



## The Lower-Risk Cannabis Use Guidelines' (LRCUG) recommendations: How are Canadian cannabis users complying?

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### ABSTRACT

Canada, alongside other jurisdictions, implemented non-medical cannabis legalization in 2018, partly towards improving public health. Evidence-based 'Lower-Risk Cannabis Use Guidelines' (LRCUG), including recommendations for cannabis users on how to decrease risk-behaviors for harms, have been developed and widely disseminated in Canada since 2017. However, knowledge on users' compliance with the LRCUG is limited. We identified four major Canadian (three national, one provincial) population surveys presenting key data on cannabis-related behaviors: the National Cannabis Survey, Canadian Cannabis Survey, Canadian Tobacco, Alcohol & Drugs Survey, and CAMH Monitor. We scanned each survey for indicator data mapping onto either of the LRCUG's recommendations for the years 2017 to 2019. Relevant indicator data, albeit with varying operationalizations, were found for six of the ten LRCUG's recommendation clusters in at least some of the surveys, and were extracted and summarized. For results, substantial – but declining – majorities of users consumed cannabis by smoking, yet with shifts towards other use modes. Between one- to two-in-five users engaged in the risk-behaviors of using high-potency cannabis products, frequent cannabis use and cannabis-impaired driving, respectively. A small proportion of pregnant or breastfeeding women continued cannabis use during the study period. The data identified found suggested a heterogeneous picture regarding cannabis users' compliance with the LRCUG's recommendations. Non-compliance is highest for recommendations regarding modes-of-use, and applies to minorities of users for other risks factors. These sub-groups are at elevated risk for acute (e.g., accidents) or long-term (e.g., dependence) cannabis-related harms contributing to the public health burden. Appropriate targeted interventions in these areas require improvement.

### 1. Introduction

Cannabis is the most commonly used illicit drug, with an estimated 250 million active users globally (Degenhardt et al., 2013, 2017). While the cannabis-associated burden-of-disease is lower than that for licit drugs like alcohol or tobacco, its use is associated with risk for multiple possible acute and chronic adverse outcomes, including psycho-cognitive impairment, cannabis use disorder (CUD), mental health problems, and respiratory problems (Hall, 2015; Volkow et al., 2014). Most of these outcomes materialize, however, in a sub-group (~30%) of 'high-

risk' users sharing a set of common risk factors (Fischer et al., 2017; Hall and Degenhardt, 2014). While most countries continue to control cannabis through variations of prohibitionist policies, several jurisdictions have recently implemented policy reforms, some including legalization of cannabis use and supply (Decorte et al., 2020; Hall et al., 2019; Pardo, 2014). Among the purported benefits of legalization policy are that it allows both cannabis use and products to be regulated, and targeted interventions (e.g., prevention, treatment) can openly be designed and legitimately applied towards reducing cannabis-related risks or harms (Crepault et al., 2016).

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Canada has been the second national jurisdiction, after Uruguay, to implement legalization of cannabis use and supply (in 2018) (Decorte et al., 2020; Fischer, 2017; Hammond et al., 2020b). Canada has long had among the world's highest cannabis use rates: about one in eight Canadians, and about one in four or more youth/young adults reported cannabis use (e.g., past-year) around the time of legalization (Rotermann, 2019). While several studies have identified cannabis-impaired driving and CUD as main contributors to cannabis-related burden of disease in Canada, other related indicators (e.g., hospitalizations) have shown increases in adverse outcomes in the period leading up to legalization (Fischer et al., 2018; Imtiaz et al., 2016).

In anticipation of cannabis legalization, and specifically of the need for effective interventions to reduce cannabis-related harms towards envisaged public health outcomes, a set of 'Lower-Risk Cannabis Use Guidelines' (LRCUG, originally developed in 2011) were updated by an international expert group, and widely disseminated (Fischer et al., 2011). The LRCUG were conceived as an evidence-based population health intervention, built on scientific data identifying user-modifiable, behavioral risk factors associated with adverse outcomes associated with cannabis use (Fischer et al., 2011). Based on this evidence, the LRCUG present a set of user-oriented recommendations towards informing and adjusting use-related risk behaviors, and consequentially reducing acute or long-term health harm for desired results. As such, the LRCUG serve as a 'targeted prevention' tool, as exists in other areas of health behaviors (e.g., low-risk drinking, safer sex, healthy eating/nutrition guidelines) (Johnson et al., 2003; Mozaffarian, 2016; Rehm and Patra, 2012; Snook, 2004). Crucial for their acceptance and uptake, the LRCUG were endorsed by ten national, leading health and addictions organizations in Canada, and subsequently disseminated through a diverse suite of 'knowledge translation' materials and activities (e.g., brochures, info cards and posters, webinars etc.; Government of Canada, 2019).

