive for marijuana and a second substance (2 categories) with alcohol being the second substance in almost three-quarters (73%) of these cases.
- One-fifth (20.6%) of fatally injured drivers testing positive for marijuana were positive for three different categories of drugs (most commonly marijuana, alcohol, and CNS stimulants).
- A smaller percentage (4.9%) of fatally injured drivers testing positive for marijuana used four different categories of drugs.

Equally concerning, a wide variety of new edible marijuana products are increasingly available in Canada. These items contain higher concentrations of THC and produce greater impairment of motor skills.

Impairing effects of alcohol and marijuana

Alcohol impairment. The impairing effects of alcohol on judgment and memory are significant. Alcohol (ethanol) can disrupt the processing of recent events and experiences into long-term memories (Westrick et al., 1988; Mintzer and Griffiths 2002). Large quantities of alcohol can produce blackouts which are periods when individuals do not remember what happened (White 2003). Blackouts are particularly common during binge drinking episodes, and individuals may engage in risky behaviours such as driving while impaired. They may be unaware of their actions and unlikely to recall them even once sober.

Alcohol exhibits a dose-dependent depressive effect on the central nervous system (CNS) which means impairing effects and levels of impairment experienced at specific blood alcohol concentration (BAC) levels are highly consistent across individuals. Alcohol is rapidly absorbed by the body and each measured drink raises BAC by about .02 per hour. Several factors influence the rate of absorption including the amount/type of food eaten, medication, fatigue, weight, sex, and dehydration. In addition, it takes about one hour for one alcoholic drink to leave your body and exercise or consumption of water does not make your body eliminate alcohol faster.

Alcohol influences numerous physiological processes and systems in the human body and produces impairing effects in terms of driving. There is a vast body of research which demonstrates alcohol consumption impairs motor coordination and impairment increases with BAC level (NHTSA 2016). Key executive functions, such as distance perception, are also affected. The following driving skills may be affected with higher levels of consumption:

- .02 BAC - Difficulty performing divided attention tasks such as driving and anticipating hazards.
- .05 BAC - Difficulty steering and tracking other vehicles.
- .08 BAC - Difficulty controlling speed, reduced concentration and impaired perception.
- .10 BAC - Difficulty staying in lane, braking and reaction time is slower.
- .15 BAC - Blurred vision and inability to control vehicle.

In addition, the impairing effects are still measurable in the post-alcohol or “hangover” phase as BACs decline (Ogden and Moskowitz, 2004; Verster, 2009; Moskowitz et al. 2000). Another 2010 study showed a .08 BAC and higher dose level corresponded to potential danger while driving due to low vigilance and underestimation of speed (Liu and Ho, 2010). This is further supported by traffic fatality data in several countries demonstrating alcohol-impairment is a leading cause of fatal crashes (NHTSA, 2016; ICADTS, 2016; Perreault, 2016; Meesmann et al., 2017; Vanlaar et al., 2012; Vanlaar et al., 2015; and Brown et al., 2017).

Marijuana impairment. In comparison to alcohol, less is known about marijuana and driving in terms of how marijuana specifically impairs driving skills. Marijuana studies have shown the psychoactive chemical delta-9-tetrahydrocannabinol (or THC) enters the user's bloodstream and brain immediately after smoking or consuming it. Since marijuana is very soluble in fat tissue, the absorption, distribution, and elimination of marijuana does not occur at a steady rate. Instead, it varies based on biological processes according to several factors, including route and frequency of intake; THC dose; titration of dose when smoked or vaporized; and, user characteristics. Not only do these factors affect the amount of marijuana intake and metabolism, they also affect the degree of behavioural impairment exhibited by users. For example, if marijuana is ingested, the onset of the impairing effects of edible marijuana products occurs more slowly and last longer as compared to smoking.

