TECHNICAL REPORT

Effects of legalizing cannabis

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1. Background and aims:

Based on the coalition agreement of the governing parties from November 2021, the German government plans to legalize the consumption of cannabis for recreational purposes. The intention of this initiative is to control the quality of the drug, to prevent the transfer of contaminated substances, and to guarantee the protection of minors. Key points of this project were worked out in October 2022 and submitted to the EU Commission for review. The introduction of the legal and controlled cannabis distribution to adults will be aimed at improving the protection of youth, the health of consumers, and at curbing and preventing the black market.

To substantiate the achievability of these goals, a study was commissioned to show the current state of research on the effects of the controlled distribution of cannabis based on an international literature review and input from experts in the field. For this purpose, the scientific findings and experiences in countries that have regulated and decriminalized not only the possession and cultivation of cannabis for personal use, but also the commercial production and distribution of recreational cannabis, as well as in countries that have implemented other forms of legalization (such as the release of possession and cultivation for personal use) should be examined. These countries include, for example, Canada, Uruguay, several US states, Switzerland, and the Netherlands.

This project seeks to provide answers to the following eight questions:

1) How did public health indicators (e.g., morbidity, cannabis use disorders, addiction treatment, prevention) change in legalizing countries?
2) What do we know about the development of cannabis use (prevalence) in legalizing countries (compared to pre-legalization)?
3) How did the protection of youth (e.g., availability of and exposure to cannabis, use trajectories, prevention, morbidity, cannabis use disorders) change in legalizing countries? Which accompanying measures have been proven successful to protect minors?
4) In legalizing countries, which regulations have had positive effects on protecting youth and public health? Which regulations had negative effects? Of particular interest are limits of THC concentration and minimum legal purchasing age.
5) In legalizing countries, was the illegal market successfully reduced? If yes, to which degree? Is there an association between the degree of reduced illegal market and regulations, such as upper limits for THC concentration, allowing legal sales of edibles, or allowing online purchases?
6) How have organized crime activities in relation to cannabis changed in legalizing countries?
7) In legalizing countries, is there a quantifiable association between the price of legal recreational cannabis and the share of the illegal market?
8) Which statutory regulations have been issued to avoid interactions between legal and illegal markets? How did these regulations affect the illegal market? Of particular interest are regulations concerning the documentation of the different steps in the supply chain (from seed to sale) and access to the market (licensing models) in legalizing countries.

2. Methods

To provide evidence-based answers to the eight questions, we (1) performed a systematic literature review and (2) consulted international experts accustomed with the relevant literature. These two working packages were mostly independent from each other. In this report, the findings of each working package are first presented separately and then used to provide answers to the eight questions.

2.1. Work Package 1: literature review

The literature search was conducted by the core research team (BJ, JK, SK, JM, MR, UV, MW).

2.1.1. Search strategy

We conducted a systematic literature review (see PROSPERO registration number CRD42023391081) on various aspects of the impact of the legalization of recreational cannabis in areas such as cannabis use, public health, and crime on 11 January 2023 (Medline and PsycInfo; Embase) and 12 January 2023 (Web of Science).

Search terms concerning the areas crime, public health indicators, youth, and cannabis use, and cannabis use disorder were used. The complete search strategy can be found in ***Appendix 1***, while a PRISMA flow diagram of the search and screening process can be seen in ***Figure 1***. The search was completed by first screening only the title and abstracts of the n=12,713 results by BJ, JK, SK, JM, MR, UV, MW. Second, n=278 full texts were screened by JM, MR, and UV. Inconsistencies were resolved by discussions between JM and MR.

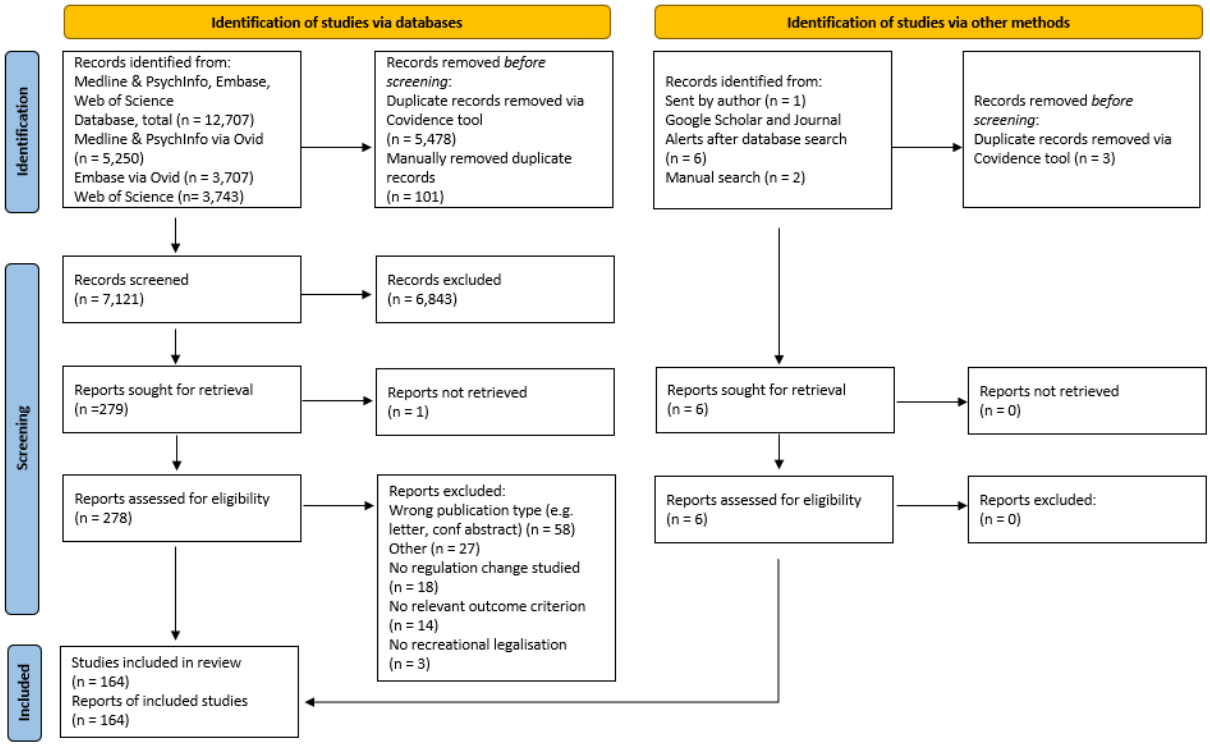

Figure 1 PRISMA flow diagram of identification of studies

Inclusion and exclusion criteria

The eight research questions (see above) were condensed into three key domains: Studies of interest had to investigate the impact of legalizing cannabis for recreational use on 1) the *illicit market* or assess the impact of legalization as a whole resp. specific regulatory measures of cannabis legalization (e.g. extent of availability, existence of upper limits for THC concentration, allowing legal sales of edibles, allowing online purchases, (minimum) prices for cannabis products, minimum legal purchasing age, and exposure to prevention campaigns) on 2) *public health* indicators (use, use disorder, health outcomes, e.g. psychosis, hyperemesis, poisonings) or 3) *youth protection*. The search strategy reflects various inclusion and exclusion criteria. Studies that met the following inclusion criteria were considered eligible and were included in the review:

Inclusion criteria that apply to all three domains:

- Quantitative or qualitative empirical studies (observational and (quasi)experimental), longitudinal studies (including pre-post-comparisons), repeated cross-sectional studies;
- published since 2012 (first legal market established);
- publication language English or German.

Inclusion criteria that apply to 1) illegal market:

- Samples of people using cannabis or samples of people selling (illicit) cannabis or samples of members of law enforcement agencies;
- studies that compare countries or federal states with or without an existing legal cannabis market;
- studies that compare the illicit market situation (market share, criminal activities) before and after legalisation of cannabis;
- (cross-sectional) studies that describe the illicit/legal market share at a given point in time (control is implicit regarding pre-legalisation period).

Inclusion criteria that apply to 2) and 3):

- General population samples (for studies requiring both users and non-users of cannabis, e.g., for prevalence rates) or samples of people using cannabis or samples of people directly affected by consequences of other's use, e.g., victims of traffic accidents in which one driver was under the influence (DUI) of cannabis;
- studies that evaluate the impact of cannabis legalization on health indicators or youth protection, e.g., in pre-/post designs or in interrupted time series analyses. The control can be the pre-legalization period or a jurisdiction that did not legalize cannabis or both (e.g., controlled interrupted time series). Additionally, studies will also be included, in which the exposure is not a binary legalization variable (yes/no) but is an indicator of one or more regulatory modalities, e.g., the increase in minimum purchasing are in one province but not in another. Thus, pre-legalization periods are not necessarily required when an adequate control condition is established in studies with measurements over time.

Studies were excluded if they met one or more of the following criteria:

- Outcomes not relevant, such as testicular cancer, housing prices, childhood asthma (1);
- Clearance rates for crimes rather than actual crimes;
- Wrong publication type, including letter to the editors with interesting data (e.g., (2, 3));

- No significance testing (e.g., Graves, Whitehill (4)).

2.1.2. Extraction strategy

We extracted study and target population details (first author, year, DOI, country, state/province, data source, representativeness, age, sex and setting of sample) and study findings (study design, main outcome details according to research questions, observation period (time pre/post legalization), definition of the date of legalization (e.g. vote, sales), and results (increase, decrease, no change) and study findings in an Excel sheet. Given the short duration of the project and the large number of studies identified, we had to restrict the extraction of study findings to the most relevant outcomes while ensuring comparability across studies. Generally, we sought to extract those findings that have the highest generalizability. This entailed several decisions, which are described in the following.

Main outcome: impact of legalization

For each study, the impact of legalization on one or more outcomes was extracted. Prior to full-text screening, a list of outcomes was specified, and this was refined during full-text screening. Finally, the following outcome categories, separated by outcome class, was agreed on:

- ***Outcome class 1 (crime):*** illegal market, violent crime, property crime, other crime.
- ***Outcome class 2 (use/health):*** use (any in any period but not explicitly during pregnancy), initiation, frequency (including daily use), quantity, cannabis use disorder (CUD, self-report or treatment), problem/risky use, hyperemesis, psychosis/schizophrenia, DUI, traffic, self-harm, poisoning (intoxication, emergency department (ED) visit for F12/T40.7), perceived availability.
- ***Outcome class 3 (youth):*** same as 2 but needs the majority of people to be younger than 18; this also included use during/after pregnancy, as well as birth outcomes (small for gestational age, low birth weight).

For each outcome within each outcome class, we classified the findings as follows:

- ***Decrease:*** significant change indicating that the legalization has had a *negative impact* on the outcome (e.g., it decreased, or it did not increase as much as in a control jurisdiction)
- ***Increase:*** significant change indicating that the legalization has had a *positive impact* on the outcome (e.g., it increased, or it did not decrease as much as in a control jurisdiction)
- ***No change:*** no significant change indicating that the legalization has had *no impact* on the outcome (e.g., it did not change, or it changed as much as in a control jurisdiction)

In most studies, statistical significance was evaluated at alpha = 5%, i.e., findings at alpha = 10% were not considered significant (e.g., Table 5 in Lu, Willits (5)). However, few studies employed different means to perform significance testing (e.g., placebo tests in synthetic controls, e.g., (6)).

Moreover, in many interrupted time series (ITS) analyses, immediate (step) and continuous (slope) changes are analyzed. Some studies report the net change at the end of a period (e.g., (7)) but some do not (e.g., (8)). When one of two parameters (step or slope) was significant, this was classified as decrease/increase. In one study, the estimates for step and slope changes were contrasting each other (e.g., Lane and Hall (9)) – in this case we only considered the immediate impact, which was nullified after some time.

Prioritization of findings within the same study:

Many studies reported only one analysis for one outcome that fell into the scope of our review. However, several studies have performed more than one analysis for one outcome of interest, e.g., subgroup analyses by gender, age and/or ethnicity. In the following, we document the prioritizations for extracting findings from the identified studies. Importantly, the documented prioritization strategy only affected findings reported within the same study, i.e., this strategy was not applied to include or exclude studies:

Legalization periods: Comparisons of various periods were undertaken, such as (general example, for actual classification, see e.g., (10)):

A) No legalization at all
B) Medical legalization
C) Medical legalization and recreational legalization but no recreational retailers (only possession and/or home cultivation allowed, sometimes called decriminalization)
D) Full recreational legalization including recreational retailers allowed

We prioritized periods that compare the implementation of legal cannabis sales (option D in the example, scenario likely to be implemented in Germany) to periods without any legalization at all (option A in the example). Unlike in Germany, the medical legalization in North America was/is not very restrictive. In practice, people can easily access cannabis for non-medical reasons under this regime. As this phenomenon is quite unique to North America and comparisons to this regime may not be as generalizable to the German setting. Accordingly, we preferred comparisons to a period of illegal cannabis (medically and recreationally), as summarized in the following: D vs A > D vs B > D vs C.

Subpopulation: If estimates were provided for a total population but also for subpopulations, we prioritized the estimates for the total population. For example, provincial/state-level estimates were preferred over subregional results (e.g., Kim, Chum (11)). If the results were opposing (i.e., increase vs. decrease), we extracted the findings for the subpopulations rather than the overall findings (e.g., findings by grade and state in Cerdá, Wall (12)).

Adjustment: We prioritized estimates from fully adjusted, as compared to crude, models.

Design: We prioritized estimates from designs that are more robust in their internal validity, i.e., in ruling out alternative explanations for the observed changes in the outcomes (other than legalization). This entailed the following hierarchy (for a detailed description of the study designs, see ***3.1***):

- Difference-in-difference > pre/post designs (Wallace, Parnes (13))
- Synthetic controls > difference in difference (e.g., Thacker, Martin (14))
- Lagged longitudinal panels > repeated cross-sectional analyses (e.g., Zuckermann, Battista (15))

Target group and outcome prioritizations: There were several prioritizations made for various findings reported in the studies:

- Outcomes that are specific to cannabis use:
    - Cannabis-related > any traffic fatalities (e.g., Hansen, Miller (16))
- Denominators that are more generalizable:
    - Fatal crashes per motor vehicles > fatal crashes per all crashes (17)
    - Traffic rate per 1 billion VMT > age-adjusted rates (state population; (18))
    - Per capita > per all-cause ED visits (7)
- The target population is more relevant for Germany

- Drivers of light motor vehicles > motorcyclists (17)

Birth outcomes: Cannabis use during pregnancy may be related to a number of adverse birth outcomes but we only considered those outcomes with the best available evidence, i.e., "small for gestational age" and "low birthweight". Thus, we prioritized birth weight over pre-term birth (e.g., Roberts, Raifman (19)) and did not consider other outcomes, such as risk for admission to neonatal intensive care unit (e.g., (20)).

Prevalence estimates: Whenever both lifetime and some form of current use (e.g., 12-months or 30-day) were reported, we prioritized the current use estimates because changes in lifetime consumption is less relevant to assess the risks associated with cannabis use. When results from both self-reported and toxicological analyses, e.g., urine drug tests, were reported (e.g., (21, 22)) we extracted both findings.

2.1.3. Definitions and terminology

Across studies, the reporting of the same phenomena varied greatly. To standardize the reporting and to allow for comparisons across studies, we defined outcomes and other terms:

<u>Outcome definitions:</u>

Use: defined by the consumption of cannabis in a given period (e.g., lifetime, past 30 days). This is often assessed via self-report but also by toxicological analyses (e.g., urine screen).

Frequency: defined by frequency of use in the past month or past year. For past-month use frequency, a variety of response scales, binary response categories or absolute number of use days were employed in the studies, such as number of days used; (almost) daily use: yes/no; 20 use days or more yes/no; 0 days, 1–2 days, 3–5 days, 6–9 days, 10–19 days, >=20 days. Use occasions were assessed using scales like 0 times, 1 or 2 times, 3 to 9 times, 10–19 times, 20–39 times, or 40 or more times; 1 −20 occasions, 21+ occasions. For past-year use, frequency was assessed with response options such as <1 times per month, 1–3/month, 1–6/ week, every day; ≥ weekly yes/no; every other day, 2-3 times per week, once weekly, 2-3 times per month; 10+ days/month. In most studies, cannabis frequency measures were analyzed within a sample of users, but not in all studies. Whenever the analyses were conducted both for the total sample and for users only, we chose the estimates from the latter analyses (i.e., users only, e.g., Cerdá, Mauro (23); Zellers, Ross (24)). If we used for example prevalence of daily use in the general population rather than in the population of users, this would be largely confounded by changes in any use, which we already assessed in another outcome. Thus, to assess changes in use patterns among people who use cannabis, we preferred to use frequency estimates among people who use cannabis.

DUI = driving under the influence: defined as driving (a motor vehicle) within a short period after having used cannabis. DUI was assessed either as a self-report (e.g., Rotermann (25)) or based on toxicological analyses (e.g., no THC limit reported: (26); various limits: Couper and Peterson (27); Tefft and Arnold (28)) or both self-report and toxicological analyses (Eichelberger (21)). In one study (29), THC limits were >0, ≥2 or ≥5ng/ml and we chose the ≥2ng/ml limit that is close to the most commonly used legal threshold in European countries (6 out of 16 countries had 1ng/ml: (30)) and is more indicative of recent intoxication than the >0ng/ml threshold.

CUD = cannabis use disorder: defined by a) hospitalizations (inpatient, overnight stays) of an adult for any ICD code related to cannabis use, b) treatment for cannabis-related problems (inpatient, outpatient), c) diagnoses (e.g., in surveys, interviews) or d) screening instruments (e.g., CUDIT-R).