While health-oriented targeted prevention tools like the LRCUG are conceptually timely and topical, their uptake and impact on behavioral choices, and outcomes in the target population, cannot be assumed, and require empirical assessment (Dawson et al., 2012; De Visser and Birch, 2012). In this context, this paper aimed to compile and review available, empirical indicators on LRCUG-related behaviors among cannabis users in Canada at the time around legalization.

## 2. Materials and methods

Our paper draws on population-level indicators data on cannabis use and behaviors pertaining to the LRCUG's recommendations, as available from major (three national, one provincial) Canadian population surveys. Four surveys were identified as retrospective sources, with basic methods and technical details described below, selected primarily based on their respective scopes and large sampling frames. Specifically, LRCUG-related indicator data from 2017 to 2019 (i.e., post-presentation of the LRCUG, and including time of legalization [2018]) were identified.

The **CAMH Monitor Survey** is a recurring (since 1977) cross-sectional telephone survey representative of the general adult population (ages 18 years and older) of Ontario, Canada's most populous province. The survey focuses on substance use, related behaviors and outcomes. The most recent (2017) survey includes data from an accumulation of four quarterly rolling samples and related data. Based on regional stratification, respondents were randomly selected through a two-stage, dual-frame random-digit-dialing (RDD) approach to landlines and cellphones, excluding people in institutions, without phones or unable to complete the interview. The 2017 survey sample included a total of 2,812 respondents, with a response rate of 35% (Ialomiteanu et al., 2018).

The **Canadian Cannabis Survey (CCS)** is a cross-sectional survey targeting the general population of Canadians aged 16 years and older to measure cannabis use-related knowledge, attitudes, and behaviors,

conducted annually since 2017. Sampling occurs based on a two-step recruitment process. Participants are initially telephone-recruited through random-digit-dialing and eligibility-screened for age, region, and sex. Subsequently, a link to an online survey is sent to eligible individuals for survey completion. In total, completed survey samples ranged from 9,215 to 12,958, with completion rates ranging from 10.9% (2017) to 12.5% (2019) respectively. Responses were weighted for sex, age, and region to represent the Canadian resident population (Health Canada, 2017a, 2017b, 2018a, 2018b, 2019a, 2019b).

The **Canadian Tobacco, Alcohol and Drugs Survey (CTADS)** is a cross-sectional telephone survey of the general Canadian (provincial) resident population ages 15 years and older to measure the use of tobacco, alcohol, and drug consumption and related behaviors across Canada. The survey was conducted twice, in 2015 and in 2017. Sampling was based on a two-phase random sampling frame based on telephone numbers, divided into geographic and household strata with over-sampling for respondents aged 15 to 24 years. Data were collected by computer-assisted telephone interviewing. The 2017 sample included 16,349 respondents, with a household response rate of 50.7% (Statistics Canada, 2018).

The **National Cannabis Survey (NCS)** is a cross-sectional, recurring survey conducted every three months (since 2018) to monitor cannabis use-related behaviors and outcomes related to legalization. The survey targets the general household population aged 15 years and older in Canada's ten provinces, excluding residents of institutions, homeless people, and people living on reserves. Respondent dwellings with mailable addresses are randomly selected based on provincial stratification, with subsequent data collection either by online questionnaire or computer-assisted telephone interviewing. Study samples are weighted for sex and age towards representativeness by province; sample sizes ranged from 5,452 to 7,285 in each quarter, with response rates from 46.9% to 51.6% (Statistics Canada, 2019a, 2019b).