Furthermore, marijuana does not display a dose-response (in this case concentration) relationship, as is the case with alcohol. Unlike BACs, peak THC concentrations do not correlate well with the degree of behavioural impairment (Huestis 2007; Compton 2017). For example, studies of marijuana use and driving impairment have shown the level of THC measured in blood or oral fluid and the degree of impairment are not closely related; peak THC levels can occur when low levels of impairment are measured, and high levels of impairment can be measured when THC levels are low (Compton, 2017; Marcotte, 2020). The lack of definitive knowledge to quantify a concentration-response relationship for marijuana may be in part due to typical differences in research methods, tasks, subjects and dosing that have been used to date (Compton, 2017). Additionally, some studies have reported a wide variability in THC levels in the blood which are affected by the means of ingestion (smoking, oil, and edibles), potency, and user characteristics (Compton, 2017). This may indicate the concentration-response relationship can vary according to specific types of marijuana products consumed and individual biology. The lack of a concentration-response relationship for marijuana has important implications. Notably, there is much debate concerning the validity of a per se limit for marijuana due to the lack of strong scientific consensus regarding THC concentration in blood that constitutes driving impairment (Grotenhermen et al. 2007; Newmeyer et al. 2017). However, generally speaking, studies on marijuana showed:

- Low doses of marijuana produce mild to moderate impairment in cognitive and psychomotor abilities; and
- Larger doses showed significant impairment in cognitive, psychomotor and driving performance.

Laboratory studies of the impairment effects of marijuana use on psychomotor and cognitive functions suggested marijuana consumption can impair driving task-related abilities such as motor control, executive function, visual processing, short-term memory, and working memory in a dose-dependent fashion (Broyd et al. 2016; Ramaekers et al. 2004; Ramaekers et al. 2006). Reviews of studies on the effects of marijuana on driving skills demonstrated marijuana can specifically impair certain skills necessary for safe driving (Hartman et al., 2012; Compton 2017; Battistella et al., 2013), such as:

- controlling speed variability;
- lane positioning;
- reaction time;
- divided attention;
- attention maintenance;
- route planning;
- decision-making; and,
- risk-taking.

In some driving simulator studies, marijuana use was shown to increase driver reaction time and the number of incorrect responses to emergencies. In addition, drivers crashed more frequently into a sudden obstacle on a high dose of THC, although this was not seen at low doses (Sewell et al., 2009: citing Smiley, 1986; Smiley et al., 1981). Starkey and Charlton (2017) conducted a systematic review of marijuana-related behavioural studies and found that marijuana use was associated with reckless driving and speeding, signaling errors and decreased ability on tracking tasks.

A recent study involving participants who smoked marijuana and used a driving simulator demonstrated a moderate effect of THC on driver performance. Some subjects showed reduced performance compared to a placebo group, while other subjects showed little difference (Marcotte, 2020). Driving performance was assessed in terms of ability to maintain lateral position while undertaking a distracting task as well as maintaining the distance from a leading vehicle. Furthermore, the effects were seen to be most pronounced in the first two hours after use, with some recovery seen after three and a half hours.

Marijuana use has been associated with a significantly increased risk of fatal crash involvement. Drivers using marijuana are at an increased risk of injury anywhere from 1.8 to 2.8 times higher. Furthermore, the odds of drivers being found responsible for a crash increased with rising marijuana concentrations in the blood (Li et al., 2013; Asbridge et al., 2012; Starkey and Charlton 2017; Els et al., 2019; Drummer et al., 2003; Drummer et al. 2004). In fact, research on drivers in fatal crashes has shown THC-positive drivers were more than twice as likely to crash as drivers without THC (Grondel 2016).

Marijuana use has been associated with a significantly increased risk of fatal crash involvement.

However, while marijuana use has been shown to have impairing effects on skills required for driving, simulator studies investigating behavioural changes driving under the influence of marijuana have concluded marijuana use by drivers may result in compensatory behaviours, such as:

- decreased speeds;
- fewer attempts to overtake; and,
- an increased following distance to the vehicle in front.