We grouped a) and b) which are based on data collected in healthcare settings as "CUD (healthcare)", which indicates some form of treatment for cannabis problems. Respective cases were for example identified in the US-based "Treatment Episode Dataset-Admissions" (TEDS-A; (31)) or were based on data on hospital admissions (e.g., (32)). We considered c) and d) as separate category "CUD (survey)" which comprise data on diagnoses (e.g., Martins, Segura (33)) or self-reported cannabis-related problems (e.g., (34)) collected in survey data in non-clinical settings.

Intoxication: accidental or voluntary intoxication by cannabis that required medical attention: defined by a) visit to emergency department (ED) or b) call to poison center; for children, this could also include hospitals because we assume no CUD to form before the age of 15; in most studies, cases were defined using primary ICD codes related to cannabis (ICD-9 – not cannabis specific: E854.1, E939.6, 969.6; ICD-10: F12.x, T40.7), but in one study this also covered secondary codes, i.e., injuries or other main codes in which cannabis contributed were considered (Yeung, Weaver (35)). Some studies also used other codes (e.g., ICD-10 codes reflective of drugs other than cannabis: T40 in Wang, Le Lait (36)).

Traffic: There are a range of outcomes related to traffic motor vehicle crashes that have been analyzed in the literature. This includes traffic injuries resulting in ED admissions (see e.g., (37)) but also fatalities (e.g., (17, 18))

Use during pregnancy: defined by cannabis consumption during any day of pregnancy. This was often based on self-report but also toxicological analyses – mostly urine drug screen tests and covered various periods of pregnancy. For urine drug screening tests, various thresholds were used, e.g., 50 ng THC per mL urine (38, 39).

Other terms:

The terms legalization and commercialization are sometimes used interchangeably in the literature (e.g., commercialization = allowing retail: Shi and Liang (10)). Some studies describe the period in which cannabis possession is legal but sales are not, as decriminalization (e.g., Thomas, Dickerson-Young (40)). We are using the following definitions:

Legalization: defined as establishing a legal market for recreational cannabis. Importantly, not all studies evaluated the impact of a legal market but evaluated the short-term effects of allowing possession and home cultivation but not (yet) legal sales. These studies were still included in the analyses, but we addressed this limitation by performing separate analyses for long-term effects, defined as at least two years follow-up (it did not take longer than two years to set up a legal retail market in any jurisdiction).

Commercialization: defined as the relaxation of rules on sales restrictions. For example, when Canada allowed the sale of edibles or Ontario eliminated the license cap (studied e.g., in (41)).

2.1.4. Synthesis

First, we give a general overview of the studies that we included in the literature review by describing key study characteristics, such as geographical variations, study populations, and outcomes reported. Second, we give a detailed summary of the study type groups that we have identified. Third, we summarize and present the studies for each outcome and for each outcome class (1: illegal market/crime; 2: use and health among adults; 3: use and health among adolescents) separately. For each outcome, we give the total number of studies, describe the geographical variation, define outcome subtypes, if required (e.g., different approaches to assess CUD), and evaluate the study designs.

The description of the studies focusses on the results as extracted according to the extraction strategy (see ***2.1.2***). In case of conflicting findings, certain studies were considered of greater importance to derive conclusions. In particular, we highlighted findings of studies that a) included nationwide data or data from more than one state/province, b) covered follow-up periods longer than 3 years, c) considered data from non-legalizing jurisdictions to strengthen the internal validity. Lastly, we presented graphical summaries for outcomes with more than 9 studies to facilitate understanding.

2.2. Work Package 2: expert testimony

For the expert testimony, we created a questionnaire that contained a brief introduction and the eight research questions. For each research question, we asked the experts to provide a response as free text and then cite a) direct empirical evidence, b) indirect empirical evidence, and c) theoretical considerations. This classification of responses served to separate insights that are based on (direct or indirect) empirical observations from considerations that are plausible but lack data and from personal opinions. The empty questionnaire including the operationalization of these response classifications can be found in ***Appendix 2***.

The questionnaire was sent to five experts (David Hammond, Daniel Myran, Rosalie Pacula, Rosario Queirolo, Frank Zobel) all of which are involved in evaluating cannabis policies in their country. The selection of experts was based on covering expertise in health consequences of cannabis legalization (the focus of this study, see 8 questions) from the three countries with legal cannabis markets (Canada, USA, Uruguay). Canada was aimed to be represented by two experts because this is the only high-income country that has fully regulated the recreational cannabis market at the federal level - as planned in Germany. Finally, we also included an expert from a European country with a liberalized cannabis policy (Switzerland) to ensure a European perspective.

Of the five experts contacted, four have returned the questionnaire. Due to non-response, David Hammond was replaced by Michael Armstrong (also a researcher based in Canada). The five expert responses to the questionnaire were compiled in one document. Based on this compilation of expert responses, a concise consensus statement for each question was developed by JM. The resulting document with the compilation of expert responses and the proposed consensus statements were then returned to the experts one week ahead of a focus group meeting.

This focus group meeting was held on the 6th of March 2023 and was moderated by JM. The focus group entailed a discussion of the proposed consensus statements. During the discussion, the experts stressed several points which were insufficiently covered in the written consensus statement. Based on these discussions, the written consensus statement was further refined by JM and distributed for a final round among the five experts. After some minor changes, a final version of the consensus statement was then approved by the experts.

3. Results Work Package 1: Literature Review

3.1. Overall description of the included studies

Overall, we included n = 164 studies in this review. The majority of studies were conducted in the USA (n=120) and only n = 40 and n = 4 studies present data from Canada and Uruguay, respectively. An overview of the number of studies by study type and outcome is presented in ***Figure 2***. As shown, the majority of studies identified reported on cannabis use outcomes, as well as health care contacts for intoxications and CUD.

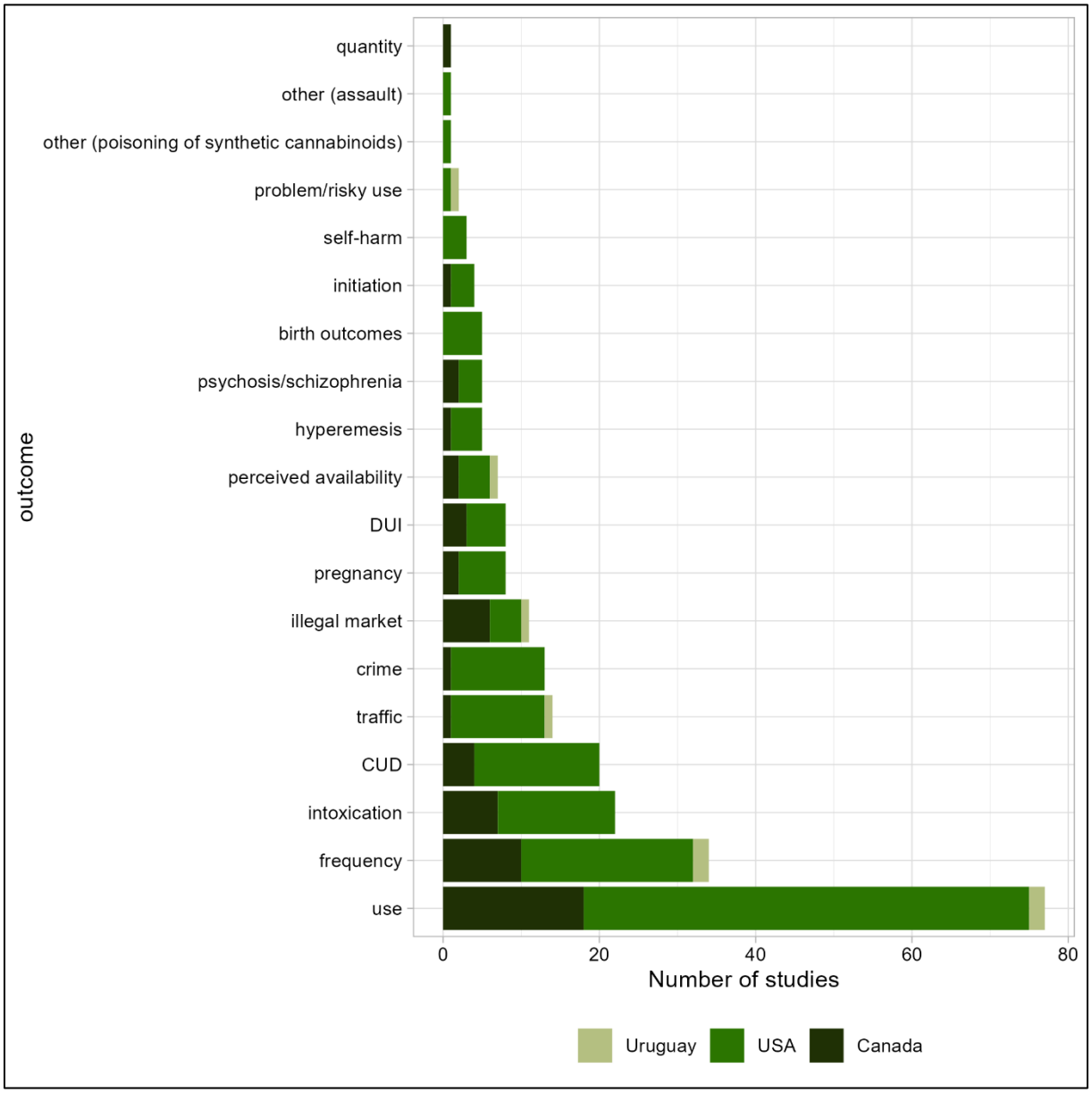

Figure 2. *Number of studies per outcome and country*

Study designs

The following study designs were employed:

Pre/post: these studies include repeated cross-sectional or longitudinal samples with data collected in one or more legalizing jurisdictions, but not in control (i.e., non-legalizing) jurisdictions. In most pre/post studies, the data was collected for the pre and post time independently, e.g., by separate assessments of different (repeated cross-sectional) or the same (longitudinal) persons. In few exceptions, retrospective assessments were performed to collect information on the pre-period during the post period (e.g., Kerr, Ye (42)), which may be confounded by memory biases. The pre/post studies are the weakest in establishing causality because they did not control for secular trends (were increases already observed before legalization?) nor did they assess whether changes were specific to the legalizing jurisdiction (and did not occur in non-legalizing jurisdictions).

ITS = Interrupted time series analyses: this study design is usually based on aggregate data from one (or more) jurisdiction(s) where cannabis was legalized. The main difference to the pre/post design is that it controls for secular trends. For example, if cannabis use has increased pre-legalization and it continues to increase post-legalization in the same rate, this would be captured in ITS but not in pre/post designs. Thus, this design is more robust to rule out alternative explanations. Classic applications of ITS are analyses of aggregated health care data (e.g., monthly counts of cannabis-related diagnoses: (7)), but we also considered analyses of individual data from several repeated cross-sectional surveys to be an ITS if they controlled for secular trends (see e.g., Gonçalves, Levy (43)).

DiD = difference-in-difference: In this study design the rate of change in the legalizing jurisdictions are compared against the rate of change in a control jurisdiction, where cannabis was not legalized. The choice of control is crucial and should be as similar as possible to the legalizing jurisdiction during the pre-period, however, this choice is based on human decisions or driven by data availability. Usually, repeated cross-sectional surveys are analyzed (e.g., (23)). In some studies, data from control jurisdictions were collected and presented but not explicitly included as control condition in the analyses (e.g., because of violating the parallel trend assumption: Chung, Salottolo (44); Lane and Hall (9)) – these results were then classified as pre/post or ITS.

Synthetic controls: As DiD, this study design also compares the changes post-legalization to the trend observed in a control jurisdiction, where cannabis was not legalized. It is however, superior to the DiD design because it creates a control condition that is statistically very similar to the legalizing jurisdiction, which is why we chose to only report the findings from synthetic controls when also DiD results are presented (e.g., Thacker, Martin (14)). In contrast to DiD studies, the control jurisdiction is not selected by humans, but it is generated from a "donor pool" of control jurisdictions. It is considered one of the strongest study designs for ruling out alternative explanations, however, its validity still relies on the selection of jurisdictions for the donor pool.

Lagged longitudinal: In this study design, data was collected from at least 2 cohorts in the same jurisdiction where cannabis was legalized (no data from control jurisdiction). In this design, one cohort was observed only pre-legalization while the other was observed pre- and post-legalization, which allows to identify within-individual changes that may be attributable to the legalization (e.g., Stormshak, Caruthers (45)). This study design is superior to the simple pre/post design with longitudinal data because it allows to control for the effect of aging, assuming that the age effect is the same in both cohorts.

Longitudinal with control: In this study design, data was collected longitudinally before and after the legalization in jurisdictions where cannabis was legalized and where it was not. Thus, some participants did not live in a state with legal market (= control). This design is similar to DiD but as it relies on multiple measurements from the same individual, it allows to study within-participant changes related to the legalization (e.g., Bailey, Tiberio (46); Kan, Beardslee (47)). The disadvantage is

that these panels are ageing, which can be controlled for by recruiting additional, younger cohort members over time (e.g., Orsini, Vuolo (48)).

Twin designs: In two studies, co-twin control designs were used (Zellers, Ross (49); Zellers, Ross (24)). These designs allow for the differentiation of environmental (e.g., legalization) and biological (e.g., genetic predisposition) determinants of behavior and are thus highly regarded tools in establishing causality.

3.2. Outcome class 1: crime and illegal market

3.2.1. Illegal market

A central criterion for the legalization of cannabis for recreational use relates to the intended reduction of the illegal market. In this context, a total of n=11 studies provide empirical data on the extent to which this goal has been achieved as described in the following.

Canada

A total of n=6 studies with data on the illegal market in Canada were identified.

A first snapshot of the legal vs. illegal market situation in Canada was provided by Mahamad, Wadsworth (50). Analyzing market data from government listings and online directories for the first two months after legalization (November and December 2018) suggested that a total of n=185 legal retailers (35% government-run and 65% privately-run) competed against n=944 illegal retailers.

In a second study, the trajectory of the legal market share during the first year of legalization was estimated by comparing sales volumes to the estimated cannabis demand of about 926 tons (51). According to that study, the legal recreational cannabis market share was estimated to have started at 8% in the first month post legalization (October 2018) and increased to almost 24% one year later (September 2019). This magnitude varied widely between single provinces ranging from Ontario with 13% to Prince Edward Island with 70%. Factors such as product availability (i.e., only minimal production shortages), density of legal stores, and retail prices were main determinants of the legal market shares.

Data from several surveys shed further light on the development of the legal market. The National Cannabis Survey provided data for three studies. In the first study, responses from before (1st-3rd quarter 2018) and after (all four quarters 2019) the legislative change were compared, suggesting that the share of consumers who partially or exclusively obtained cannabis from legal sources increased from just under 23% to 52% (25). Similarly, Hathaway, Cullen (52) estimated that, on average, legalization reduced illegal cannabis purchases by 37% within the first year. Extending the follow-up data up to the 4th quarter of 2020 showed that the proportion of individuals (also) using legal sources to obtain cannabis increased by about threefold (from 23% in 2018 to now over 68% in 2020; Rotermann (53). According to these studies, several correlations could be observed. On average, residents in Quebec and Ontario had the highest probability of illegal purchases, while the lowest probability of illegal purchases was observed in British Columbia. Further analyses showed that being a high intensity user, younger age (<64 years), having an education less than a high school diploma, and consumer preferences (nominating price and access as important) predicted continuing buying cannabis from a dealer (52). However, the decline in consuming cannabis from illegal sources appear to be independent of the level of cannabis expenditures (25).

The International Cannabis Policy Study is another survey providing insights on the legal cannabis market share by product type using data up until 2021. According to Wadsworth, Rynard (54), more consumers reported using products that solely came from legal/authorized sources in 2021 compared to 2020. This trend holds true for ten product types with 49% for solid concentrates at the lower end of the spectrum (2020: 37%) to 82% for drinks at the upper end of the spectrum (2020: 71%). For dried flowers, which were already legalized in 2019, this trend was observed over 3 years (2019: 37%; 2021: 54%). Compared to occasional consumers, frequent consumers reported more often that some of their products (1-99%) stem from legal sources (vs. none). Interestingly, the likelihood of purchasing cannabis flowers from legal sources was lower for residents of British Colombia vs. those in Quebec – thus, somehow contrary to the findings from Hathaway, Cullen (52)

who determined that, in 2019, respondents from Quebec were most likely to buy illegal cannabis while respondents from British Colombia were the least likely.

USA

A total of n = 4 studies with data on the illegal market in the US were identified.

A key study analyzed wastewater in Washington state to quantify the extent of cannabis use in the population via the measurement of a THC metabolite (55). The study spanned 3 years and covered 8 months before the first legal retail stores opened in August 2014. The findings found that the growth of THC sales at legal retail shops was about 70% larger than the growth in THC exposure in wastewater. Thus, this suggests that the legal market has replaced a large proportion of the illegal market, while THC consumption has grown overall.

A second study assessed how self-reported cannabis selling has changed in a sample of young males with contact to the criminal justice system (47). In a multi-site, longitudinal study participants were sampled from two different states: California where recreational cannabis was legalized and Pennsylvania where recreational cannabis use was still prohibited. Compared to pre-legalization (in California in 2016), the rates of illicit cannabis dealing increased among respondents from Pennsylvania but not from California post-legalization. Also, the impact of the legislative change was not dependent on the age of the respondents (below or above 21 years as the threshold to legally consume cannabis).

Another research approach dealt with pooled administrative and crowdsourced data to explore net effects of cannabis legalization on illegal market developments (56). Employing a DiD study design to examine changes within and between US states with (n = 11) and without (n = 40) recreational cannabis laws, the legalization of cannabis has led to declines in law enforcement seizures of cannabis, but also other drugs such as heroin or methamphetamine. The reduced number of seizures may be indicative of a less active illegal market and/or shifts in the priorities of law enforcement agencies.