For the present analyses, we reviewed all survey content, and identified respective indicator data pertaining directly to the LRCUG recommendations. For results, relevant indicator data from 2017 to 2019, in most instances prevalence values, including 95% confidence intervals where available, were extracted and summarized by LRCUG indicator group, survey source, and data year (see Table 1).

## 3. Results (see Table 1 for data details)

We identified empirical indicators on relevant risk behaviors among cannabis users in Canada for six of the LRCUG's eight individual recommendation clusters (i.e., excluding the universal precaution and combination behavior-focused recommendations).

Data on age of cannabis use initiation were available from two surveys (CCS and CTADS). Both these surveys, and across multiple data collection years (2017–2019), showed a mean age of cannabis initiation of 19 years. The CCS showed significantly lower mean ages of initiation among younger users, compared to those aged 25 and above.

Only the CCS included indicator data on potency of cannabis used, and only in one survey year (2019). Of CCS respondents, 37% reported typically using 'higher THC/lower CBD' cannabis products. The categories, 'higher CBD/lower THC' and 'balanced' products, accounted for about 29% of users combined. Notably, one in three (32%) CCS users could not specify the cannabis product characteristics used, in part likely related to the absence of reliable potency information for unregulated products.

All four surveys reported on modes of cannabis administration, albeit involving inconsistent item structure (e.g., primary as exclusive versus multiple mode options). 'Smoking' cannabis was reported as the primary mode of use by substantial, but partially decreasing majorities of users: from 83.2% (2018) to 65.4% (2019) in the NCS (exclusive); 93.9% (2017) to 84.0% (2019) in the CCS; 77.5% in CAMH (2017); and 91.0% in CTADS (2017). The prevalence rates for alternative, non-smoking modes of use varied considerably, with some suggesting

**Table 1**  
Survey-based indicator data for the LRCUG's recommendations, Canada 2017–2019.

LRCUG RECOMMENDATION	SURVEY	SURVEY INDICATOR	2017, % (95%CI)*	2018, % (95%CI)*	2019, % (95%CI)*
#2: Avoid early age initiation of cannabis use	CCS	Average age of initiating cannabis use among non-medical users (lifetime)	18.7 (18.5, 18.9)	18.9 (18.7, 19.1)	19.2 (19.0, 19.4)
	CTADS	Mean age of initiating cannabis use among cannabis users (lifetime)	18.6 (18.1, 19.1)		
	CCS	Relative levels of THC and CBD in cannabis products typically used among non-medical cannabis users (in the past 12 months)	NA	NA	36.5 (34.8, 38.4)
#3: Choose low-potency THC or balanced THC-to-CBD-ratio cannabis products		Higher THC, lower CBD			13.4 (12.2, 14.8)
		Higher CBD, lower THC			16.0 (14.7, 17.4)
		Equal levels of THC and CBD			31.8 (30.1, 33.6)
#5: Avoid combusted cannabis inhalation and give preference to nonsmoking use methods	CCS	Methods of cannabis consumption for non-medical use (past 12 months; (select options, multiple mentions)	93.9 (92.5,95.1)	88.6 (87.3,89.8)	84.0 (82.5, 85.4)
		Smoked (e.g., joint, bong, pipe or blunt)	33.8 (31.6,36.1)	41.7 (39.7,43.7)	46.1 (44.3,48.0)
		Eaten it in food (e.g., brownies, cakes, cookies or candy)	14.4 (12.8,16.2)	14.4 (13.0,15.8)	14.9 (13.6,16.2)
NCS		Vaporized it with a vaporizer (non-portable)	20.3 (18.5,22.3)	25.5 (23.8,27.3)	27.2 (25.6,28.8)
		Method of cannabis consumption most often/ commonly used among non-medical users (past 3 months; select options, exclusive responses)			
		Smoking	NA	83.2 (77.5, 87.7)	65.4 (61.9, 68.9)
CAMH		Eating or drinking		7.7 (4.7, 12.6)	12.1 (9.9, 14.6)
		Vaporizing		8.7 (5.7, 13.0)	13.8 (11.4, 16.7)
		Other		#	8.7 (7.1, 10.6)
CTADS		Modes of cannabis use among users (past 12 months; select options, multiple mentions)	77.5	NA	NA
		Smoke cannabis in a joint	52.3		
		Smoke cannabis in a pipe, bong, or waterpipe	48.0		
NCS		Used in a food product or edibles (such as a brownie, cookie, candy)	7.8		
		Used in a vaporizer or e-cigarette			
		Methods of cannabis consumption among users (the past 12 months; select options, multiple mentions)			
CCS		Smoking	91	NA	NA
		In edibles (brownies, etc.)	38		
		Vaporizing	29		
CCS		Daily or almost daily cannabis use (past 3 months) among general respondent population	NA	5.9 (5.4, 6.5)	6.1 (5.4, 6.8)
		Daily cannabis use among non-medical users (past 12 months)	18.4 (16.6, 20.3)	18.6 (17.1, 20.2)	17.5 (16.1, 19)
		5 to 6 cannabis use days per week among non-medical users (past 12 months)	5.8 (4.8, 7.0)	6.3 (5.4,7.3)	6.4 (5.5, 7.4)
NCS		Daily or almost daily cannabis use among users (past 3 months)	32	NA	NA
		Daily or almost daily use among past year cannabis users (last 3 months; random subsample)	21.2	NA	NA
		Driving a vehicle within two hours of having consumed cannabis among cannabis users with a valid driver's license (last 3 months)	NA	14.2 (12.1, 16.6)	14.7 (12.3, 17.5)
CAMH		Driving within two hours of smoking or vaporizing cannabis among users (past 12 months)	39.0 (36.7, 41.3)	38.7 (36.8,40.6)	26.4 (24.8, 28.1)
		Ever driven within four hours of ingesting cannabis among users (past 12 months)	NA	NA	15.9 (14.6, 17.3)
		Driving within one hour after consuming cannabis among general population respondents with drivers' license (past 12 months, random sub-sample)	2.6 (1.7, 4.0)	NA	NA
CCS		Cannabis use during pregnancy or breastfeeding among female lifetime users ages 16 to 44 (2018)/50 (2019) years (past 5 years)	NA	# (0.5, 1.0)	6.9 (4.8, 9.9)
		Used cannabis while pregnant with their last child		4.4 (3.1, 6.3)	8.5 (6.0, 11.9)
		Used cannabis while breastfeeding their last child			