These findings are in sharp contrast to studies investigating the effects of alcohol use (Hartman et al., 2016; Sewell et al. 2009). Other studies have demonstrated no adverse effects of marijuana use on sign detection, a sudden lane-changing task, or the detection of and response to hazardous events. (Sewell et al., 2009: citing Sexton et al., 2000; Smiley, 1986; Stein et al., 1983). It has been hypothesized that despite the impairing effects of marijuana, drivers using marijuana alone tend to overestimate their level of impairment and rely on compensatory behaviours to reduce crash risk. In one study, following a 7 ng dose of THC, drivers rated themselves as impaired even though their driving performance was not. Conversely, alcohol at a relatively low BAC of .04 resulted in impaired driving performance although drivers rated themselves as unimpaired (Sewell et al.,2009: citing Robbe and O'Hanlon, 1993). In other words, drivers using marijuana may be more aware of their level of impairment whereas drivers using alcohol under-estimate their impairment. However, this may not always be the case. One study

(Marcotte, 2020) measuring driver performance in a simulator showed subjects perceived the impairing effects of THC to be eliminated before a measurable improvement in driving performance was seen.

Impairing effects of alcohol and marijuana combined

Persons using marijuana often consume it with other drugs, notably alcohol, as evidenced by self-report surveys and drug-testing of drivers in fatal crashes described previously. The evidence suggests there is an additive and prolonged impairment effect when the two substances are combined (Lenné et al. 2010). To date, there has been limited research investigating the combined impairing effects of alcohol plus marijuana on driving skills and many studies are dated. However, they have shown the use of marijuana in combination with other drugs can produce impairments which are distinct from those observed with marijuana alone.

Both older and more recent research into the combined effects of alcohol and marijuana revealed an additive or even multiplicative effect on impairment (Chesher 1986; Hartman et al. 2015). Further, it showed even small amounts of alcohol can substantially impact the level of impairment when combined with marijuana (Beirness and Porath, 2017: citing Downey, et al., 2013, Ramaekers, et al., 2000, and Sewell, 2009: citing Sexton et al, 2000; Sexton et al., 2002). This is particularly concerning since the use of marijuana is also associated with the consumption of larger amounts of alcohol when the substances are used together (Capler et al., 2017). In addition, Downey et al. (2013) demonstrated driver performance in a simulator was worse among regular marijuana users who consumed alcohol, and the level of THC detected in blood samples was higher.

The evidence suggests there is an additive and prolonged impairment effect when alcohol and marijuana are combined.

One reason the combined use of alcohol and marijuana has more significant impairing effects on driving skills may be that alcohol reduces the perceived negative consequences of risk-taking. This can result in increased willingness to take risks after drinking even at low alcohol doses (Sewell et al., 2009). As such, any behavioural modifications (i.e., compensatory behaviours or choosing not to drive) which may limit the negative impacts of marijuana-impaired driving may not be realized when alcohol is also consumed and there is some evidence to support this hypothesis. A study of drivers involved in fatal crashes showed drivers with alcohol and THC in their system were 3.7 times as likely to not be wearing a seatbelt compared to drivers with no alcohol or drugs in their system. In comparison, these odds were 3.5 for alcohol and just 1.55 for marijuana. In other words, results indicated drivers under the influence of alcohol and marijuana were more at risk than those using alcohol or marijuana alone (Capler et al., 2017: citing Liu et al., 2016).

Another reason the combined use of alcohol and marijuana is more impairing is the evidence shows both substances impair driving skills but not in the same way. The types of impairments on driving skills do not completely overlap, meaning the combined use results in a deeper level of impairment even at low doses of these drugs. Currently, in Canada, there are maximum limits for alcohol and THC, presumably which at levels under those thresholds, the increased risk of driving is low enough to not be an enforcement priority. The research about combined use suggests these limits may not be sufficient to detect impairment when alcohol and marijuana use are combined. It is therefore possible that truly impaired drivers could remain below per se limits for both alcohol and marijuana but pose an increased crash risk.

Further research is required to fully understand the impairment effects at different doses of each substance and how these effects may differ according to the physical characteristics of drivers, consumption habits and mode of ingestion. This information is highly relevant to the development of legislation as well as programs and strategies to reduce impaired driving.

As described above, the dose-response relationship between alcohol consumption and driving impairment is well understood but a similar relationship between marijuana use is less clear. More concerning, the interaction effects of alcohol plus marijuana use and the combined effects on driving impairment have not yet been established. To ensure effective laws are in place to deter impaired driving, additional research is essential to measure the dose-response relationship for the consumption of alcohol and marijuana and driving skills.