Worrall, Han (57) took advantage of the fact that it remained illegal to ship cannabis through the United States Postal Service, even though cannabis has been legalized in some states, in his study. Consequently, seizures by the United States Postal Inspection Service were used as an indicator for illegal market activities. State-level panel data between 2010 and 2019 were analyzed to explore the effects of legalization. After controlling for different law enforcement and population factors, the results consistently showed that recreational legalization was not associated with increased or decreased seizures relative to criminalization states.

Uruguay

The only study from Uruguay (58) was based on a pre-post design with two independent samples of frequent cannabis users (i.e., consuming cannabis at least weekly). These samples were interviewed in 2014 with the onset of regulation implementation (n = 298) and in 2017 (n = 289). Results showed that cannabis users gradually moved to the legal market and, in particular, to the gray market. The gray market covers cannabis that was initially legally sourced (e.g., bought in a pharmacy) but distributed in some illegal way (e.g., purchasing from friends). In detail, in 2014 legal access modes were preferred by 0.6% of participants, illegal modes by 78%, and gray modes by 22%. Three years later, the respective numbers were 14% (legal), 41% (illegal), and 44% (gray). No substantial differences existed between cannabis users who switch to legality and those who remain in contact with the illegal market in terms of their sociodemographic profile and their consumption patterns.

Conclusion

The identified studies mostly converge on the fact that the illegal market can be successfully reduced by cannabis legalization. This shift appears to be gradual and continuous, but its extent depends on user preferences, product categories, and market factors (e.g., availability and pricing). Additionally, the barriers to purchase legal cannabis appear to change over time. Overall, a quickly growing legal market appears to effectively reduce the illegal market but it may also stimulate demand in its own e.g., by introducing new products or lowering prices to compete with the illegal market.

3.2.2. Crime

In n = 13 studies, the impact of cannabis legalization on crime outcomes were studied. We did not find any study examining the legalization impact on organized crime. Studies on drug-related and specifically cannabis-related arrests were excluded because it has been robustly established that legalizing cannabis substantially reduces arrest rates for cannabis possession (see e.g., Gunadi and Shi (59)). Here, we identified studies that examined the impact of cannabis legalization on property and violent crimes, as well as certain subtypes (e.g., car theft for property crimes or aggravated assault for violent crimes). Other crimes (e.g., public disorder) were considered in three studies.

In all except one study (from Canada: Callaghan, Vander Heiden (60)), the impact of legalization on crime was studied with data from legalizing as well as control jurisdictions in the US using DiD designs or synthetic controls. In most studies, crime rates in entire states were compared to states where cannabis was not legalized. In n = 4 studies, however, the control jurisdiction were those communities within a legalizing state where legal cannabis sales have not (yet) occurred (14, 61, 62, 63). Thus, the internal validity of the findings on crimes can be assessed as comparably high.

Violent crime

A total of n = 3 studies found evidence that violent crime has increased following the implementation of cannabis legalization in Colorado (63) and (64, 65). In contrast, n = 9 studies found no evidence for the legalization to have impacted rates of violent crimes in Colorado (61, 62), Oregon (66), Washington (14, 67), as well as Colorado and Washington (5, 68, 69), and in a nationwide sample (states not reported; Sabia, Dave (70)). No single study reported that legalization decreased the rates of violent crimes. Thus, there is mixed evidence on whether the legalization of cannabis has increased violent crimes in the US. The single study conducted in Canada (nationwide) found no increases in violent crimes following the legalization (60).

Property crime

Studies on property crimes found increases related to legalizing cannabis in Colorado (62, 63, 68), and Oregon (65). No impact was identified in Colorado (61), Washington (14, 68), as well as in Colorado and Washington (5, 69), and in a national sample (states not reported; Sabia, Dave (70)). A single study found that property crimes decreased in Washington following the legalization of cannabis (67). Thus, the US-based evidence on the impact of cannabis legalization on property crimes is mixed. For Canada, the only study identified found that property crimes were unaffected by the legalization (60).

Other crime

For criminal activities unrelated to property or violent crimes, three studies were identified. Two studies assessed changes in public disorder in Colorado, suggesting no impact (62) or an increase following the legalization (63). Another study examined offenses that were not classified as property, violent, or drug offenses and included – among others – trespassing, prostitution, and liquor violation (14). No change in the occurrence of these crimes were found.

Conclusion

We have not found a single study on the impact on organized crime. Studies on cannabis-related crimes were not considered because it was a priori known that legalization massively reduces arrests for possession – which make up the vast majority of cannabis-related crimes.

The reviewed literature on the impact of cannabis legalization on crime outcomes – mainly violent and property crimes – includes many methodologically sound studies, but the findings are heterogeneous and mostly limited to few western US states. Importantly, none of the studies have attempted to identify the causal pathway that would explain changes in crime outcomes. However, there are some suggested explanations.

According to some studies, one explanation for the legalization to possibly increase violent crimes is related to the gateway hypothesis (see e.g., Wu, Wen (65)). According to this hypothesis, cannabis use is an entry-point for other (illegal) substance use, which can cause social drift and violent behavior. However, this hypothesis is disputed and the causal pathway for initiating use of other (illegal) substances, or for exerting violent behavior, is not well understood. Yet, there is robust evidence that cannabis use, in particular heavy use, is associated with violent behavior (71), which would make it plausible that violent crimes may increase following the legalization – assuming that cannabis use is increasing (see section ***3.3.1***). For property crimes, the observed increase in some US states has been linked to the fact that cannabis remains illegal at the federal level, which requires retailers to rely on cash payments because they are not allowed to use bank transactions for cannabis retail activities. Thus, cannabis retailers can be an attractive target for burglaries – a common type of property crime, which may sometime also involve violent behavior, i.e., violent crimes. In a completely legal environment, as planned in Germany, such causal pathway would be eliminated.

Based on the available evidence, it can be assumed that legalizing cannabis in Germany will not decrease violent or property crimes. Moreover, it appears unlikely that the legalization of cannabis will increase criminal activities in the short run.

3.3. Outcome class 2: health and use

This section describes the impact of cannabis legalization on adults, defined as samples with less than 50% respondents aged 17 or younger. For more details on the respondents' age, see ***Appendix 3***.

3.3.1. Perceived availability

The perceived availability of cannabis among adults was studied in only n = 1 study from Canada. In Ontario, up to 10 months post legalization, a selective sample of young adult (mean age 19 years) survey respondents reported no change in the perceived availability of cannabis (72). It should be acknowledged that this period was associated with very strict sales controls and about one third of respondents were below the legal age of 19 to be allowed to purchase cannabis legally in this province.

Conclusion

There are too few empirical studies to make generalized conclusions on the impact of cannabis legalization on perceived availability among adults.

3.3.2. Cannabis use

We identified a total of n = 45 studies reporting on the impact of cannabis legalization on cannabis use. Those studies collected data primarily in the US (n = 32) but also in Canada (n = 12) and Uruguay (n = 1). In about two out of three studies, only data from legalizing jurisdictions were analyzed (n = 29), while the remaining studies also included data from control jurisdictions (n = 16). Among the latter studies, the majority adopted DiD study designs (n = 15), but we also found n = 1 study with a co-twin control design (24).

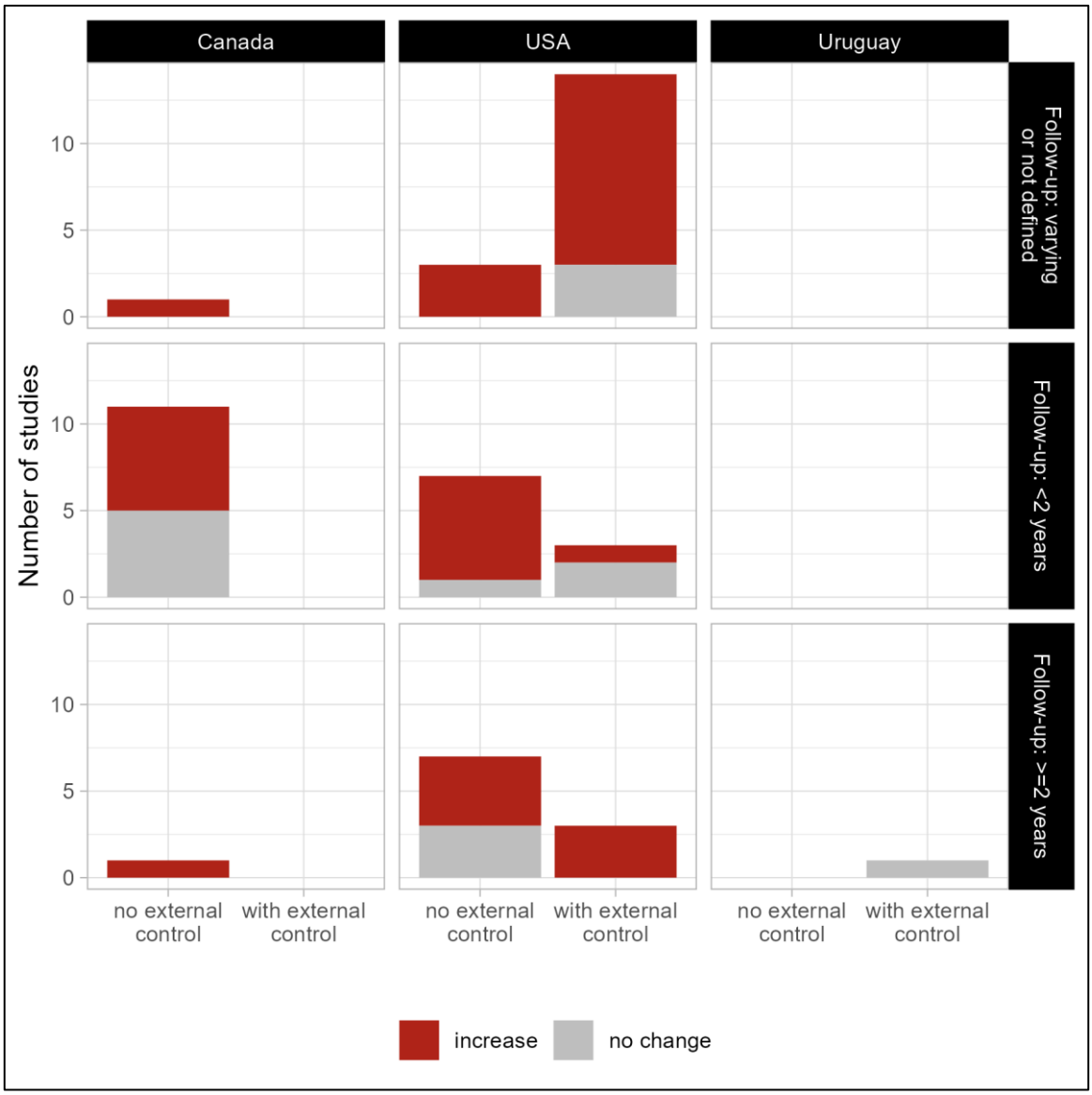

Figure 3*. Study findings on the impact of cannabis legalization on adult use outcomes, by use of external control, country, and length of follow-up. All studies provided one estimate, except for (6, 23, 73, 74, 75), which provided two or three estimates because of inconsistent age-stratified findings or because of different outcome definitions (e.g., past-year vs. past-month use).*

Across all n = 45 studies, a total of n = 51 findings were extracted. For one study (23), the findings differed by age group (18-25 vs 26+ years) and could not be collapsed. For n = 4 other studies (22, 73, 74, 75), results for different consumption indicators (e.g., cannabis use but no tobacco use vs. cannabis and tobacco co-use; past-year vs. past-month use) were reported. Of all n = 51 findings, n = 36 or 71% suggested that cannabis use has increased following the legalization of cannabis, while the remaining studies suggested no change and not a single study suggested decreased cannabis use. Looking only at studies that employed samples representative of the target population did not change this pattern (21 out of 30 findings: 70%).

A breakup of the study findings by country and length of follow-up post legalization is illustrated in ***Figure 3***. In Uruguay, the single study identified (76) found no change in cannabis use rates among adults following cannabis legalization. In the US, the share of results suggesting that cannabis legalization was followed by increased use rates was 75%, similar to Canada (67%). The increasing trend of cannabis legalization in the US was also observed when considering data from jurisdictions that did not legalize cannabis as external controls (n = 20 findings, 75% suggesting an increase).

Moreover, there was a trend suggesting that studies with a follow-up of two years or longer post-legalization in US states were more likely to find increased cannabis use (n = 10 findings: 80%) than those with a shorter follow-up (n = 11 findings: 64%). This was similar in Canada (n = 1 finding with longer follow-up: 100% increase; n = 10 findings with shorter follow-up: 60%), but not in Uruguay (n = 3 findings with longer follow-up: 0% increase).

Some key studies shed light on the magnitude of change in cannabis consumption. Analyzing the impact of cannabis legalization in Colorado, Washington, Alaska, and Oregon on self-reported use in the past 30 days, Cerdá and colleagues found no significant changes among the population aged 18 to 25 years, but a 28% higher likelihood to report use among those 26 years or older (23). This translates in a prevalence increase from 5.7% to 7.1%. Findings from another study suggests that the gap in cannabis consumption between states with and without legal cannabis markets grows over time. Bae and colleagues analyzed data from 18- to 26-year-old college students from Colorado and Washington and compared them against students from other US states with non-legal cannabis markets (77). At the end of a follow up of 6 years, the likelihood of reporting past-month cannabis use was 63% percent higher for students from these states as compared to student from other states – up from 26% in year two post-legalization.

The key disadvantage of self-reported cannabis use is that it may be confounded by the fact that the people are more willing to disclose this previously illegal behavior. Thus, it is possible that cannabis use itself has not changed but only the likelihood to report it. There are some findings using non-survey data on consumption that can be used to address this concern. One study relied on results from nationwide workplace drug tests. According to Hollingsworth, Wing (73), the odds that a workplace test for THC was positive increased by 35% after the retail sales started in those US states that legalized cannabis up to 2019. Another study showed that the levels of THC in wastewater in the state of Washington increased after retail sales started in 2014 (55). Two further studies focused on clinical samples. In the first sample of patients admitted to an emergency department in two hospitals in Massachusetts, a 7% increase in the odds of a THC positive test results was found (78). The share of patients testing positive for THC was 18% before medical cannabis was legalized and it rose to 25% after the start of retail sales. In Ontario, cannabis legalization appeared to have no impact on cannabis use according to both self-report and urine drug screening in a sample of patients with opioid use disorders (22). Lastly, two studies present data on THC levels among deceased persons. In New Brunswick, the proportion of cannabinoid-positive samples increased post-legalization (20.6% versus 17.1% based on a sample of 3,060 dead persons), but this difference was not statistically significant after correcting for multiple comparisons (79). In Nevada, THC positivity following cannabis legalization increased in similar magnitude in a sample of 20,636 deceased persons (10.7% versus 8.6%), which was statistically significant according to the study authors (80).

Conclusion

The majority of studies using self-report or objective data on THC consumption indicate increasing prevalence of use among adults following the legalization of cannabis, especially in the long run. While this pattern is rather consistent for studies conducted in the US and Canada, cannabis legalization appears to not have impacted cannabis use rates in Uruguay. Thus, it appears reasonable to assume that cannabis use may increase in Germany if a legal approach similar to the North American models would be adopted.

3.3.3. Initiation

To better understand how cannabis use has changed post-legalization, the likelihood to initiate use is insightful. We found n = 2 studies measuring cannabis use initiation in the US. Both studies analyzed

nationally representative samples and found an increased likelihood to start using cannabis post-legalization. The first study followed up adults aged 21 years and older from across the USA in a longitudinal study. Respondents who reportedly did not use cannabis at baseline were about 70% more likely to have used cannabis at follow up, when they resided in one of four states that legalized cannabis (California, Massachusetts, Nevada or Maine) between the baseline and follow-up assessment (81). In an analysis of repeated cross-sectional survey data, initiation of use was measured as the first use in the past 2 years. According to the findings, respondents aged 18 and older were about 32% more likely to initiate use when they resided in states that opened retail stores (73).

Conclusion

We identified two studies with robust methodologies on the impact of cannabis legalization on cannabis use initiation. Based on the findings, it can be cautiously concluded that legalization in US states has increased the likelihood of adult non-users to initiate cannabis consumption.

3.3.4. Frequency

Frequency of cannabis use among adults was studied in n = 24 studies from Canada (n = 8), USA (n = 15), and Uruguay (n = 1). Each study provided one study finding, except for one study which described frequency changes stratified for different age groups (23). As described in the methods section, frequency was measured with quite different items and some studies only considered current users, while others also considered non-users. In half of the studies (n = 8), the impact of legalization was examined without considering data from external controls. The remaining studies employed DiD designs (n = 8), or longitudinal with control (n = 2), or twin study designs (n = 2).

The majority of study findings suggested that cannabis use frequency has not changed (n = 14 or 56%), with the remaining largely suggesting increased (n = 10 or 40%) rather than decreased frequency (n = 1 or 4%). Looking only at studies with representative samples increases the share of findings suggestive of no change (n = 11 or 69%) as compared to increased use frequency (31%). As shown in ***Figure 4***, most studies with at least two years of follow-up data suggest no changes or decreased cannabis use frequency. The perhaps largest study on this topic showed that legalization in Colorado, Washington, Alaska, and Oregon was not linked to an increased proportion of frequent use in age groups 18-25 and 26+ (23).