CCS = Canadian Cannabis Survey; <https://www.canada.ca/en/health-canada/services/publications/drugs-health-products/canadian-cannabis-survey-2019-summary.html>.  
 CTADS = Canadian Alcohol, Tobacco and other Drug Survey; <https://www.canada.ca/en/health-canada/services/canadian-tobacco-alcohol-drugs-survey/2017-summary.html>.  
 CAMH = CAMH Monitor; <https://www.camh.ca/-/media/files/pdfs---camh-monitor/camh-monitor-2017-ereport-final-pdf.pdf?la=en&hash=A411E25BB4E8838EE41F89D46799C3E527352B21>.  
 NCS = National Cannabis Survey; <https://www150.statcan.gc.ca/n1/daily-quotidien/191030/dq191030a-eng.htm>.  
 (\*) = 95% Confidence Interval (values reported where available from the datasource).  
 (#) = High sampling variability or small sample size.

increases. For example, ‘vaporizing’ (exclusive) increased from 8.7% (2018) to 13.8% (2019) among NCS respondents. Similarly, vaporizing (i.e., with a vape pen/ e-cigarette or a vaporizer) was reported by 20.3% to 27.2% (2017–2019) and by 14.4% to 14.9% of CCS respondents, respectively. Furthermore, 7.8% (CAMH) and 29% (CTADS) of users, respectively, indicated consuming cannabis by ‘vaporizing’ in 2017. ‘Eating’ cannabis increased from 33.8% (2017) to 46.1% (2019) in the CCS; similar proportions reported ‘eating’ cannabis in 2017 in CAMH (48%) and CTADS (38%). A combined measure of ‘eating or drinking’ cannabis (exclusive) increased from 7.7% (2018) to 12.1% (2019) among users in the NCS.