Impairing effects of alcohol and marijuana on crash risk

More than 40 years of research have clearly established alcohol increases crash risk. Comparatively, much less research investigating marijuana use and crash risk is available, but overall, it generally indicates marijuana use is associated with increased risk. Most of the available research investigating crash risk related to alcohol and marijuana use has focused on these substances in isolation, overlooking the interactive effects of combined use. Given that different substances are often used together, understanding these potential interactive effects on crash risk is critical.

Studies examining the relationship between drivers testing positive for marijuana and crash risk have generally suggested approximately a twofold increase in risk after the consumption of marijuana (Li et al., 2017; Ashbridge 2012; Hels et al., 2011; Lacey et al., 2009; Laumon et al., 2005; Drummer et al., 2004). A recent study in rural Norway (Jamt et al, 2019) showed a higher crash risk of 15.3 times when THC was detected. In addition, it appears crash risk begins to increase at very low levels of marijuana which escalates with dose (Beirness and Porath, 2017). While available studies associated increased crash risk with marijuana consumption, there have been challenges establishing a causal relationship. Notably, the presence of THC does not necessarily imply impairment at the time of a crash. Future research should explore the relationship between the effect of marijuana on certain skills necessary for safe driving and crash risk (Robertson et al., 2019).

At present, several studies have examined the interactive effects of alcohol and marijuana and demonstrated the crash risk associated with combined alcohol and marijuana use exceeds the risk of either substance alone. For instance, one Canadian study analyzed data on alcohol and drug presence among drivers killed in a crash between 2008 to 2012 in British Columbia and compared these data to the presence of alcohol and drugs among drivers participating in roadside surveys. Analyses revealed the odds of being involved in a fatal crash to be 40.1 times higher for drivers testing positive for both alcohol and marijuana, compared to 4.95 times higher for marijuana on its own and 6.77 times higher for alcohol on its own (Beirness et al., 2013).

Similar findings have been reported in other studies. A review by the OECD International Transport Forum (OECD, 2010) contained clear evidence alcohol used concurrently with marijuana was associated with a higher crash risk, citing several studies:

- Brault et al., (2004) reported increased crash risks of 1.6 for marijuana alone, 69.9 for alcohol .08 BAC and 203.8 for marijuana plus alcohol > .08 BAC.
- Drummer et al., (2004) noted an increased crash risk of 2.9 for THC combined with alcohol > .05 BAC and 2.7 for any amount of THC on its own.

Two other studies cited from the OECD report that considered whether drivers were the cause of a crash confirmed the increased risks of combined alcohol and marijuana use. They showed lower risks for marijuana alone compared to drivers with no alcohol or drugs in their system, although the findings for marijuana alone were not statistically significant:

- Williams et al., (1985) revealed increased risks of 5.0 for alcohol, 0.5 for marijuana and 8.6 for alcohol combined with marijuana.
- Longo et al., (2000) showed increased risks of 8.0 for alcohol, 0.82 for marijuana and 5.4 for marijuana combined with alcohol.
- Laumon et al., (2005) had similar findings and estimated increased risks of 14.0 for marijuana combined with alcohol and 3.32 for marijuana alone. This study also provided evidence of a concentration-response relationship for marijuana only presence and reported increased risks of 2.18 for THC <1 ng/ml (nanograms per millilitre) and 4.72 for THC >= 5 ng/ml.

A recent study in British Columbia (Brubacher et al., 2019) also found that crash responsibility was related to the presence of THC and alcohol, with increased risks of 6.8 when THC ≥ 2 ng/ml and alcohol was detected, compared to just 4.2 when alcohol was present with a BAC of at least .08.

While the available evidence has established the combined use of alcohol and marijuana is associated with higher crash risks than either substance on its own, the exact relationship is difficult to quantify because the presence of marijuana does not necessarily imply impairment at the time of a crash. Nevertheless, combined use is a serious issue that merits concerted attention. Further research should explore the relationship between combined use in various doses and its effects on crash risk. This information can inform the development of laws and strategies for dealing with this problem. Notably, limited findings from a few studies suggesting the use of marijuana alone may decrease crash risk are not statistically significant and should not be accepted as fact without additional research.

Combined use of alcohol and marijuana is a serious issue that merits concerted attention. Further research should explore the relationship between combined use in various doses and its effects on crash risk.