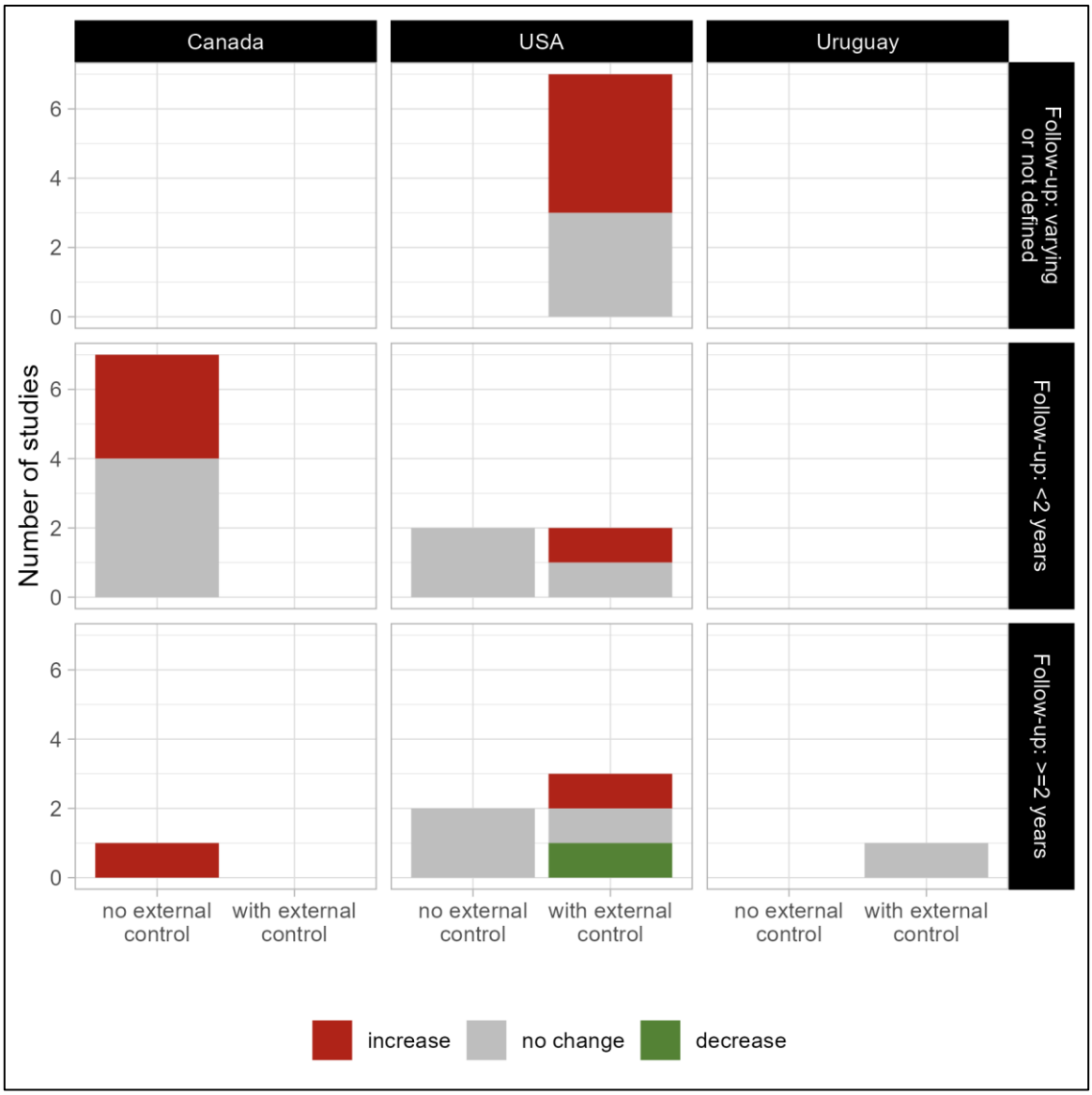

Figure 4. *Study findings on the impact of cannabis legalization on adult use frequency outcomes, by use of external control, country, and length of follow-up. All studies provided one estimate, except for Cerdá, Mauro (23), which provided two estimates because of age-stratified findings.*

There are n = 2 studies with a follow-up period with at least two years that reported increased frequency. The first study from Canada found that prevalence of daily or near daily use among (using and non-using) adults increased from 5.4% in 2018 to 7.9% in 2020 (53). As any current use in the past 3-months also increased by a similar magnitude in this period, the increase in frequency was likely due to an increase of new users, rather than changes in current users. Another Canadian study with longitudinal data on self-reported cannabis consumption confirmed this hypothesis. They found that the overall increased use frequency was due to previously non-users that had not only initiated cannabis use, but also increased their use frequency during legalization, while people who used cannabis prior to legalization used it overall less frequently (34).

The second study reporting that cannabis legalization was linked to increased cannabis frequency compared twins aged 24-49 years that lived in Colorado or in states with non-legal cannabis markets (49). Analyzing data from before and up to five years after start of legal sales in Colorado, they measured frequency as the number of days used in the past 180 days, which included 0 use days and thus the results could be driven by increased any use, i.e., initiation of cannabis use. A second study

analyzing the same sample confirmed this hypothesis, as it showed that frequency among recent users did not change (24).

Conclusion

Among adults that use cannabis, use frequency was not impacted by cannabis legalization. Any increase in frequent use in the population is likely to due to an increase of new cannabis users.

3.3.5. Quantity

One study from Ontario analyzed how use quantities changed following the legalization in 2018. According to the findings, adults aged (on average) 35 years slightly increased their average consumption by 0.03 gram on a typical use day. Furthermore, subgroup analyses suggest that the overall increase in mean quantities was driven by increased use among formerly non-users, while people who used cannabis pre-legalization decreased their use (34).

Conclusion

Based on only one study from Canada, general conclusions on the impact of cannabis legalization on cannabis use quantities cannot be drawn. However, in Canada, legalization appeared to have not had a major impact on cannabis use quantities.

3.3.6. Risky/problem use

Only n = 1 study identified provided insights on the impact of cannabis legalization on risky use. The data was collected in urban areas in Uruguay and suggest that risky use among young adults (ages 18 to 21) has followed a similar trend as in Chile, where cannabis was not legalized (76).

Conclusion

Based on only one study from Uruguay, general conclusions on the impact of cannabis legalization on risky cannabis use cannot be drawn. However, in Uruguay, legalization appeared to have not impacted risky cannabis use among young adults.

3.3.7. CUD

A total of n = 16 studies evaluated the impact of cannabis legalization on CUD in adult samples, of which n = 13 were conducted in the USA and n = 5 analyzed data from Canada. As summarized in ***Figure 5***, we differentiate between two different types of CUD outcomes: a) data collected in healthcare settings, reflective of treatment demand, and b) data collected through self-report in surveys, reflective of treatment need.

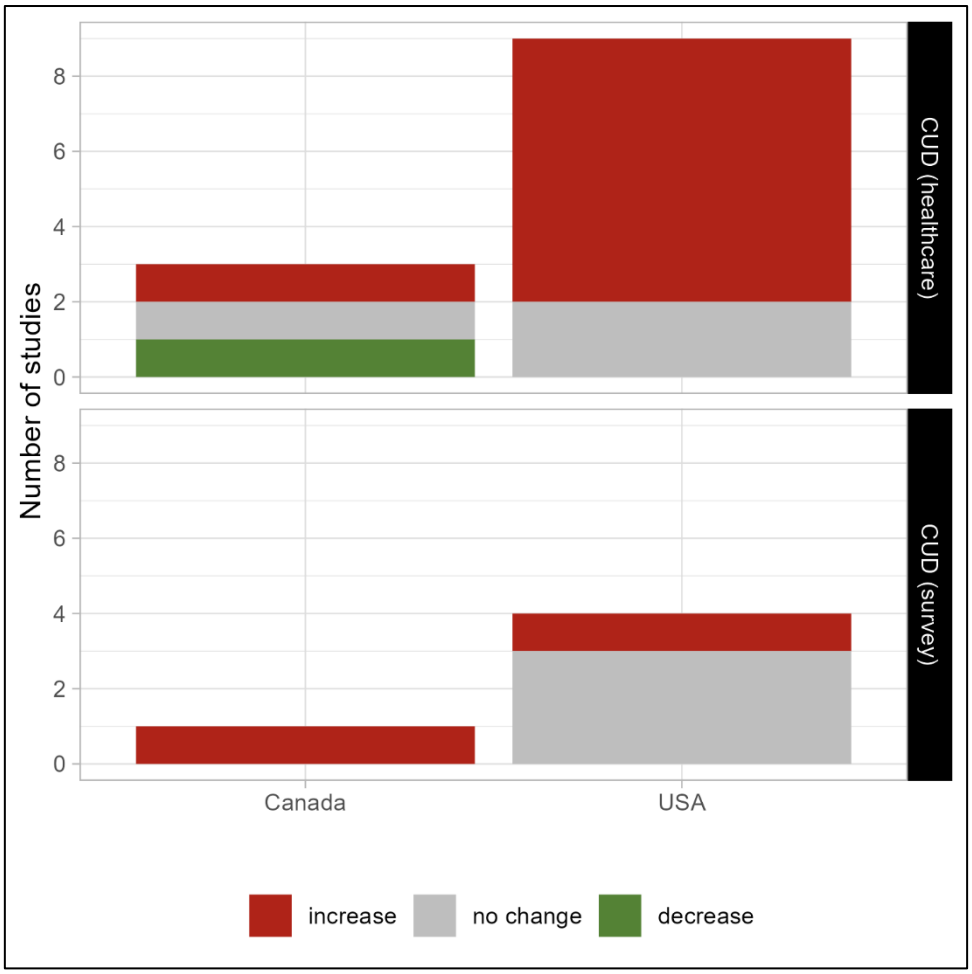

Figure 5. *Study findings on the impact of cannabis legalization on CUD among adults, by country. All studies provided one estimate, except for Cerdá, Mauro (23) which provided two estimates for different age groups (18-25 and 26+).*

CUD healthcare

In most of the n = 12 studies on CUD in healthcare settings, simple pre/post and ITS analyses were conducted, but n = 5 studies adopted DiD study designs, i.e., they included data from states where cannabis was not legalized (70, 82, 83, 84) or from communities in the same state where cannabis retailers have not (yet) opened (85).

The majority of US studies suggest increasing occurrence of CUD in healthcare settings following the legalization of cannabis in Colorado (82, 85, 86, 87, 88), Colorado and Washington (89), or twelve legalizing states (84). One study found no change following the legalization in a nationwide sample in the USA (states not reported; Mennis, McKeon (83)). Data from Canada suggests no changes in Quebec (90) or decreases in Quebec (91) or increases in Ontario (32).

Restricting the CUD healthcare studies to analyses of data with control jurisdictions found increases in healthcare settings in three studies (82, 84, 85) that analyzed hospitalizations for cannabis-related problems. For example, Delling and colleagues found that admissions for cannabis abuse diagnoses in Colorado increased to a larger extent than in New York (+27%) or Oklahoma (+16%; Delling, Vittinghoff (82)). Similarly, communities in which cannabis retailers opened experienced an increase of cannabis-related hospital discharges (+4.8 per 1,000 discharges; Gunadi (85)). The most recent study on this topic found that the prevalence of CUD diagnoses among veterans aged 18 to 75 years increased from 1.4% to 2.6% between 2005 and 2019 in those states that legalized cannabis for

recreational purposes. About 10% of this increase was estimated to be attributable to legalizing cannabis (84).

Two other studies on CUD with a DiD design did not analyze hospital admission data but focused on the provision of treatment for substance use disorder in public and private treatment centers. Both studies did not find that the legalization impacted the admission rates for CUD (70, 83). Notably, one of the two studies restricted the analyses to non-criminal justice referrals, which could confound the impact of cannabis legalization because declining arrests following legalization may also reduce criminal justice referrals to the treatment system. According to the study findings, the legalization of cannabis did not impact the rates of CUD treatment among young adults (age 18 to 25; Mennis, McKeon (83)).

CUD survey

In n = 4 studies from the US (23, 33, 49) and Canada (34) self-reported data on CUD diagnoses or cannabis-related problems were analyzed. One study reported findings separately for younger (18-25 years) and older (26+ years) adults (23), resulting in five findings (see also ***Figure 5***).

Using survey data from adults aged 18 years or older, Cerdá and colleagues found no evidence that CUD diagnoses (DSM-IV criteria) were more common among current users following the enactment of legal cannabis laws in Colorado, Washington, Alaska, and Oregon, as compared to control states (23). Re-analyzing the same data but with a longer follow-up (up to 2017) to include additional states (Massachusetts, Michigan, DC, Vermont, California, Maine, Nevada), Martins and colleagues confirmed that the proportion of CUD among current users did not increase overall after legalizing cannabis (33). However, they found increased rates in respondents with an ethnicity other than non-Hispanic Black, non-Hispanic White, or Hispanic. Another US-based study analyzed changes in CUD in a longitudinal sample of twins aged 24-49 years, of which some lived in states that legalized cannabis and some did not. This twin study showed that likelihood of reporting CUD symptoms was not related to cannabis legalization (49). The only Canadian study on CUD using survey data analyzed a sample of adults residing in Ontario. Compared to the time before cannabis was legalized, this sample reported more cannabis-related problems post legalization. In this sample, the increase was driven by people who have not used cannabis before legalization, while experienced users reported a decline in cannabis-related problems (34).

Conclusion

Differentiating between different approaches to measure CUD or cannabis-related health problems, we observed that small increases in hospitalizations for cannabis-related problems in relation to the legalization in US states are commonly reported in the literature. However, there is good evidence suggesting that the likelihood of reporting cannabis use problems among users is unaffected by legalization, thus, the observed increases may be primarily driven by increased use, rather than changes in problems among users. Treatment rates for CUD remained unaffected but longer follow-ups may be required to see a possible impact of cannabis legalization.

3.3.8. Intoxications

We found a total of n = 12 studies on cannabis intoxications among adults in the US (n = 8) and Canada (n = 4). Most studies employed pre/post study designs but n = 1 study also included data from an external control group in a DiD analysis (10).

Across the n = 12 studies, we extracted n = 16 findings. In two studies, data on different sources indicating poisoning (ED visits, calls to telehealth, visits to poison center) were reported, with

partially different results (35, 88). One other study reported different findings for different age groups (11).

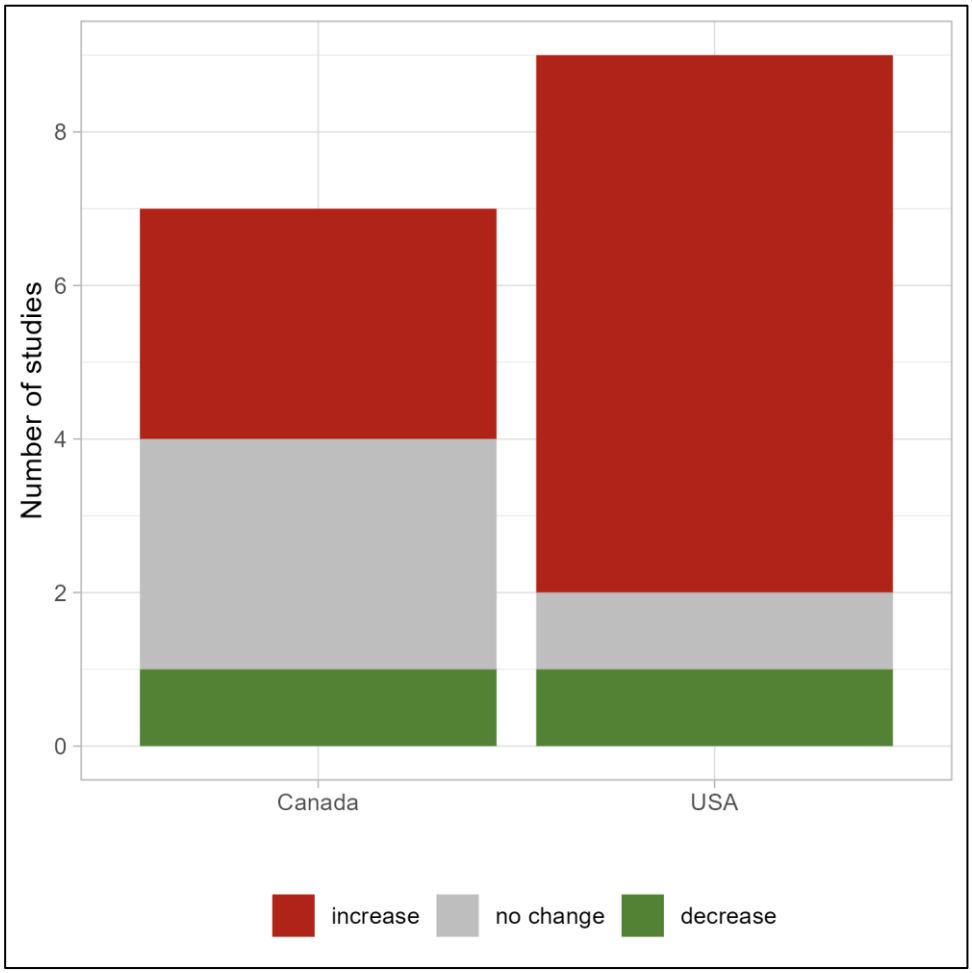

***Figure 6**. Study findings on the impact of cannabis legalization on adult cannabis intoxication, by country. All studies provided one estimate, except for (11, 35, 88) which provided two or three estimates because of inconsistent age-stratified findings or because of different outcome definitions (e.g., calls to poison center vs. emergency department admissions).*

The majority of study findings (n = 10 or 63%) on intoxications suggest that cannabis legalization was associated with increased cases, while the remaining found decreases (n = 2) or no changes (n = 4; see also ***Figure 6***). This pattern remained unchanged when restricting the analyses to representative studies (n = 8 out of n = 13 findings suggesting increases). Studies finding increased number of intoxications were conducted both in the US and in Canada. The largest and probably most robust study on this topic analyzed data from the US national poison data system between 2010 and 2017, which compiles data on calls to regional poison centers across the country (10). With the start of retail sales in nine US states (Alaska, California, Colorado, DC, Maine, Massachusetts, Nevada, Oregon, and Washington), the number of cannabis-related calls by adults aged 21 or older to poison centers increased by about 77%. Data from emergency departments in Colorado (86, 88, 92), Massachusetts (78), Ontario (32), and Alberta (35) support these findings.