All four surveys provided indicator data on ‘frequency’ of cannabis use. Among NCS respondents, 5.9% (2018) and 6.1% (2019), or a correspondingly estimated 39.6% and 36.7% of users, respectively, reported current ‘daily’/‘near-daily’ use. In the CCS, 18.4% (2017) and 17.5% (2019) of users reported ‘daily use’, and 5.8% and 6.4% reported ‘near-daily’ use, respectively. In 2017, 32% of cannabis users in CTADS, and 21.2% of users in CAMH reported ‘daily/near-daily’ use. Select surveys (NCS, CCS) showed higher proportions of frequent use for younger and male users, respectively.

Three surveys reported on driving under the influence of cannabis. NCS users reported similar rates of driving within two hours of cannabis use in 2018 (14.2%) and 2019 (14.7%). In contrast, the CCS reported declining (lifetime) rates: from 39% of users in 2017 to 26.4% in 2019, while 15.9% (2019) indicated driving after ‘ingesting’ edibles. In 2017, 2.6% of CAMH’s general adult respondents with a valid driver’s license (approximately 13.4% of cannabis users) indicated driving within one hour of cannabis use. Furthermore, while 2.7% (2019) of NCS users indicated driving after combining cannabis and alcohol use, corresponding rates increased from 15.2% (2017) to 20.5% (2019) among CCS (ever) users (data not shown). Two surveys (NCS, CCS) also indicated higher rates of driving after cannabis use for men compared to women.

Data on pregnancy- or newborn-health risk indicators were available only from the CCS, where 6.9% (2019) of reproductive-age female respondents who had given birth in the last 5 years reported ongoing cannabis use while pregnant; 4.4% (2018) and 8.5% (2019) reported ongoing use while breastfeeding their last child.

#### 4. Conclusions

The legalization of cannabis use and supply has been implemented in Canada and other jurisdictions with the improvement of cannabis-related public health outcomes as a primary objective (Decorte et al., 2020; Hall et al., 2019). The LRCUG were developed and widely disseminated in Canada as an evidence-based population health and prevention tool to inform and guide active cannabis users towards reducing risk behaviors for adverse (acute or chronic) health outcomes (Fischer et al., 2017). While the evidence behind the LRCUG’s recommendations is evolving, little is systematically documented about cannabis users’ actual behaviors vis-à-vis the LRCUG’s recommendations in Canada or elsewhere. Such knowledge, though, is important to inform intervention (e.g., targeted education and prevention) needs and development (Dawson et al., 2012; Glasgow et al., 2004; LaRocca et al., 2012; Scott et al., 2012). This paper begins to fill this knowledge gap, based on a review and mapping of available relevant indicator data from major Canadian surveys.

We found survey indicator data on the majority – but not all – of the LRCUG recommendations, while presumably including those contributing most to cannabis-related disease burden (Degenhardt et al., 2013; Fischer et al., 2015; Imtiaz et al., 2016). The development of additional survey items related to other LRCUG recommendations is recommended to close these partial indicator and knowledge gaps.

Available indicators from the surveys suggest that adult Canadians, on average, initiate cannabis use around age 19 years. This age makes them eligible for legal cannabis use and procurement (in most

provinces) under legalization, and thereby should help to reduce risks for key cannabis-related health and social harms as particularly evidenced for young people (D’Amico et al., 2017; Hammond et al., 2020a; Macleod et al., 2004). However, the initiation ages reported are partly artefactual since the surveys’ sampling frames are limited mainly to adult samples and, overall, sizeable proportions of Canadians are reported to initiate cannabis use at ages below 18 years. For example, in addition to the CCS’ youth sub-sample, the mean age for cannabis use initiation is 14 – 15 years in the large-scale CSTADS and OSDUHS surveys comprising youth samples (i.e., grades 9 – 12) (Boak et al., 2018; Health Canada, 2017c). These underage users cannot legally purchase or use cannabis, and so place themselves at possibly amplified risk for both cannabis use or illegality-related health and social harms, including brain/cognitive development, CUD, or enforcement (e.g., warnings or formal charges) (Haines-Saah et al., 2019; Leung et al., 2020; Plunk et al., 2019; Scott et al., 2018).