Behaviours & Attitudes: Driving Under the Influence of Alcohol & Marijuana

Self-reported behaviours. Misperceptions associated with marijuana use and driving are evident in the self-reported behaviours of drivers. According to the 2019 Road Safety Monitor by TIRF, cited previously, 7% of drivers in Canada admitted to driving within two hours of using marijuana at least once in the previous 12 months. A Canadian self-report survey (Health Canada, 2013) showed:

- The reported prevalence of driving after using marijuana was higher among young people and males; and,
- Drivers aged 18 to 19 years were most likely to report driving after using marijuana (8.3%), followed by those aged 15 to 17 years (6.4%).

Other data similarly revealed males were three times more likely than females to drive after marijuana use. A more recent Canadian self-report survey (Health Canada, 2019) asked those who admitted to marijuana use in the past 12 months about their driving habits relative to use. In this sub-population of respondents consuming marijuana:

- 26% reported ever having driven within two hours of smoking or vaping in the past 12 months; and of those who did so, 43% reported doing so within the past 30 days.
- Males (32%) were more likely than females (19%) to have reported ever having done so.
- This behaviour was highest amongst drivers aged 25 years or older (29%) than persons aged 20 to 24 years (23%) and 16 to 19 years (16%).

Similar questions were posed to respondents for driving within four hours of consuming edible products. In this same subpopulation who consumed it:

- 16% reported ever having driven within four hours of consuming edible marijuana, and of those who did so, 37% reported doing so within the past 30 days.
- Males (19%) were more likely than females (12%) to have reported ever having done so.
- This behaviour was highest amongst drivers aged 25 years or older (17%) than for persons aged 20 to 24 years (13%) and 16 to 19 years (11%).

Capler et al. (2017) reported that amongst self-described marijuana users, 20% admitted to driving within two hours after marijuana use. Comparable usage trends have been demonstrated in roadside surveys. Capler et al. (2017) noted roadside testing indicated 4% to 6% of drivers drove within two hours of marijuana use in the past year.

Similar public survey data on the combined use of alcohol and marijuana are less common but some data are available. Woods-Fry et al. (2019) reported 3% of Canadian drivers admitted to driving within two hours of using alcohol and marijuana together. The Canadian self-report survey (Health Canada, 2019) showed of those respondents admitting to ever driving within two hours of smoking or vaping or within four hours of ingesting marijuana:

- 20% said they had driven a vehicle within two hours of using marijuana in combination with alcohol;
- 38% did so within the past 30 days; and,
- Males (24%) were more likely than females (13%) to have reported ever having done so.

Comparable results were reported in the United States. Arnold and Tefft (2016) reported 2.4% of all drivers reported driving within one hour after using both alcohol and marijuana compared to 4.6% for marijuana alone. Males were twice as likely to have reported doing so. Following the legalization of marijuana use in Canada in October 2018, continued monitoring of self-reported behaviours is needed.

Self-reported attitudes. Misperceptions regarding the negative effects of marijuana alone on driving skills contribute to at least some drivers choosing to drive after consuming marijuana. Often these drivers believe they drive better after consuming marijuana. In the U.S., results from the Traffic Safety Culture Index by the American Automobile Association (AAA) Foundation for Traffic Safety (Arnold and Tefft, 2016) revealed slightly more than half of respondents believed using marijuana within one hour of driving increased crash risk. Similar findings were reported by Ogourtsova et al. (2018) who recorded the self-perceptions of participants (aged 18 to 24 years) in Canada regarding their ability to drive safely

after consuming marijuana as part of a driving simulation study. Their results showed 51% of participants thought their driving would be worse than usual and 49% thought their driving would be the same. The Canadian self-report survey (Health Canada, 2019) revealed:

- 85% of respondents thought marijuana use affected driving; and,
- Of those who reported marijuana use in the past 12 months, only 69% agreed and 19% reported it depended on circumstances.

In 2019, Woods-Fry et al. (2019) reported 15.7% of Canadian drivers agreed marijuana does not impair driving as much as alcohol. These results suggest there is a large proportion of drivers who are unaware that marijuana use increases crash risk. This misperception has important implications for the combination of this substance with alcohol, and ultimately road safety. The lack of awareness about the impairing effects of marijuana on driving can directly impact the rates of marijuana-impaired driving and marijuana-related crashes.