In n = 2 studies, a decreasing number of cannabis intoxication was observed following legalization (41, 87). Of note, Myran and colleagues reported that cannabis legalization with strict control, as introduced in the first year in Ontario, attenuated the pre-legalization trend of increasing number of intoxications in emergency departments (41). In Colorado, the start of retail sales in 2014 was linked to a trend reversal of increasing cannabis intoxications which was observed after the successful vote in 2012 (87).

Conclusion

With few exceptions, the literature suggests that the number of acute intoxications among adults has increased post legalization in Canada and US states.

3.3.9. Hyperemesis

In n = 5 studies, the impact of cannabis legalization on hyperemesis among adults was studied. An assessment of hyperemesis-related hospitalizations in Colorado showed that cases went up by 32% from 895 in 2012 – the year of the vote – to 1,180 in 2014 – the year in which retail sales started (93). Another study, however, found that the observed increase in Colorado inpatient settings was not different to the increase observed in two control states that did not legalize cannabis (82). Similarly, hyperemesis diagnoses in inpatient data were found to have not increased in Colorado and Washington when compared to two control states in another study (89). The only study from Canada also found that during the first 17 months of legal cannabis sales in Ontario – which was strictly regulated – the number of cannabis hyperemesis hospital admissions did not change (7).

Conclusion

Based on the available data, cannabis legalization in Canada and US states appears to have not led to immediate increases in hyperemesis cases.

3.3.10. Psychosis/Schizophrenia

The impact of cannabis legalization on psychosis or schizophrenia outcomes among adults was evaluated in n = 4 studies from Canada (n = 1) and the US (n = 3). The only study from Canada observed no changes in the number of presentations to emergency departments for cannabis-induced psychosis in both Alberta and Ontario (94). This study used a little more than 1 year of data post legalization which included data from a period of a strictly regulated legal market in Ontario. In Colorado, the rates of admissions due to psychosis or schizophrenia was reportedly not impacted by the start of legal retail sales, based on 12 months of follow-up data (82). However, based on a longer follow-up interval (comparing 2012 to 2018), but without comparison to an external control, Wang and colleagues found increased emergency visits for psychosis but not for schizophrenia (95). Importantly, they found that the growth in psychosis rates was restricted to areas that did not have medical cannabis dispensaries before the onset of retail sales in 2014. The largest and possibly most robust study on this topic compiled health insurance claims data on persons aged 16 or older from across the USA and measured the impact of cannabis legalization in Alaska, Colorado, Nevada, Oregon, and Washington as compared to control states (96). According to the study findings, psychosis-related diagnoses were not found to significantly increase in states after legal retail sales started, using up to four years of follow-up data. Only among 55–64-year-olds, the diagnoses increased significantly.

Conclusion

The literature on the impact of cannabis legalization in Canada and USA on psychosis or schizophrenia is mixed. Based on the available evidence it appears that cannabis legalization has had no short-term impact on psychoses, but there is less certainty for a long-term impact.

3.3.11. Self-harm

In n = 3 studies from USA, changes in self-harm outcomes relative to cannabis legalization were assessed. Compared to two control states, the inpatient diagnoses of self-harm increased in Colorado in the 12 months after the start of legal sales (82). Data from Colorado and Washington was also

analyzed with regards to suicide mortality. When compared to synthetic controls, the upward trend in the number of suicide deaths was not affected by the start of legal retail sales in these two states (97). While this was true for the overall population, more pronounced increases were observed among 15-24-year-olds in Washington, but not in Colorado. Lastly, the most robust study on this topic analyzed health insurance claim data from underage and adult persons from across the USA (98). The rates of self-harm injuries, including non-suicidal and suicidal (attempts) were not affected by the opening of retail stores in Alaska, Colorado, Nevada, Oregon, and Washington. Age-specific analyses, including under 21-year-olds, confirmed this finding, except for 21-to-39-year-old males, which were found to experience increased self-harm.

Conclusion

Based on n = 3 studies from the US, there is little evidence that cannabis legalization has generally increased self-harm among adults. However, there might be increases among young (male) adults.

3.3.12. Traffic

A total of n = 20 studies evaluated the impact of cannabis legalization on traffic-related outcomes in adult samples, of which n = 15 were conducted in the USA, n = 4 analyzed data from Canada, and n = 1 study presented findings from Uruguay. We differentiate between a) data on driving under the influence (DUI) of cannabis and b) data on traffic outcomes, including crashes, injuries, and fatalities. The figures are descriptively summarized in ***Figure 7***.

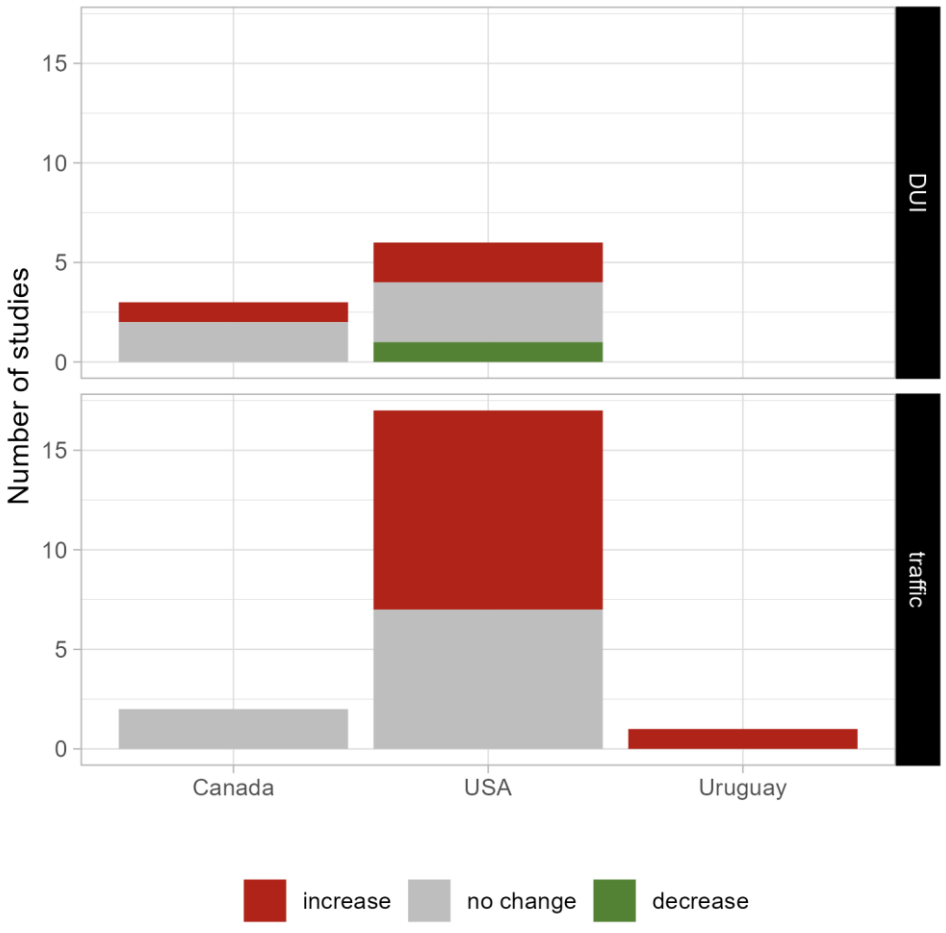

Figure 7. *Study findings on the impact of cannabis legalization on driving under the influence (DUI) and traffic outcomes (crashes, injuries, fatalities), by country. All studies provided one estimate, except for six studies which provided more than one estimate because of findings for adults and youth (37), inconsistent state-stratified findings (8, 18), or because of*

different outcome definitions (Eichelberger (21): self-report vs. toxicological analyses of DUI; Farmer, Monfort (99): crash injuries vs. fatalities; Windle, Eisenberg (100): fatal collision vs. death from collision).

Driving under the influence (DUI)

There were n = 8 studies on DUI, which were either established using a self-report or using toxicological analyses or both. Overall, there were n = 3 studies showing an increasing proportion of drivers who used cannabis before driving (27, 28, 29), n = 4 studies that did not find any change in this behavior relative to legalizing cannabis (21, 25, 26, 101) and n = 1 study that found a decrease (47).

Of those n = 5 studies with toxicological rather than self-report data, n = 3 found increases in DUI following cannabis legalization. Brubacher, Chan (29) analyzed the tetrahydrocannabinol (THC) concentration in injured drivers in four trauma centers in the Canadian province of British Columbia. Using the Canadian legal limit of at least 2 ng THC per milliliter blood as a threshold, the prevalence of moderately injured drivers with a THC level above this threshold more than doubled after legalization (from 3.8% to 8.6%). Analyses adjusting for various potential influencing factors corroborated these results. Couper and Peterson (27) compared blood toxicology results from all suspected impaired driving cases submitted by law enforcement officers from Washington State pre and post legalization. They showed significant increases in the THC concentration between the years 2009 and 2012 (pre) and year 2013 (post). Longer follow-up data up to 2019 confirmed that that the legalization in Washington was linked to a twofold increase of the proportion of drivers who died in an accident with any THC detected (9.3% vs. 19.1%; for THC ≥10 ng/ml: 3% vs. 5.5%; Tefft and Arnold (28)). In roadside surveys in Washington, an increase in DUI could only be observed 6 months after legalized sales, but not 1 year later. Notably, self-reports of cannabis use in the 24 hours before driving did not change in this study (21). Only one study reporting on toxicological test results showed no effect of the legalization on THC positive cases. Borst, Costantini (26) examined the rate of motor vehicle or motorcycle crash patients testing positive for THC in five trauma centers in California and found no association with cannabis legalization.

Traffic outcomes: Interrupted time-series analyses

There were n = 6 studies that analyzed the impact of cannabis legalization on traffic outcomes with ITS, of which some but not all found an association between legalization and an increase in traffic outcomes, mostly fatal crashes.

In the US, n = 4 studies were conducted. Woo (102) analyzed the association of opening of retail stores for recreational cannabis in Washington State with fatal crashes, and found an increase in the trend of fatal crashes after opening (no abrupt effect, but increase in slope/trend). Calvert and Erickson (8) examined all motor-vehicle crashes and pedestrian-involved crashes separately for changes in level and slope in three US states (Colorado, Washington State, Oregon), and found one significant result in 12 comparisons: an increase in the trend of all motor-vehicle crashes in Colorado. Lane and Hall (9) compared traffic fatalities in the same three legalizing states (Colorado, Washington State, Oregon) against 9 neighboring control jurisdictions, using opening of retail stores as the time point for legalization. They found an abrupt increase followed by a decreasing trend after the opening of retail stores. However, the control states showed similar results, so the changes cannot causally be attributed to the changes in legalization. Lastly, data from 7 US states allowing retail stores for recreational cannabis (Alaska, California, Colorado, Massachusetts, Nevada, Oregon, and Washington) were analyzed by Windle, Eisenberg (100). They found increases for the rate of fatal traffic crashes and the rates of death resulting from these crashes. No significant differences were found between the first 12 months after legalization, and subsequent time periods, indicating a permanent effect.

The only study from Canada suggested that traffic outcomes were unaffected by cannabis legalization (37): In two Canadian provinces (Alberta, Ontario), no significant changes in presentation to the emergency departments were seen. In contrast, data from Uruguay is indicative of increases in traffic fatalities (both abrupt and gradual permanent) associated with the implementation of cannabis legalization, in particular in the capital city and for light motor vehicles (17).

Traffic outcomes: Difference-in-difference models

We found n = 6 studies with DiD study designs.

Data from Colorado was analyzed in two studies. Gunadi (85) examined the association of the opening of retails stores in different counties of Colorado with traffic crashes and traffic fatalities and found no significant differences between counties that opened and those that did not open retail stores. However, another study compared healthcare encounters in Colorado to New York and Oklahoma and the findings suggested that traffic accidents increased following the legalization of cannabis (82).

In one study, data from Washington was compared against 42 other states by Hake (103) and the findings, which included data up to 2015 did not suggest an increase in traffic fatalities involving cannabinoids following the legalization of cannabis in this state.

Data from multiple states were analyzed in three studies. Comparing data from Colorado and Washington to other US states, Lee, Abdel-Aty (104) found increases in fatal crashes associated with the transition from medical legalization or de-criminalization to full legalization. Similarly, Aydelotte, Mardock (105) examined fatal crash rates in these two states in the five years after legalization, using 9 other states as controls. The opening of commercial dispensaries as date of the effective intervention was linked to a significant increase in fatal crash rates. Lastly, Farmer, Monfort (99) combined the data of five US states (California, Colorado, Nevada, Oregon, Washington State) and used other Western US states as controls. They found significant increases for the combined effect of legalization and the start of retail store on injury crash rates, but a non-significant increase on fatal crash rates. Both indicators went in the same direction for all legalizing states.

Traffic outcomes: Synthetic controls

There were only n = 2 studies using synthetic controls, both concerning legalization in the same states. The results are mixed, with one study showing no effects, and one study showing an effect only in one state.

In the US states of Colorado and Washington, cannabis-involved traffic fatalities increased after legalization. However, when these increases were analyzed using synthetic controls, other factors could not be excluded as explanation, as other states without legalization showed similar increases (16). Another synthetic control study on the same two states (18), using the effective date for legal commercial retail sale as indicator of legalization, found different results: an increase in traffic fatalities in Colorado but not in Washington State.

Conclusion

While self-reported driving under the influence of cannabis appears not to increase with legalization, there is likely an increase in drivers with THC in their blood following cannabis legalization. Moreover, several studies have linked cannabis legalization to an increasing number of traffic outcomes, including but not limited to fatal crashes. Importantly, none of the n = 14 articles included showed a decrease in traffic harm indicators.

Overall, legalization was associated with increased prevalence of THC in traffic participants and traffic harm, most importantly in the form of fatal traffic crashes. Our conclusion corroborates the conclusion of the systematic review of Windle and colleagues (106) that legalization of recreational cannabis use was associated with increases in positive cannabis tests among drivers, and fatal motor vehicle crashes. However, as the effects of legalization are not consistently observed across all studied jurisdictions, it is possible that other unobserved factors (e.g., legal THC threshold, co-use with alcohol, risk awareness, road safety) may determine whether the cannabis legalization in Germany will increase traffic crashes.

3.3.13. Other health outcomes

We found n = 2 studies with outcomes that could not be classified anywhere else. The first study analysed data from poison control centres from across the US and examined the number of calls for intoxications from synthetic cannabinoids between 2016 and 2019. In the legalizing states Alaska, California, Colorado, District of Columbia, Illinois, Maine, Massachusetts, Michigan, Nevada, Oregon, Vermont and Washington state, the number of calls was 37% lower than compared to states without medical or recreational legalization (107). The other study concerned the diagnoses of injuries reflective of assaults, which did not change following the legalization in Alaska, Colorado, Nevada, Oregon, Washington when compared to control states (98).

3.4. Outcome class 3: use and health among youth

This section describes the impact of cannabis legalization on youth, defined as samples with at least 50% study participants aged 17 or younger. For more details on the respondents' age, see ***Appendix 3***.

3.4.1. Perceived availability

The perceived availability of cannabis among adolescents was studied in n = 6 studies from Canada (n = 1), USA (n = 4) and Uruguay (n = 1). Perceived availability is measured in surveys by asking adolescents how easy they find it to obtain cannabis if they wanted to use it. The only Canadian study on this topic analyzed nationwide repeated cross-sectional survey data on 15-18-year-olds and found that 1 year post legalization, perceived availability increased by about 8 percentage points. This increase was greater for 15-16-year-olds (10 percentage points) than for 17-18-year-olds (5 percentage points; (108)). In n = 3 studies from the US, responses to repeated cross-sectional surveys were compared pre and post legalization, finding increased perceived availability among students in Oregon aged 11-17 years (109) or only 17 years (110), as well as students in Colorado aged 11-18 years (111). A more refined analyses on Colorado students from the same survey as in Harpin, Brooks-Russell (111) examined whether changes in perceived availability are dependent on opening of cannabis retail stores in the county of residence but found no relationship (112). Lastly, the Uruguayan study also found perceived availability to increase among school students aged 13 to 17 years (6).

<u>Conclusion</u>

The literature converges on the observation that adolescents find it easier to access cannabis post legalization and this increase does not appear to be dependent on the opening of retail stores.

3.4.2. Cannabis use

We identified a total of n = 33 studies reporting on the impact of cannabis legalization on cannabis use among youth. Those studies collected data primarily in the US (n = 26) but also in Canada (n = 5) and Uruguay (n = 2). In about two out of three studies, only data from legalizing jurisdictions were analyzed (n = 20), while the remaining studies also included data from control jurisdictions (n = 13). Among the latter studies, the majority adopted DiD study designs (n = 10), but we also found n = 1 study with synthetic controls (6) and n = 2 studies with a controlled longitudinal study design, i.e., studies that analyzed longitudinal data from jurisdictions with and without cannabis legalization (46, 48).