Based on one survey’s data only (CCS), about one third of Canadian users report using high-potency (e.g., high-THC) products. High-potency products are known to increase the risk for adverse outcomes from cannabis use (e.g., cognitive and mental health problems, CUD) (Volkow et al., 2016; Wilson et al., 2019). Recent US-based data have shown trends towards increased high-potency product use in legal markets (Caulkins and Kilborn, 2019; Smart et al., 2017). In Canada, various policy measures (e.g., regulation, education) aim to reduce high-potency cannabis product use from legal sources, although high-potency products continue to be available from illegal sources and remain difficult to control (Hammond, 2019; Seigny et al., 2014; Smart et al., 2017). In addition, unregulated (e.g., illicit) cannabis products are unlabelled, and potency estimates need to rely on subjective guesses rather than objective information.

Data also show that the vast majority of users in Canada consume cannabis via smoking (‘combustion’), many in combination with tobacco, as has been the norm in North America (Russell et al., 2018; Schauer et al., 2016). Nevertheless, rates of smoking cannabis seem to be declining, with parallel increases in the use of alternative use modes (e.g., vaping, edible use); it is unclear, however, whether these are mostly experimental or more regular as, for example, within mixed patterns of multiple use modes (Fataar and Hammond, 2019; Goodman et al., 2020; Knapp et al., 2019). This shift, in part, is facilitated by the recent introduction of legal, non-smoking cannabis products to the Canadian market. While these ‘alternative’ use modes come with their own specific health risks, as exemplified by recent cannabis vaping-related lung injury cases, as well as concerns of over-ingestion (edibles), non-smoking modes of administration appear to provide overall ‘safer’ use options overall, especially for long-term (e.g., respiratory) health outcomes (Borodovsky et al., 2016; Chen et al., 2017; Glasser et al., 2017; Spindle et al., 2019; Steigerwald et al., 2018). There is substantial need for improved knowledge in this domain, as the majority of active cannabis users should be encouraged to transition from smoking to alternative modes. Clear and consistent public health messaging from primary stakeholders (e.g., health authorities) is required to facilitate this.

The literature unequivocally recognizes intensive or frequent cannabis use patterns (e.g., daily/near-daily use) as a primary predictor of acute/chronic adverse outcomes (e.g., brain development, mental health, CUD) (Crean et al., 2011; Hall, 2015; Volkow et al., 2014). Based on available data, between one and two in five cannabis users in Canada engage in frequent/intensive cannabis use, and form a distinct ‘high-risk’ group for potentially severe cannabis-related harm. While some of these ‘intensive’ users may be reached by simple prevention messaging emphasizing decreased frequency of use, a sizeable proportion are likely to feature criteria for CUD. These users are likely less receptive or able to follow simple behavior-change advice and instead may require professional help or treatment (Karila et al., 2014; Kimmel and Lopez, 2018; Lee et al., 2014).

Driving immediately following cannabis use involves (dose-



dependent) impairment, and is a behavior that about doubles risk for traffic crash involvement, and related injury and/or fatalities (Asbridge et al., 2012; Elvik, 2013; Rogeberg and Elvik, 2016). Cannabis-impaired driving is also a main contributor to cannabis-related disease burden, as it provides a (rare) cause of direct cannabis-related mortality, and thus represents a primary target for prevention (Calabria et al., 2010; Imtiaz et al., 2016). The Canadian surveys indicate that substantial minorities of users engage in cannabis-impaired driving, with a further subset of these (20%) engaging in driving co-impaired by alcohol, which further amplifies risk for injury (Downey et al., 2013; Vitale and Mheen, 2006). Moreover, as the surveys relied on short and varying time periods for impairment risk (e.g., driving 1–2 h after use), these rates likely represent under-estimates of the risk total. Irrespectively, these risk behavior rates are high and disconcerting overall. They are likely facilitated by multiple factors, including common beliefs about non-existent, or only very limited ‘impairment’ effects of cannabis, as well as a low likelihood of apprehension under current enforcement for cannabis-impaired driving (Bull et al., 2017; Davis et al., 2016; Goodman et al., 2019; Watson et al., 2019a, 2019b). These circumstances urgently require intensified targeted education and enforcement efforts. These efforts should draw on crucial lessons from alcohol/drunken-driving intervention strategies, which have achieved substantial decreases in alcohol-impaired driving and related crashes (Babor et al., 2010; Hyder, 2018).