Misperceptions also exist about legislation related to marijuana and driving. It has been reported drivers have little knowledge of per se laws for marijuana. Moreover, drivers tend to believe police officers do not have the tools to test marijuana-impaired drivers and cannot remove them from the road. This misperception has important implications for enforcement, as the lack of knowledge about the laws and police investigative powers can erode the deterrent effects of laws and may encourage increased levels of marijuana-impaired driving among potential offenders (Robertson et al., 2019).

While public understanding of the risks of alcohol-impaired driving is high, significant misperceptions related to driving and marijuana use persist. It would similarly be expected that public understanding of the risks of combining alcohol, even in small amounts, and marijuana on driving is low. Further research is needed to identify what misperceptions exist, what are the characteristics of those drivers most likely to drive after consuming both alcohol and marijuana and the situations they are likely to do so. This information is required to address the problem through education and enforcement.

Legislation and enforcement issues

Canada's Bill C-46 permits police officers to require drivers suspected of drug use to provide a sample of oral fluid to test for the presence of drugs, similar to the current approach for breath alcohol screening at the roadside using approved devices. Individually, the alcohol limit is .08 BAC and marijuana blood THC concentrations of 2 ng/ml but less than 5 ng/ml is a lower offence with 5 ng/ml or more a more severe offence. In addition, driving with alcohol at a .05 BAC or higher combined with 2.5 ng/ml of THC constitutes an offence with the same consequences as driving with 5 ng/ml or more of THC. In addition, provinces and territories may enact additional low BAC laws and sanctions to complement Federal law.

As with per se BAC limits for alcohol, the adoption of THC per se limits are intended to facilitate enforcement, prosecution, and achieve a deterrent effect. Although per se limits for alcohol impairment are largely undisputed, the same cannot be said for impairment by marijuana. The opinion of the research community has largely been that the concentration-response relationship for marijuana use and impairment is not sufficiently known to define a reliable per se limit for THC similar to the BAC limit for alcohol (Hartman and Huestis, 2013; Lacey et al., 2010; Grotenhermen et al., 2007; Sewell, Poling, and Sofuoglu, 2009). In the absence of precise knowledge, proposed per se limits for THC have been recommended based on crash risk studies aimed at defining a risk similar to alcohol BAC limits (e.g., Peaire et al., 2017).

Since the degree of impairment due to marijuana is not closely related to measurable THC levels, the implication for enforcement is profound. When crashes occur and impairment is suspected, it is most likely only relatively low levels of THC will be detected by the time an oral fluid or blood sample is obtained (Compton, 2017). Peak THC concentrations occur during marijuana inhalation, prior to peak behavioural impairment, and behavioural impairment continues to be present at ensuing low THC concentrations from a single dose (Robertson et al., 2019). Further complicating the diagnosis of impairment, with each route of ingestion there is inter-subject variability in terms of measurable THC concentrations and impairing effects. This means, two individuals consuming the same marijuana product may demonstrate different concentrations of THC in their system and may not exhibit the same degree of impairment (Robertson et al., 2019).

The lack of precision in knowledge about THC level and impairment can have broader societal consequences. Notably, THC can stay in the body up to seven days (Karschner et al., 2009; Bergamaschi et al., 2013), long after impairment effects were present. As such, situations can arise where a regular user of marijuana relies on law enforcement to recognize impairment is not present even if a roadside test determines the presence of THC.

Another enforcement issue relates to the tests used to determine the presence of THC. Blood analysis to measure the concentration of THC in a driver's system offers one of the most reliable means of testing for recent drug use when drug-impaired driving is suspected. However, it is an invasive and inefficient method of sampling at the roadside. Conversely, the analysis of oral fluid samples presents a promising alternative since it is quick and non-invasive and can be undertaken at the roadside. As such, research to better understand the relationship between the THC concentration in oral fluid and blood can increase efficiency at the roadside while ensuring tests are non-invasive. Therefore, future research is needed to explore the relationship between these two methods of sampling and gain a broader understanding of the complexities that exist (Robertson et al., 2019).