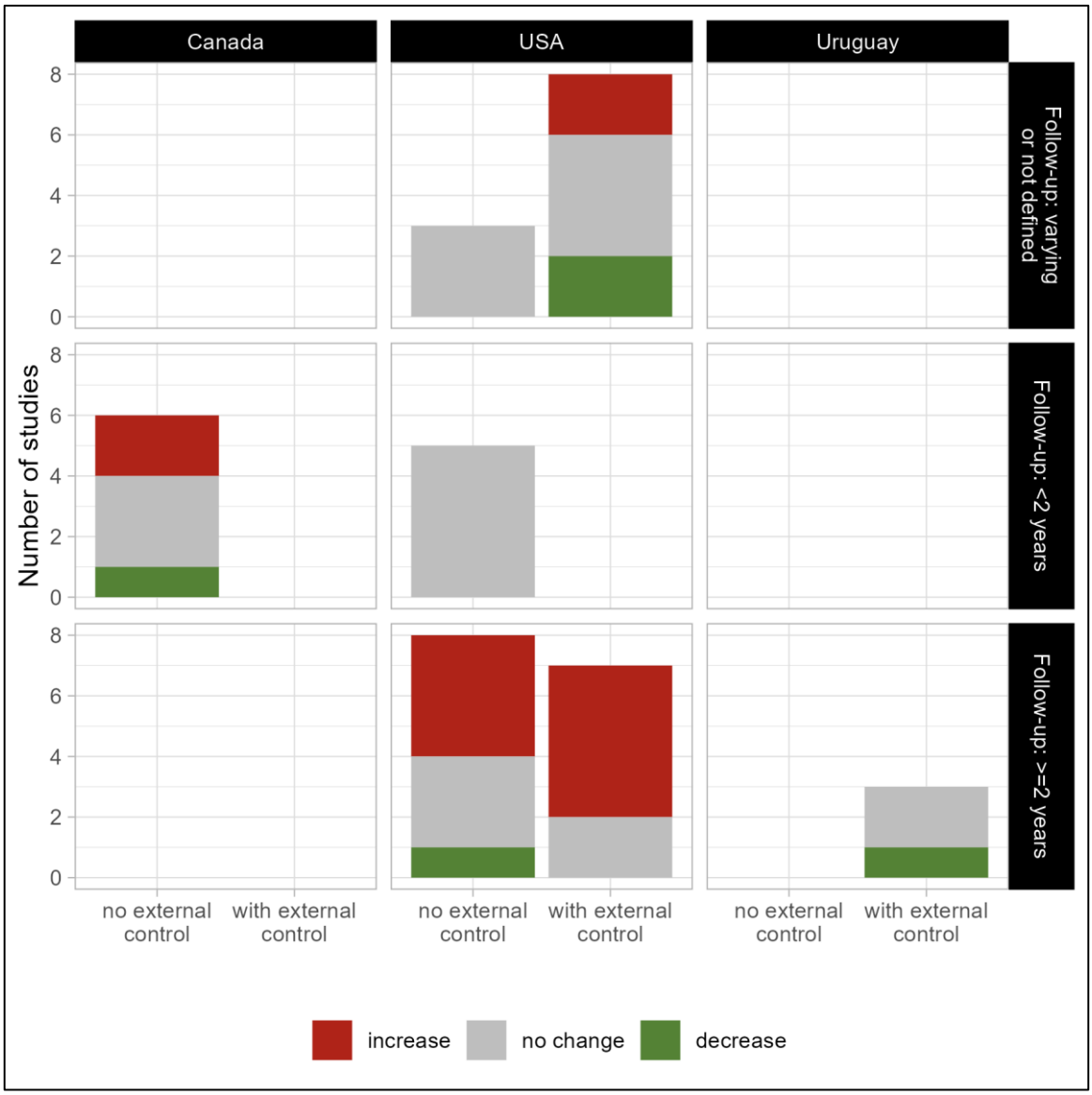

***Figure 8**. Study findings on the impact of cannabis legalization on youth use outcomes, by use of external control, country, and length of follow-up. All studies provided one estimate, except for (6, 12, 73, 75, 113, 114), which provided two or three estimates because of inconsistent age-stratified or state-stratified findings or because of different outcome definitions (e.g., past-year vs. past-month use).*

Across all n = 33 studies, a total of n = 40 findings were extracted. For two studies (12, 114), the findings differed by gender (female vs male), age group (8^{th}/10^{th} vs 12^{th} graders) or state (Washington vs. Colorado) and could thus not be collapsed. For four other studies (6, 73, 75, 113), results for different consumption indicators (e.g., cannabis use but no tobacco use vs. cannabis and tobacco co-use; past-year vs. past-month use) were reported. Of all n = 40 findings, about half (n = 22 or 55%) suggested that cannabis use has not changed following the legalization of cannabis. According to n = 13 (32.5%) findings, cannabis use has increased following legalization, but n = 5 findings (12.5%) suggested decreased cannabis use. Looking only at studies that employed samples representative of the target population, there was a slight increase in the share of findings indicating increased cannabis use (11 out of 28 findings: 39%).

A breakup of the study findings by country and length of follow-up post legalization is illustrated in ***Figure 8***. In Uruguay, both studies found no increased cannabis use among adolescents aged 12 to 17 years (no change: (6); decrease: (76)). In the US, the share of results suggesting that cannabis legalization was followed by increased use rates was 35%, similar to Canada (33%). In the US, studies

were more likely to find an increasing trend of cannabis use among youth when they considered data from jurisdictions that did not legalize cannabis as external controls (n = 15 findings, 47% suggesting an increase). Moreover, studies with a follow-up of two years or longer post-legalization in US states were even more likely to find increased cannabis use (n = 15 findings: 60%) than those with a shorter follow-up (n = 5 findings: 0%). Limiting the analysis to findings of studies with external control and a long follow-up period, we find that n = 5 out of n = 7 findings suggest increased cannabis use among youth in the US. The only two findings suggested no change in cannabis use among youth were from the same study, which found different use trajectories with regards to age group and state (12). While past month use prevalence did increase in Washington among 8th and 10th graders, it did not in the same age group in Colorado and it did further not change post legalization in both Washington and Colorado among 12th graders. In Canada, data with a longer follow-up of at least two years or analyses including data from external controls were not available.

In the US, two studies suggested decreasing cannabis use. The first observed this trend in a sample of male grade 10 students from one county in the state of Washington, while no change was recorded among female students (114). The other study analyzed a nationwide sample of students aged 12-17 and evaluated changes in cannabis and tobacco co-use, as well as cannabis use without tobacco (in the past 30 days). For both outcomes, the likelihood of reporting was about 30% lower for students residing any of the eleven legalizing states (Alaska, California, Colorado, DC, Massachusetts, Maine, Michigan, Nevada, Oregon, Vermont, Washington) – as compared to states that did not legalize cannabis (75). The same dataset was previously analyzed in another study, including less data from fewer states, and not differentiating between cannabis and tobacco co-use. That study found that legalization was not associated with a change in reporting past-month cannabis use (23).

In Canada, one study found cannabis use in a nationwide sample of youth aged 15 to 17 to decrease considerably 1 year post legalization, from 19.8% to 10.4% (25). However, cannabis use among 16- to 19-year-olds has reportedly increased from 22.5% in 2017 to 27.0% in 2019 according to the analyses of another study (113).

Conclusions

The impact of cannabis legalization on cannabis use among youth cannot be determined with certainty. While legalization in Uruguay has had no negative impact on cannabis use among youth, there are mixed findings reported in the literature for Canada and the US. The picture becomes clearer when examining studies with data from longer follow-ups: legalizing cannabis may not increase cannabis use in those countries in the short term, but perhaps in the long term.

3.4.3. Initiation

A total of n = 4 studies from USA (n = 3) and Canada (n = 1) have studied the impact of legalization on the likelihood to initiate use. In the first study, data from 13-to 20-year-olds were collected before and after cannabis was legalized in four US states (California, Massachusetts, Nevada, or Maine), as well as in control states where cannabis was not legalized. Adolescents and young adults who reportedly did not use cannabis at baseline were about 120% more likely to have used cannabis at follow up, if they resided in those states that legalized cannabis (81). Another study defined initiation of use as the first use in the past two years. According to the findings of repeated cross-sectional survey data, respondents aged 12 to 17 were about 14% more likely to initiate use when they resided in states that opened retail stores (73). One other study from the US analyzed survey data from adolescents aged 16 on average and compared initiation rates observed in Hawaii and Alaska (the latter legalized cannabis). The generally decreasing trend of cannabis initiation was interrupted post legalization in Alaska but not in Hawaii, suggesting a 29% increase of cannabis initiation attributable

to the legalization (115). One final study from Canada found that legalization was associated with increased cannabis initiation by 2.7 percentage points, similar for age groups 15-16 and 17-18 years (108).

Conclusion

The findings from four studies with robust methodologies agree that legalization in North America has increased the likelihood of youth non-users to initiate cannabis consumption.

3.4.4. Frequency

We identified n = 14 studies from Canada (n = 2), USA (n = 10), and Uruguay (n = 2) that studied changes in use frequency relative to cannabis legalization. All studies provided a single finding. In n = 6 studies, changes were studied without considering data from external controls. In the remaining n = 8 studies, DiD designs (n = 5), synthetic control designs (n = 1), or longitudinal designs with external control (n = 2) were adopted.

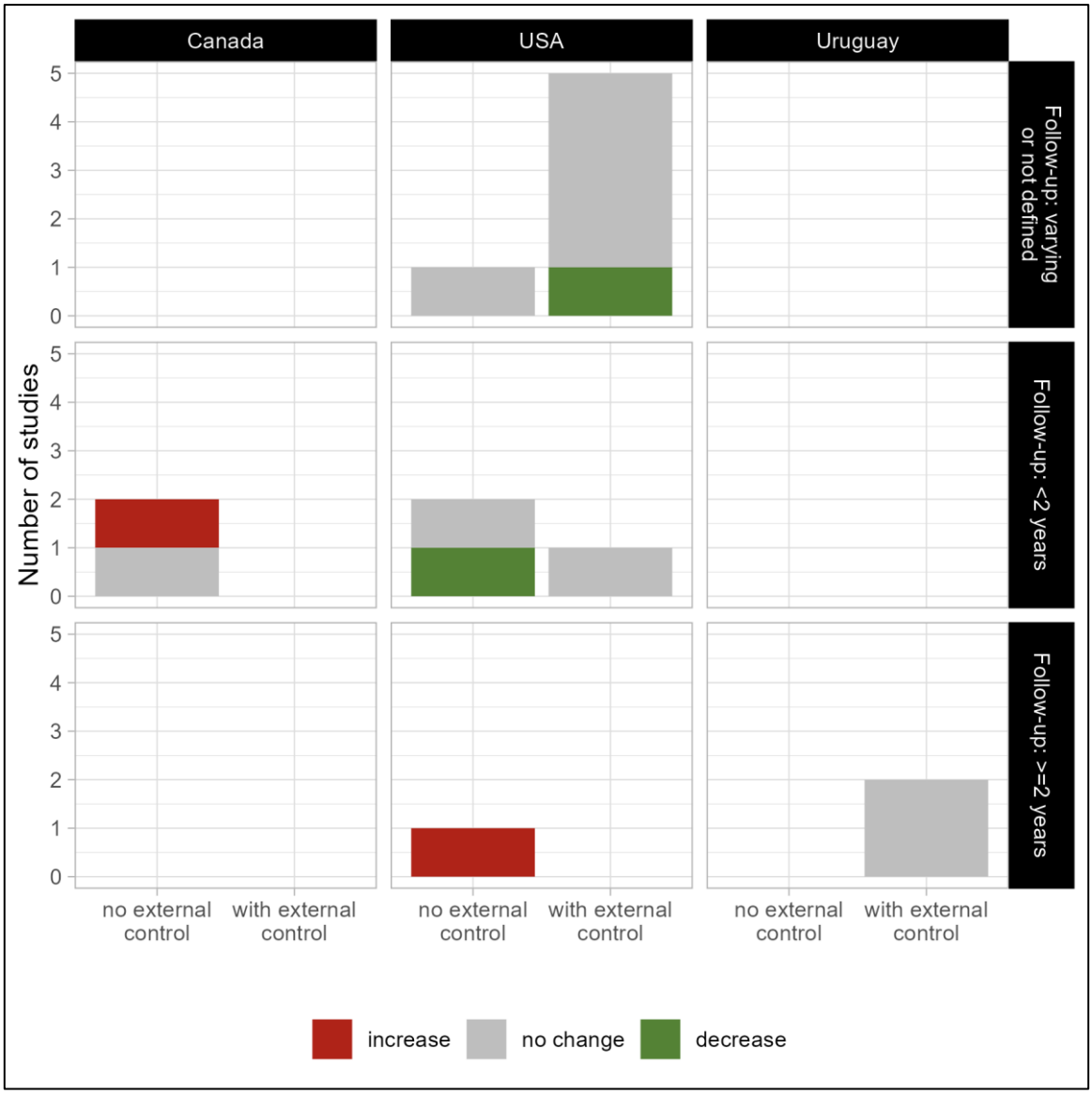

Figure 9. *Study findings on the impact of cannabis legalization on youth use frequency outcomes, by use of external control, country, and length of follow-up. All studies provided one single estimate.*

In the majority of studies (n = 10 or 71%), cannabis legalization was not linked to any change in cannabis use frequency. The remaining studies found either decreasing (n = 2) or increasing (n = 2) use frequency. The three studies with non-representative samples all found no changes in cannabis use frequency. Notably, the largest study analyzing repeated cross-sectional survey data from 12-17-year-olds from across the US found that cannabis legalization in Colorado, Washington, Alaska, and Oregon was unrelated to frequent use practices among current users (23).

As shown in ***Figure 9***, the two studies with decreasing use frequency were both conducted in the US. The first study analyzed a repeated cross-sectional survey of 14- to 18-year-old high school students in Colorado and found that about 18 months after the start of retail sales, current users were less likely to report frequent use (at least 20 use days in the past 30 days). Specifically, the share of frequent users declined from 33% to 27% (116). The other study analyzed repeated cross-sectional survey data collected from 11- to 17-year-olds across the US and found that the legalization of cannabis in Alaska, California, Colorado, Massachusetts, Maine, and Nevada was linked to a 15% relative reduction in use frequency among current users, when compared to US states that did not legalize cannabis.

The two studies reporting increased use frequency were conducted in Canada and the US. The US-based study analyzed cannabis use frequency among 12- to 17-year old middle and high school students that engaged in both cannabis and alcohol use in the past month in California (117). In the two years after retail sales started, frequency of cannabis use has slightly but significantly increased in this selective sample. In the Canadian study, an increase of the prevalence of daily use in the entire population of youth aged 16 to 19 was observed (113). As an increase of similar magnitude was also observed for any past 30-day use prevalence, changes among users are unlikely.

Conclusion:

The available evidence from Canada, USA, and Uruguay suggest that cannabis legalization is unlikely to increase cannabis use frequency among cannabis using youth. One robust study from the US found cannabis use frequency to have *decreased* among youth following legalization.

3.4.5. CUD

We found n = 9 studies with data on CUD from the USA (23, 31, 33, 83, 118, 119, 120) and Canada (90, 91). As done with data for adults, we differentiate between two different types of CUD outcomes: a) data collected in healthcare settings, reflective of treatment demand, and b) data collected through self-report in surveys, reflective of treatment need.

CUD healthcare

While one US-based study found that the legalization of cannabis was linked to increased hospitalizations for CUD in a population of 11 to 17-year-olds (120), the other two US studies (31, 83) and the other two Canadian studies (90, 91) found CUD health care contacts to not be affected by the cannabis legalization.

In the US, one study found CUD hospitalizations to have increased in California, Colorado, DC, Massachusetts, and Washington when compared to states where cannabis was not legalized. Specifically, the annual number of cannabis-related hospitalizations increased by 15% every year in legalizing states – compared to a 5% annual increase pre-legalization (120). Conversely, the number of treatments for CUD in private or public treatment centers across the US in the population of 12 to 17-year-olds were not impacted by cannabis legalization based on data covering the legalization in Colorado and Washington (31) and in extended analyses (83). In the latter study, criminal-justice

referrals were excluded because they might reflect changes resulting from reduced arrest rates rather than changes in self-motivated treatment seeking post legalization.

In Canada, both studies were conducted in Quebec and reflect data from one hospital (90) and from across the province (91). In both studies, the number of admissions remained largely unchanged comparing the period before and after legalization.

CUD survey

We identified n = 3 studies that presented data on the impact of cannabis legalization on CUD among adolescents using survey data. Analyzing nationwide data from the USA, Cerdá and colleagues found that the risk of being diagnosed with CUD (according to DSM-IV criteria) among current users aged 12 to 17-years increased following cannabis legalization in Colorado, Washington, Alaska, and Oregon. Compared to non-legalizing states, the CUD risk was elevated by 27%. The share of past-year users meeting DSM-IV CUD criteria increased from 22.8 to 27.2% in this study (23). Another study re-analyzed the same survey data but included one additional year of data and thus also covered short-term legalization periods from Massachusetts, Michigan, DC, Vermont, California, Maine, and Nevada. According to this analysis, no increase in CUD risk among past-year users could be identified when stratifying for four different ethnic groups (33). The last study assessed changes in cannabis use consequences in a non-representative sample of high-school students from Washington who were identified as problematic substance users. Here, the reported consequences were reported to have increased considerably following the legalization of cannabis (119).

Conclusion

The literature on CUD among adolescents is mixed. Following the legalization of cannabis, several studies report higher rates of CUD among current users. Increased CUD hospitalization rates were also reported in the US but not in Canada. Moreover, the number of adolescents seeking CUD treatment remained unaffected by legalization.

Possibly, the increased rate of self-reported problems reflects a tendency to be more willing to self-disclose problems post legalization. The inconsistent effects reported by relatively few studies makes it difficult to infer generalizations. It can be assumed that the CUD risk among adolescent users will not decrease following the legalization. Whether or not the CUD risk among adolescent users increases may depend on unobserved determinants, such as access to (legal or illegal) cannabis, that no study has evaluated.

3.4.6. Intoxications

We found a total of n = 13 studies on cannabis intoxications among children and adolescents in the US (n = 9) and Canada (n = 4). Most studies employed pre/post study designs, but n = 3 studies also included data from an external control group in DiD analyses (10, 36, 121). Each study provided one finding and the distribution of results is displayed in ***Figure 10***.