While some evidence exists about cannabis use-related adverse reproductive/infant health outcomes during pregnancy and/or breastfeeding, rather small minorities of women reported ongoing use during these periods. While cannabis compounds may be passed on to the foetus via intrauterine transmission or through breastmilk, some women use cannabis ‘therapeutically’ to combat pregnancy-related nausea (King and Murphy, 2009; Ryan et al., 2018). Overall, adverse outcomes for newborns are uncertain and likely limited (Gunn et al., 2016; Ryan et al., 2018; Thompson et al., 2019). However, avoiding cannabis use during pregnancy and breastfeeding represents a relatively simple prevention effort of possible harm to others (i.e., foetus or neonate). Moreover, this recommendation aligns with other precautionary health behavior adjustments (e.g., concerning nutrition or alcohol use) among pregnant women or new mothers (Kaiser and Allen, 2008; Szymanski and Satin, 2012).

Overall, current indicator data from major surveys indicate that respective majorities of cannabis users in Canada – with the exception of ‘smoking’ as the primary mode of use – are generally mostly compliant with the main LRCUG recommendations for which such data exist. At the same time, the proportion of users non-compliant with other LRCUG recommendations represent sizeable sub-populations of the currently 4–5 million cannabis users, many of which likely engage in more than just one risk behavior, and thus face considerable risk for acute and/or chronic adverse health outcomes (Hall, 2015; Karila et al., 2014; Volkow et al., 2014). While population-level harms for cannabis are more limited than those for alcohol or tobacco, the ensuing disease burden is substantial, also given that cannabis use disproportionately occurs among youth/young adults where key LRCUG-defined risk behaviors (e.g., frequent or high-potency use) are commonly concentrated (Degehardt et al., 2017; Degehardt and Hall, 2012; Hall, 2017).

Thus, in order to achieve legalization’s objective of improved public health outcomes, key cannabis-related risk behaviors need to be more effectively addressed. Active and widespread dissemination and promotion of the LRCUG recommendations may lead to increased awareness and adjustment of relevant risk-behaviors among users (Glanz et al., 2008; Schwarzer, 2008). The behavioral uptake potential of interventions such as the LRCUG is uncertain, for example among intensive, chronic users. However, it should be emphasized that the LRCUG represent a targeted prevention measure, rather than a (self-)treatment tool for individuals possibly characterized by CUD (Budney et al., 2019; Caulkins and Kilborn, 2020; Jutras-Aswad et al., 2019). Nevertheless, other complementary, targeted intervention measures

combined with appropriate regulatory provisions focusing on specific risk behaviors (e.g., lower-risk product availability, content labeling) are required in order for a prevention tool like the LRCUG to be effective (Caulkins and Kilborn, 2019; Hall, 2018; Parmar and Sarkar, 2017). In addition, the impacts of such targeted measures on cannabis-related risk behaviors require consistent assessment and improved understanding (Fischer et al., 2018, 2017; Hall and Lynskey, 2016).

The data used in the present review feature some limitations. Specifically, the survey sources for the indicator data relied on different sampling frames, essential methods details and item design (see technical descriptions), limiting the surveys’ reference populations full comparability. Only some of the surveys are considered population-representative; the CAMH Monitor is an Ontario-based survey, not generalizable to populations elsewhere in Canada. All the surveys rely on (non-verifiable) self-report data, which also may be burdened by recall or other biases. In addition, survey items for certain indicators were based on differential operational definitions (e.g., cannabis and driving), or included subjective estimates with unknown reliability in select instances (e.g., cannabis potency). These may entail limitations for possible intrinsic and extrinsic indicator data validity or comparability.

Overall, while the scientific evidence behind the LRCUG is evolving, consistent population-level measurement of risk-behavioral indicators for cannabis use-related health outcomes (e.g., from surveys) is essential for effective monitoring of public health-related cannabis risks and harm outcomes, especially in the era of legalization as an ongoing ‘policy experiment’.

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## Author contributions

BF designed the overall study. CL and ML searched, collected and processed data as required. All authors substantially contributed to data analyses and interpretation. BF led the manuscript writing. All authors reviewed, and contributed substantial intellectual content and revisions to iterative drafts of the manuscript, and reviewed and approved the final draft submitted.

## Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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