In the absence of a reliable test of impairment based on THC level, the use of Drug Recognition Evaluators (DREs) may provide the best method of detecting impairment in drivers. However, the number of trained and certified DRE offices in Canada is currently inadequate. A recent newswire article (Government of Canada, July 2019) reported the number of trained, certified and active police DRE officers in the country is estimated at just 1,129 certified DREs as of July 2019 for approximately 24 million licensed drivers. At present, reports from police services in several jurisdictions highlighted the inconsistency in meeting the number of requests for a certified DRE officer. This has resulted in an inordinate number of suspected drug-impaired drivers being permitted to continue driving in the absence of administrative sanctions to remove them from the road (Robertson et al. 2016). Given evidence that drivers who have used marijuana can be significantly impaired with even low doses of alcohol, this is a serious issue as such impaired drivers may be below the BAC limits for even administrative sanctions but are still significantly impaired.

While the science and laws supporting blood alcohol limits for driving are known and accepted, the same cannot be said for those concerning marijuana use as well as the combined use of alcohol and marijuana. This uncertainty adds to the complexity of enforcement. The increased impairment effects due to consuming even low doses of alcohol and marijuana concurrently exacerbate this challenge. Although administrative license revocation is widely utilized as an immediate penalty for persons arrested or convicted of alcohol-impaired driving, this penalty is not yet consistently applied to drug-impaired driving across jurisdictions. However, a few provinces in Canada have recently implemented this tool, including Ontario, Alberta and British Columbia (Robertson et al., 2019).

Impaired driver programs

For many years, all jurisdictions have had strategies in place to prevent alcohol-impaired driving offences and repeat offences. Elements have most often been included in driver licensing provisions and impaired driving programs. The content and orchestration of these strategies are both varied and usually multifaceted. In broad strokes, programs involve a driver assessment to detect the misuse of alcohol and other recidivism risk factors as well as guide individualized prevention planning. This may involve either mandated or voluntary programs designed to assist drivers in decoupling alcohol from driving. The use of technology (e.g., alcohol ignition interlocks and transdermal alcohol monitoring), or referral to psychosocial interventions focused on behavioural change related to substance misuse and driving is increasingly common (Robertson et al., 2019).

Existing programs are primarily focused on alcohol-impaired driving. While many of them may assess the use of other drugs, detection may not have direct implications for programming. The propensity for polysubstance use and the heterogeneity of impaired drivers is not consistently recognized and for drivers using both alcohol and marijuana, effective treatments are likely to be different depending on their patterns of substance use. For example, some of these impaired drivers may primarily use alcohol but also use marijuana occasionally, while others may be primarily marijuana users but occasionally also consume alcohol. Acknowledgement of the reality of polysubstance use in drivers is important since there is evidence indicating that polysubstance misuse increases recidivism risk (Impinen et al., 2009).

There is evidence driving while impaired prevention programs can be modestly beneficial to reduce recidivism in alcohol-impaired drivers (Miller, et al.,2015; Wells-Parker et al., 1995), however, findings demonstrating their effectiveness for preventing drug-impaired driving recidivism is scant. Research into the effectiveness of programs targeting alcohol- plus marijuana-impaired drivers is challenged by the heterogeneity in the characteristics of these offenders. For example, drivers detected for driving while impaired by drugs in many cases will present with patterns of substance misuse, behavioural risk-taking, and dysregulation in associated neurobiological systems that are meaningfully distinct from those seen in drivers detected primarily for driving while impaired by alcohol (Brown et al., 2016).

It is important to understand the heterogeneity in characteristics of impaired drivers using alcohol plus marijuana because not all offenders require the same intensity of supervision. Research shows over-servicing offenders by using stricter conditions of supervision than required can be detrimental (Andrews and Bonta, 2010; Bonta, Wallace-Capretta, and Rooney, 2000; Myers, 2017; Cracknell, 2018). A more efficient use of resources is to allocate individuals posing a greater risk of re-offending to more comprehensive programs and to reduce the intensity of interventions for offenders who are unlikely to re-offend. Assessment, followed by monitoring of progress towards behavioural goals and objectives, and re-adjusting as needed, is a proven approach (Robertson et al., 2019).