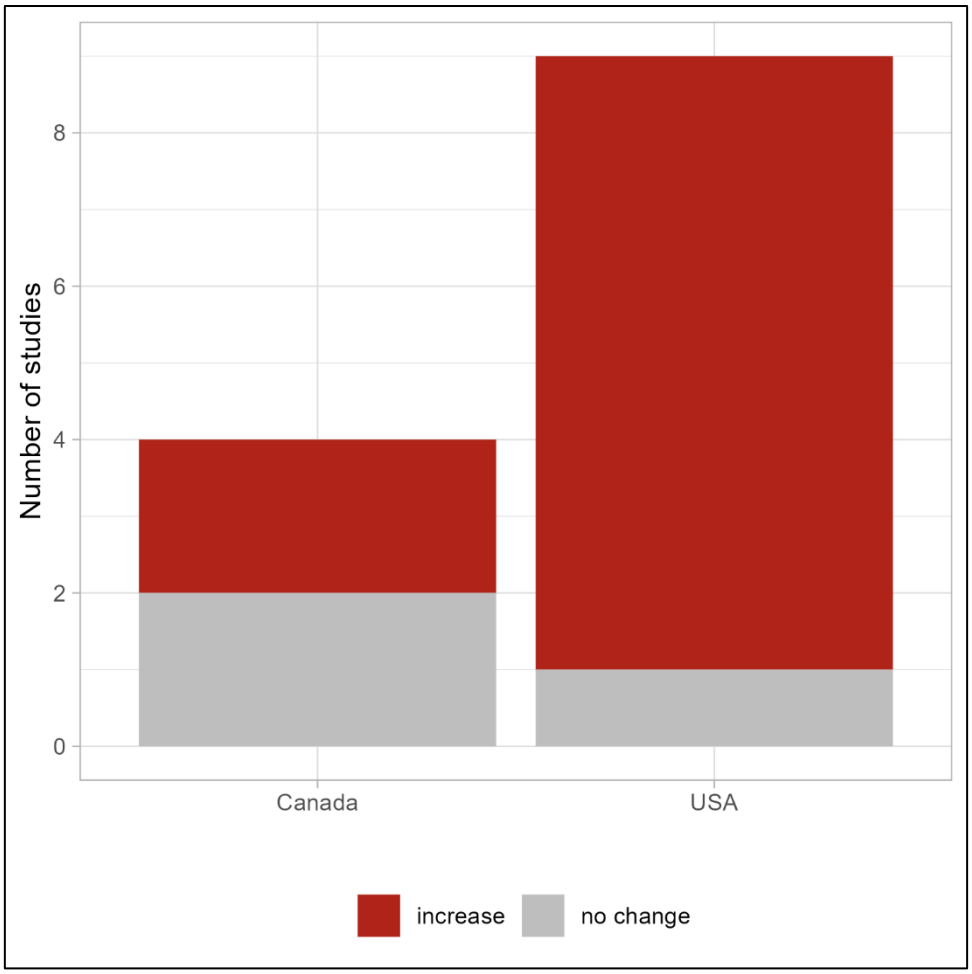

***Figure 10**. Study findings on the impact of cannabis legalization on youth cannabis intoxication, by country. All studies provided a single estimate.*

The majority of study findings (n = 10 or 77%) on intoxications among youth suggest that cannabis legalization was associated with increased cases, while the remaining found no changes (n = 3). Looking only at representative samples, all n = 5 studies reported increasing cannabis intoxications post legalization in Canada (122) and US states (10, 123, 124, 125).

The largest study from the US analyzed cannabis-related calls to poison centers by youth up to age 20 between 2010 and 2017 (10). With the start of retail sales in nine US states (Alaska, California, Colorado, DC, Maine, Massachusetts, Nevada, Oregon, and Washington), the number of cannabis-related calls to regional poison centers increased by about 61%. Data from emergency departments and hospitals in four Canadian provinces (122), in Alberta (35) in California (126), in Colorado (127), and Washington (40) support these findings.

Importantly, increased cannabis intoxications were found among children aged 0 to 9 years (122, 124) and adolescents (127). For children, the intoxications are mostly attributed to the accidental intake of cannabis edibles.

Conclusion

There is robust evidence showing that the number of acute intoxications has increased post legalization in Canada and US states among both children and adolescents.

3.4.7. Hyperemesis

The impact of cannabis legalization on hyperemesis among adolescents was examined in n = 1 study with data from California, Colorado, DC, Massachusetts, and Washington (120). Unlike in control states, the number of cannabis-related hyperemesis diagnoses in inpatient settings among 11- to 17-year-olds increased from 124 to 179. It should be noted that the absolute number of diagnoses in this population remains very low.

Conclusion

Generalized conclusions on the impact of cannabis legalization on hyperemesis among adolescents cannot be derived due to a scarce literature base. In US states, hyperemesis among adolescents appeared to have increased following cannabis legalization.

3.4.8. Psychosis/Schizophrenia

Among adolescents, the impact of cannabis legalization on psychosis or schizophrenia outcomes was analyzed in a single study from Quebec (90). In a psychiatric emergency unit in a single hospital, diagnoses of psychotic disorders did not change in the first 5 months post legalization.

Conclusion

There is insufficient evidence to derive general conclusions on the impact of cannabis legalization on psychosis or schizophrenia among adolescents. In one Canadian province, a short-term change was not observed.

3.4.9. Use during/after pregnancy and birth outcomes

A total of n = 10 studies examined how legalization was related to cannabis use during pregnancy or to birth outcomes (Canada: n = 2; USA: n = 8).

Use during pregnancy

There were n = 8 studies on use during pregnancy from Canada (128, 129) and USA (38, 39, 130, 131, 132, 133).

Use during pregnancy has increased according to n = 3 studies that examined the legalization effects in California (38), Colorado (133), and nine legalizing states (Alaska, Colorado, DC, Maine, Massachusets, Nevada, Oregon, Vermont, Washington: (130)) using data from pregnant women in hospitals. In the first study, positive tests for THC (cutoff: 50ng/mL) increased from 6% to 11% in the year after retail sales started in California (38). In the second study, the number of cannabis-involved pregnancy hospitalizations per 10,000 live births increased from 13.2 to 55.7 between 2011 and 2018 in Colorado (133). The last study examined the share of pregnancy-related hospitalizations with a CUD diagnosis in 34 US states. They found that cannabis legalization was linked to a 23% increase in the proportion, with more pronounced effects observed in longer periods post legalization.

Of the remaining n = 5 studies that found legalization to not be related to cannabis use during pregnancy, n = 3 were also from the US and analyzed data from pregnant women in hospitals. In Washington, about 20 to 25% of pregnant women tested positive for cannabinoids but this share appeared to be unaffected by legalization (39, 132). In the last US study on this matter, self-reported cannabis use during pregnancy remained unaffected by legalization in Alaska and Maine, when compared to New Hampshire and Vermont (131). Lastly, the two Canadian studies found no change cannabis use during pregnancy in Ontario (share of pregnant women testing positive for cannabis was constant at about 10%, see (129) and British Colombia (self-reported cannabis use constant at about 4%, see (128)). Notably, both studies were conducted at relatively short periods post legalization (less than two years) and before market commercialization in Ontario.

Birth outcomes

We identified n = 4 studies on the impact of legalization on birth outcomes. In the only study reporting a beneficial impact, the risk of small gestational age was 7% lower post legalization in Colorado (20). In another study examining the risk of small gestational age in Colorado and Washington, no changes were observed relative to cannabis legalization (134). Similarly, the risk of low birth weight was not related to cannabis legalization in Washington (132). Lastly, the only study on this topic with a DiD study design found that legalization in Alaska, Colorado, DC, Maine, Massachusets, Nevada, Oregon, Vermont, Washington was unrelated to the risk of low gestational age (<37 weeks) and low birth weight (<2,500g; (130)).

Conclusion

In the US, cannabis use during pregnancy has increased in some but not all jurisdictions that have legalized cannabis. Increases in adverse birth outcomes have not been reported in any study from the US. In Canada, the two available studies suggest no short-term changes in use during pregnancy.

3.5. Evaluation of regulation changes after legalizing cannabis

We found n = 9 studies that have evaluated different forms of regulations within a legally regulated market in Canada and USA.

THC dose restrictions

THC dose restrictions were studied in n = 2 studies with the same data source: health insurance claims from individuals across the USA. The main analyses examined changes with respect to legalizing cannabis. In secondary analyses, states were grouped according to THC dose-related restrictions, such as THC dose per serving size, THC content per package, or product types, e.g., bans on edible products (implemented in Colorado, Nevada, and Washington but not in Alaska and Oregon). A THC cap was not mentioned in the two studies and likely not covered in these analyses, as no US state has such a cap implemented.

In the first study, the enactment of THC restrictions were not associated with injury claims, neither for self-harm nor for assault (see eFigure 4 in Matthay, Kiang (98)). In the second study, the enactment of THC restrictions was associated with increased onset of psychosis diagnoses (see eTable 14 of Elser, Humphreys (96)). Specifically, states that legalized cannabis and enacted THC restrictions, as defined above, had a 61% higher rate of psychosis diagnoses than states that did not legalize cannabis (also not for medical purposes). In contrast, states that legalized cannabis and enacted no THC restrictions experienced no increased rate of THC restrictions.

Drawing generalized conclusions from these two studies may not be warranted but the little empirical evidence suggests that THC restrictions – as defined in the studies – may not positively impact public health.

Allowing edible sales

The start of edible sales was delayed in Canada and only started in March 2020, 17 months after the start of legal flower sales in October 2018. Notably, this period was also characterized by the onset of the COVID-19 pandemic, which complicates the interpretation of the evaluations. The impact of edible sales was analyzed in n = 2 studies from Ontario (11, 32) and n = 1 study from Ontario, Quebec, Alberta, and British Columbia (122).

Two studies examined the impact of legalizing cannabis edible sales among adults. The first study analyzed the number of cannabis intoxications resulting in ED visits (11) or hospitalizations (32) among adults aged 18 or older. When compared to the months post legalization in October 2018, both studies suggest that the start of edible sales was not linked to an overall increase in cannabis-related ED visits (11) or hospitalizations (32) among adults. However, there was a significant step increase in ED visits followed by a decreasing slope trend for adults aged 18-44, suggesting that cannabis intoxications among younger adults may first increase when cannabis edibles can be sold legally but this may only be a temporary phenomenon. For hospitalizations, the increasing trend post legalization in October 2018 stabilized or even decreased with the start of edibles/onset of the COVID-19 pandemic (32).

One study examined the impact of legalizing cannabis edible sales among children aged 0 to 9 (122). In four Canadian provinces, there was an abrupt and permanent increase in intoxications: the number of cases approximately doubled after the start of edible sales (122). Additional analyses showed that this abrupt increase was not observed in Quebec, where the sale of edibles potentially attractive to children and young adults (e.g., sweets and candies) was prohibited.

To conclude, the sale of cannabis edibles can result in an increased rate of intoxications that require medical care among children. Among adults, intoxications may also increase but only temporarily. Restricting legal edibles to not be attractive to children and adolescents is likely to attenuate the negative impact of legal edibles.

Commercialization

The commercialization of cannabis retail was evaluated in n = 2 studies from Ontario (7, 41), where legal cannabis was only available through web order in the first 6 months post legalization. In the subsequent 12 months, the number of legal stores was capped to 67 for a province of about 15 million individuals. In April 2020, this cap was finally lifted nearly parallel to the start of legal edible sales and the onset of the COVID-19 pandemic, resulting in a drastic increase in the number of retail stores (742 stores by May 2021), which was called a commercialization of the legal market (41).

The impact of cannabis retail commercialization in Ontario was evaluated for cannabis intoxications resulting in ED visits (41) and for hyperemesis (7). For the population aged 15 and older, the introduction of a limited number of retail stores in Ontario was associated with a slight (+12%) level increase in per capita ED visits, however, the previously increased trend of ED visits was nullified, resulting in a total reduction of ED visits by 18%. Then, with the legal market being commercialized and with the onset of the pandemic and the start of edible sales, the number of ED visits increased abruptly by 22%, without any further change in the trend, resulting in a total 22% reduction attributable to the commercialization, which coincided with the COVID-19 pandemic and the start of edible sales. In absolute terms, the monthly number of cannabis intoxications resulting in an ED visit in the population aged 15 or older was 805 during the 33 months leading up to the legalization, 1,215 in the months post legalization with strict control, and 1,531 during the last period marked by market commercialization, edible sales and the COVID-19 pandemic. Subgroup analyses for adolescents and young adults (ages 15-24) also found net reductions associated with a strictly regulated market, but no significant change for market commercialization (41).

An evaluation using data on cannabis-involved hyperemesis showed very similar results: during the period of strict market regulation, the increasing trend of hyperemesis cases that resulted in ED visits observed pre-legalization remained mostly stable, with indications of being attenuated. Then, with market commercialization, coinciding with edible sales and the COVID-19 pandemic, the rate of cannabis-related hyperemesis cases went up by 32%. This was observed for younger adults of legal purchasing age (ages 19-44) but not for adolescents aged 15-18, making it more plausible that the market commercialization was the driving factor (7).

To conclude, market commercialization, defined as a drastic increase in physical availability through retail stores, may increase (acute) health problems resulting from the use of cannabis. Conversely, capping the number of stores is likely associated with a positive public health impact.

Minimum legal age

The impact of raising the legal purchase age was studied in a single study from Canada (135). In Quebec, the minimum age to purchase cannabis legally was increased from 18 to 21 years in January 2020. Analyzing repeated cross-sectional survey data from this and other provinces, it was shown that cannabis use among 15-20-year-olds increased to a lesser degree in Quebec. Specifically, past 3-months cannabis use increased from 20% to 23% in Quebec and from 21% to 30% in other provinces, where the minimum legal age remained at 18 or 19 years. Subsequent analyses showed that the attenuating effect of raising the minimum legal age was restricted to 18-20-year-olds and it did not impact use behavior of 15–17-year-olds.

To conclude, a higher minimum legal age can deter some young adults from using cannabis.

Warning labels

In June 2016, Washington state made it mandatory that cannabis products have warning labels advising against the use of cannabis during pregnancy, which was evaluated in n = 1 study (19). The impact of this policy was evaluated by analyzing data on birth outcomes from Washington and three neighboring states that also legalize cannabis but did not require such warning labels (Alaska, California, Nevada). Adopting a DiD study design, the findings suggest that the enactment of pregnancy-related warning labels was associated with a small decrease in the average birth weight (-7g), as well as a very small increase in the number of new-borns with a low birth weight (less than 2,500g; +0.3%).

To conclude, mandatory warning labels advising against using cannabis during pregnancy are not linked to improved health among new-borns. On the contrary, this study showed that the mean birthweight of new-borns was minimally reduced following the implementation of warning labels.

3.6. Limitations

There are some limitations inherent to the literature review and the synthesis of results.

Regarding limitations concerning the literature review, we were able to include all but one study (136) due to a lacking full text. Moreover, the literature base is constantly growing and multiple relevant studies (e.g., (84, 96)) were published after the search was completed. We aimed to include all relevant studies but cannot guarantee that we have covered all studies, especially those published after conducting the search. Finally, the selection of studies may have introduced an unwanted bias. As we only included studies with data from before and after legalization, we may have overlooked studies that provide valuable insights on consumption or health indicators. For example, access to legal cannabis may have improved dosing of THC because THC levels are contained on legal products. Improved dosing may in turn reduce the risk of developing acute problems, including cognitive impairments but also the ability to drive. Similarly, the legal market may have improved self-recognition of cannabis use problems as cannabis use becomes normalized and the public stigma is attenuated. Given our focus on consumption and tangible health indicators, such as diagnoses, the subjective perspective of users and their subjective well-being or quality of life was not explicitly included in this review.

Regarding the synthesis, we need to acknowledge several limitations that result from the standardization of study findings. First, we restricted the results to fully adjusted models but this sometimes included analyses that accounted for variations in local policies (e.g., Rusby, Westling (137)) or the availability of legal cannabis (138). If consumption or cannabis-related problems only occur in those areas where legal cannabis is more available (138), then it is not surprising that no overall change in the outcome of interest was observed relative to legalization when availability was controlled for. These nuances could not be considered in the standardized extraction process performed for this review.

Second, we only assessed overall changes in the outcomes of interest but largely ignored subgroup analyses. This implies that if changes occurred only in a subpopulation, this might not be reflected in overall changes. For example, one study found that legalization was associated with violent crime reductions in wealthier neighborhoods, however, there were no changes in the overall sample (e.g., Burkhardt and Goemans (61)). Similarly, suicide rates did not change in the total sample from Washington and Colorado, but increased among young adults in Washington following the legalization (97).

Third, there are some limitations inherent to the study designs employed. For example, one study found increases in cannabis use in patients admitted to a Colorado hospital for trauma injuries (44), which we considered as “increase” in our analyses. However, increases were also recorded in control states that did not legalize in that study, but these findings were not explicitly included in the analyses and so not considered in our classification of the main study finding. This circumstance would reduce our confidence that legalization has caused an increase in cannabis use because it could be that increases in use are reflective of secular trends that affect not only legalizing jurisdictions but also other populations (control groups). To counter this possible bias, we analyzed studies with external control separately, strengthening our confidence in the presented conclusions.

Despite the outlined limitations, we believe that our approach is a careful summary of a wealth of studies and provide a balanced insight in the short- and long-term impact of cannabis legalization for recreational purposes.