To better treat this population of impaired drivers, more knowledge is needed about the criminal profile of impaired drivers using alcohol combined with marijuana. For example:

- Are these offenders more likely to have other criminal history or traffic offenses compared to impaired drivers using alcohol only?
- Do the driving records of these offenders reveal different types of violations or infractions than those of impaired drivers using alcohol alone?
- Are these offenders more or less likely to re-offend than alcohol-impaired drivers?
- Does this population present with more or different risks and needs that require attention?

Careful classification of offenders is essential to the delivery of appropriate supervision, as those with polysubstance abuse may be miscategorized based on violations. In addition, it is important to determine if there is a subpopulation of *high-risk* offenders who pose a greater risk than others.

More generally, a greater understanding of the distinctions between different types of impaired drivers can inform enforcement and supervision efforts, and tailor intervention strategies to better address the prevalence of this behaviour. Increased awareness about patterns of use can also help supervision officials assess the level of risk and potential for re-offending.

At present, technologies to aid in the supervision of alcohol-impaired driving offenders are more advanced than those for drugs. Alcohol interlock systems have been proven effective in preventing convicted impaired drivers from driving after drinking, even at low BAC thresholds, and in reducing crashes (McCartt et al., 2018; Vanlaar et al., 2017, Voas et al., 2016, Kaufman and Weibe 2016; McGinty et al., 2016). There is also some evidence suggesting offenders actively tested for drugs may potentially switch to alcohol as their substance of choice (Stodola, 2017). Consequently, some jurisdictions legalizing marijuana continue to require drug-impaired drivers to install an alcohol interlock on this basis. No large-scale study has yet been undertaken to examine potential safety benefits of this approach.

The lack of existing knowledge about the characteristics of impaired drivers who combine alcohol with marijuana is a barrier to the development of effective intervention programs to reduce recidivism among this population,

The lack of existing knowledge about the characteristics of impaired drivers who combine alcohol with marijuana is a barrier to the development of effective intervention programs to reduce recidivism among this population. While programs aimed primarily at alcohol-impaired drivers can be effective to reduce offending, it is unknown whether these same programs may be effective for drivers using both alcohol and marijuana.

Conclusions

Impaired driving involving the combined use of alcohol and marijuana is a priority concern among road safety stakeholders given the prevalence of alcohol-impaired driving in conjunction with the new legal status of marijuana, the potency of new marijuana products, and the increased impairment effects when combined with alcohol. The evidence shows driving skills are more impaired and crash risks rise to a greater degree when alcohol and marijuana are consumed together than for either substance on its own, even at low doses.

Currently, in Canada, there are per se limits restricting driving after consuming alcohol and THC above a specified threshold. Presumably, at levels lower than those thresholds, the increased crash risk is sufficiently low and not deemed an enforcement priority for this reason. Of concern, the research on the impairing effects of combined use suggests these limits may not be sufficient to detect impairment when alcohol and marijuana use is combined.

While public understanding of the risks of alcohol-impaired driving is high, significant misperceptions related to driving and marijuana use persist. For this reason, it is also likely public understanding of the risks of combined alcohol, even at low doses, and marijuana and driving is low.

Knowledge gaps regarding the characteristics of alcohol plus marijuana-impaired drivers are a barrier to the development of effective intervention programs to reduce recidivism. While programs aimed primarily at alcohol-impaired drivers may be equally effective for drivers using both substances, research is needed to determine if this is, indeed, the case.

To address important gaps in knowledge associated with the impairing effects on driving of alcohol in combination with marijuana, researchers are encouraged to investigate the role of polysubstance use and

the implications for effective impaired driver programs. Identification of misperceptions, characteristics of those drivers most likely to drive after consuming both alcohol and marijuana and in what situations they are likely to do so is required to address the problem through education and enforcement. Likewise, further research is required to fully understand the impairment effects at different doses of each substance and how these effects may differ according to the physical characteristics of drivers, consumption habits and mode of consumption. This information may have important implications for laws and strategies to deal with this problem. Similarly, legislation aimed at impaired driving must acknowledge the reality of polysubstance use in impaired driving.

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Email: tirf@tirf.ca

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