4. Results Work Package 2: Expert testimony

The following chapter will present the testimony given by the five experts from Canada, USA, and Uruguay:

- Dr. Michael J. Armstrong, Associate professor of operations research, Brock University
- Dr. Daniel Myran, MD, MPH, CCFP, FRCPC, Innovation Fellow University of Ottawa Department of Family Medicine, CIHR Research Fellow Ottawa Hospital Research Institute
- Dr. Rosalie Liccardo Pacula, Professor and Elizabeth Garrett Chair, Sol Price School of Public Policy, University of Southern California
- Dr. Rosario Queirolo, Professor of Political Science, Department of Social Science, Universidad Católica del Uruguay
- Dr. Frank Zobel, Deputy Director and Co-Head of research department, Addiction Switzerland

Preliminary remark

For the interpretation of the expert responses presented in this document, a number of aspects should be considered. First, cannabis legalization is a process rather than singular event. Importantly, it takes time for laws to be implemented and for the legal market to develop, as illustrated in three examples:

- In Canada, the legal sale of cannabis edibles and vapes was only allowed more than one year after the retail of cannabis flowers. It took almost four years after legalization for retail store networks to expand and for retail sales growth to taper off.
- In California (USA), the possession of cannabis was decriminalized in November 2016 following a state-wide referendum and years of easy access to medical cannabis (similar to Canada). Only in January 2018 licensed retail sales started in this state.
- In Uruguay, the legalization of cannabis started in 2014 with cultivation by registered persons and cannabis social clubs being allowed. The retail of cannabis products in pharmacies started only in 2017.

Consequently, insights from short-term evaluations should be interpreted with caution because there may be long-term impacts that take time to unfold, e.g., because legal sales take years to expand or because chronic problems develop over time. Secondly, the public health impact likely depends on the exact regulation implemented (e.g., allowing the sales of edibles), which is something that may also change over time. Beyond these aspects, it should thirdly also be considered that the evaluation of cannabis legalization has been complicated by the impact of the COVID-19 pandemic. Lastly, given the loosely regulated medical market in North America prior to legalization, it is not easy to determine how generalizable the findings from cannabis legalization are for other countries, e.g., Germany.

4.1. Question 1: Legalization and public health

Question

How did public health indicators (e.g., morbidity, cannabis use disorders, addiction treatment, prevention) change in legalizing countries?

4.1.1. Expert response

Based on the available evidence, the legalization of cannabis has been linked to increases in some public health indicators, including acute (i.e., intoxication) and chronic problems (e.g., vomiting/hyperemesis). There is some uncertainty regarding other indicators, such as development of cannabis use disorders or motor vehicle accidents.

4.1.2. Evidence and reasoning

Canada

In Canada, the legalization of cannabis likely increased the number of cannabis-related emergency department (ED) visits. While no such increases were found in the first months of legalization during a period of high restrictions (e.g., (41, 139)), more recent data during periods of increasing market commercialization (e.g. unrestricted stores and new products) suggests increases in ED visits related to cannabis intoxications (41), and cannabis hyperemesis (cyclic vomiting syndrome; (7, 140)). For example, in Ontario (the most populous province), the number of admissions to emergency departments for cannabis in Ontario increased nearly 10-fold between January 2010 (1.7 ED visits per 100,000 individuals aged 15-105) and June 2021 (12.6 ED visits per 100,000 individuals; (41)).

For cannabis use disorder (CUD), mixed results are reported. In 2019, studies found CUD increases among new users but decreases among experienced ones (34), or increases among adults but not youths (90). For psychoses, a short-term impact of cannabis legalization could not be observed (94). Importantly, these data were collected mostly before the commercialization of cannabis retail became widespread in Canada.

No clear impact of cannabis legalization on traffic accidents could be observed. Self-reported driving after cannabis use found no change from 2014 to 2019 (141), or from 2018 to 2019 (101), but decreases from 2018 to 2022 (142). In British Columbia, legalization was associated with an increased proportion of individuals with moderate traffic injuries that tested positive for THC in their bodily fluids (9.2% pre-legalization versus 17.9% post legalization; (29)). However, short-term changes in overall car accidents were not observed in Ontario (37) or across Canada (143). Lastly, the number of law enforcement-reported incidents involving drugs other than alcohol have increased pre- and post-legalization in Canada but there is no cannabis-specific data available (144).

On the positive side, Canadians increasingly recalled seeing warning labels on packages (145), felt comfortable discussing use with physicians (146), and recognized that cannabis could be habit forming and impairing (142).

USA

In the US, increases in relation to the legalization of cannabis could be observed for cannabis use disorder (23, 147), child poisonings (driven by higher potency products; (148)), and cannabis hyperemesis (149). Demand for cannabis treatment overall has fallen (due in large part because of reduced criminal justice referrals) but we are seeing treatment cases rising in some populations, so evidence is mixed (31). While the number of annual fatal motor vehicle crashes has decreased over

the last two decades in general, the percent of fatalities involving any alcohol (i.e., a blood alcohol concentration [BAC] >0.00%) has remained around 37% and the percent of fatalities involving any cannabis increased from 9% in 2000 to 21.5% in 2018 (150, 151). Studies evaluating the impact of cannabis liberalization laws on motor vehicle crashes in the U.S. tend to examine overall crash rates rather than cannabis-involved crashes due to the imprecise and inconsistent methods for documenting cannabis involvement across states during this time period (Lira et al., 2021).

Uruguay

In Uruguay, prevalence of cannabis dependence has increased since 2006 and this trend was unchanged after cannabis was legalized. Cannabis legalization had likely no impact on treatment seeking behavior among people with cannabis dependence, as similar (low) rates are reported for Uruguay, Chile, and Argentina (with cannabis remaining illegal in the latter countries: (152)). One unpublished study found no evidence of a short-term change after cannabis legalization on the prevalence of cannabis dependence (study title: Impact of cannabis legalization in Uruguay on cannabis, alcohol, and tobacco use among adults: a synthetic control approach). Generally, there is a general lack of systematic evidence on the impact of cannabis legalization on prevention or morbidity in Uruguay. Some evidence exists of a positive association between cannabis legalization and an increase in fatal motor vehicle crashes, mainly in light motor-vehicles and urban areas (17). In addition, more people allowed to home-grow cannabis is positively associated with traffic crashes involving injuries (153). However, these studies do not capture the impact of the regulation on accidents occurred with people driving under the influence because it is not systematically registered.

Theoretical considerations

All the research so far has only been able to examine short run effects of legalization, as we haven't had enough time yet to evaluate long-term impacts. There are at least two reasons why long-term impacts could differ from short term impacts. First, in the US and, since 2020, Canada, higher potency products have been allowed on the market. As the average potency of the product consumed rises, we expect larger impacts on not just acute intoxication but also on cannabis dependence. The health impacts of consuming high potency products on the central nervous system, respiratory system, gastrointestinal system, and immune system – all systems that are part of the endocannabinoid system – are unknown at this time. Second, the competitive markets that have been allowed in the US and Canada continue to push purity-adjusted prices down. The high exposure to these competitive firms will likely change among youths and adults, and more people are likely to use (or at least to try) cannabis in the long run than in the short run. Increased use prevalence in turn is expected to have a negative impact on public health.

4.2. Question 2: Legalization and cannabis use

Question

What do we know about the development of cannabis use (prevalence) in legalizing countries (compared to pre-legalization)?

4.2.1. Expert response

Where cannabis was legalized, the number of people using cannabis (riskily) has risen prior to legalization and has continued to rise post legalization. There is robust evidence that cannabis use has increased to a quicker pace where cannabis is legal for recreational purposes. In Canada and Uruguay, it is difficult to disentangle increases post legalization from pre-existing trends and from increased willingness to disclose cannabis consumption (a previously illegal behavior). In the US, legalization has likely caused risky cannabis use (e.g., during pregnancy) to increase.

Importantly, the exact impact of legalization on cannabis use likely varies according to the regulatory framework, such as availability (e.g., there were 24 times more stores per capita in Alberta than in Quebec 2 years after legalization). Given that the market is still developing (e.g., declining retail prices and increasing sales) and attitudes towards cannabis are changing, more people are likely to use cannabis in the long run than in the short run.

4.2.2. Evidence and reasoning

Canada

For cannabis use in the general population, increases over time can be consistently observed in several national or provincial surveys conducted in Canada. For example, the prevalence of past 12-month cannabis use went from 10% in 2010 to 21% in 2019 according to the Canadian Alcohol and Drug Survey (154) and from 22% in 2017 to 27% in 2021 according to the Canadian Cannabis Survey (with the risk of overestimating cannabis use (155)). Provincial surveys also found increases (156, 157, 158, 159). Quebec, which stuck with a public model for cannabis sales and implemented more strict controls (e.g., prohibition of selling vape liquids or edibles in forms attractive to youth), had the lowest rates of cannabis use both before and after legalization: one study reported no change there in past-3-month use between 2018 and 2020 (53), while another reported increases (157). Lastly, Cannabis use at workplace settings has not changed (160). It is important to note that increases in cannabis use started several years prior to cannabis legalization in 2018 (161).

For risky use patterns, prevalence of daily cannabis use and cannabis use during pregnancy are of interest. Among those who had used cannabis in the last 12 months, the share of daily users remained largely unchanged in Canada (53, 142). Similarly, cannabis use during pregnancy appears to have not been impacted by cannabis legalization (128, 162). However, it should be noted that cannabis use during pregnancy increased before (163) and after cannabis legalization (162) in Canada.

Generally, changes in cannabis use (patterns) in Canada are difficult to attribute to legalization, because self-reported prevalence had been increasing since 2011 (164) and the post-legalization growth might partly reflect a continuation of previous trends or increased willingness to self-report (155, 165). Interestingly, post-mortems detected cannabis in corpses in New Brunswick at similar rates in 2019-2020 as in 2016-2017 (79).

Further insights on consumption can be derived from sales data. During 2018-2020, the rate at which provinces opened stores was only weakly related to prevalence increases (166). However, the

maturing market may be starting to impact overall cannabis use. Since 2018, monthly legal recreational cannabis sales (i.e., excluding legal medical spending and estimated illicit spending) have rapidly increased; e.g., sales in December of each year were $59 million in 2018, $148 million in 2019, $297 million in 2020, $354 million in 2021, and $426 million in 2022 (167). The increases in legal sales have largely outpaced decreases in illegal sales, resulting in a net increase in estimated overall cannabis spending (i.e., recreational, medical, and illegal combined) of around 40% between the third quarters of 2018 (i.e., pre-legalization) and 2022 (Statistics Canada, 2023a).

USA

In the US, adult cannabis use has been on the rise nationally, following a consistent upward trend since states first began liberalizing medical cannabis laws. Information from the National Survey on Drug Use or Health show that nationally, past year cannabis use rose from 10.4% in 2002 (95% CI: 9.97-10.82) to 15.3% (95% CI: 14.85-15.78) in 2017 (168). Data from three different waves of the National Epidemiologic Survey on Alcohol and Related Conditions (NESARC) confirm these trends, showing that cannabis use among adults increased between 4.1-9.5% between the first wave of the study (in 2001-2002) and the second wave (2012-2013), with significant increases among all sociodemographic groups, age groups and geographic regions (169). Evidence from studies exploiting cross-state variation in the adoption of state medical cannabis laws show that rates of past month use were higher among adults in states that adopted medical cannabis policies (170, 171, 172), and recent studies show a rise in adult prevalence rates due to adult-use laws as well (23, 73). In addition to these findings for the general population, a particularly disturbing trend is on the rise in cannabis use during pregnancy, which has also increased following legalization (133, 173, 174).

Uruguay

In Uruguay, lifetime prevalence of cannabis use among adults has increased since the regulation (2001: 5.3%, 2006: 13.1%, 2011: 20.0%, 2014: 23.3%, 2018: 30.2%; (175)). However, cross-country comparisons show that the development of cannabis use in the population in Uruguay is similar to Chile, where cannabis was not legalized (176). One unpublished study found no evidence of a short-term change after the regulation on the prevalence of cannabis use (study title: Impact of cannabis legalization in Uruguay on cannabis, alcohol, and tobacco use among adults: a synthetic control approach).

Theoretical considerations

There are two issues to consider when thinking about cannabis use: (1) prices and sales volumes in jurisdictions with competition have not yet stabilized, so as prices continue to decline that is going to impact use and amount of use above and beyond what has currently been observed; (2) youth use will change over time as use becomes more normalized for adults (as we have observed for cigarettes and alcohol).

4.3. Question 3: Legalization and protection of youth

Question

How did the protection of youth (e.g., availability of and exposure to cannabis, use trajectories, prevention, morbidity, cannabis use disorders) change in legalizing countries? Which accompanying measures have been proven successful to protect minors?

4.3.1. Expert response

Here, the term youth is defined as anyone underage as proposed by the German government, i.e., 17 or younger. Additionally, we have taken the transition period of ages 18 to 21 into consideration, for which cannabis use may be riskier than for older adults.

Among youth, cannabis consumption appears to have remained largely unchanged following the legalization of cannabis, or, in the case of Uruguay, the increase is the same than before the regulation. For young adults in the transition phase, cannabis use has increased.

Before legalization, cannabis use was already widespread enough that most youths and adults could probably access it illegally. Legalization increased legal access for adults, but not for youths: they are not allowed to go in licensed stores or to buy their products. Despite the mostly unchanged use rates among youth, there may be long-term impacts as cannabis use among adults becomes more normalized and markets mature.

One important aspect of youth protection concerns the rising cases of accidental cannabis poisoning among children (0 to 9 years) requiring ED visits. It is likely that this surge is associated with allowing the legal sales of edibles in Canada.

To protect youth, one can reduce exposure to use (e.g., by non-smoking laws), regulate store density, keep taxes high, reduce marketing (of stores) and kid-friendly products, or restrict the choice of products that can be legally sold (e.g., only flowers as in Uruguay). However, there is a lack of empirical studies that have evaluated these measures, thus, one cannot recommend for or against them based on evidence but only based on theoretical reasoning.

4.3.2. Evidence and reasoning

Canada

In Canada, prevalence among youths seemed mostly unchanged after legalization. Surveys variously reported no change in past-12-month prevalence among youths in 2019 (108), no increase from 2018 to 2020 in past-3-month prevalence among youths aged 15-17 (53), no increase from 2016-2017 to 2018-2019 in past-12-month prevalence among grade 7-12 students (177), or no change in 2019 in youths' heavy use or dependency (72). One study did report increases from 2016-2017 to 2018-2019 among high school students, but only in line with prior trends (15).

By contrast, prevalence among young adults increased. The past-3-month prevalence of cannabis use among those aged 18-24 increased from 28% in 2018 to 36% in 2020 (Rotermann, 2021). A follow-up study of those aged 18-20 found that prevalence increased only half as much in Quebec as in the other provinces, presumably because it had raised its minimum legal age from 18 to 21 (135). Past-12-month prevalence among those aged 20-24 increased from 44% in 2018 to 50% in 2022, whereas among those aged 16-19 it was unchanged (Public Health Agency of Canada, 2022).

For cannabis-related hospitalizations and emergency room admissions among children, no changes were observed initially (e.g., (91, 178)). More recent data suggests that cannabis poisonings in

children rose considerably, likely due to the introduction of legal edibles in December 2019. The share of hospitalizations for any form of poisoning in children aged 0-9 years in Canada caused by cannabis increased from 3.1% in 2015 to 29.0% in 2021 (122) and most cases appear to involve unintentional ingestion of edibles at home (179). For cannabis use disorder (CUD), prevalence among youths remained stable, but increases were observed among young adults (90).

USA

Youth annual and 30-day prevalence seems to be relatively unchanged but near daily use is rising (2, 23). Some studies have reported that youth access to cannabis has declined with legalization, other studies have shown associations between youth use and retail cannabis exposure (particularly advertising and proximity of retailers; (180, 181)). Also, prevention campaigns (thus far) have been ineffective (182).

Uruguay

Lifetime prevalence has increased over time among 13 and 17 year-olds (2003: 11.9%, 2009: 16.2%, 2014: 20.1%, 2016: 25.3%, 2018: 24.8%, 2021: 25.9%; (175)). However, increases in current (e.g., past-month) or risky use among youth existed before the regulation, and cannot be attributed to it (6, 76). In fact, the negative association between perceived risk and use weakened in Uruguay among adolescents but this may be a general trend, which also occurs in neighboring countries (183). Perceived availability remained strongly positively associated with use (183).

4.4. Question 4: Best regulations for protecting youth and public health

Question

In legalizing countries, which regulations have had positive effects on protecting youth and public health? Which regulations had negative effects? Of particular interest are limits of THC concentration and minimum legal purchasing age.

4.4.1. Expert response

There is a general scarcity on studies evaluating the impact of certain regulations to protect youth and public health. The only empirical evidence collected so far suggests that (enforced) minimum legal ages and restrictions in cannabis edibles (e.g., prohibiting forms that are appealing to youth) appear to be feasible and effective to protect youth. There are no empirical studies on the effectiveness of THC limits.

There are other regulations to protect youth and public health but there is only very limited empirical support for most of them. Generally, restrictions on physical availability, pricing policies and marketing restrictions are considered effective measures based on the experiences from alcohol and tobacco. There is some evidence that restricting the number of cannabis retailers can reduce the number of cannabis poisonings. Lastly, the experts agree that marketing restrictions (e.g., products not attractive to youth; storefront of physical retail stores being discreet) are more important than regulations of minimal distance between schools and retailers.

4.4.2. Evidence and reasoning

Canada

Store Restrictions: Restricted access to legal cannabis products may attenuate the increase in adverse health outcomes (41): during the initial period following legalization, where there were very few legal cannabis stores in Ontario (e.g., 67 for a province of 14 million people) and low per-capita legal cannabis sales, the pre-legalization trend of increases in cannabis-attributable emergency department (ED) visits over time was attenuated. Conversely, the period of commercialization (when the number of stores increased to >1,500) and the COVID-19 pandemic was associated with an increase in rates of cannabis-attributable ED visits.

However, restricting store numbers may not directly impact use rates but mainly attenuate legal sales. One study showed that the rate at which provinces opened licensed stores was only weakly related to prevalence increases (166) during 2018-2020. That is, provinces saw similar prevalence increases regardless of store numbers, but those with more stores saw more legal sales; that implies provinces with fewer stores got more illegal sales instead. Consequently, limiting store numbers may not necessarily limit overall cannabis consumption.

Currently, there are physical availability restrictions (i.e., store density cap) that only exist in Quebec. In other provinces, it has been observed that cannabis retailers highly cluster in certain urban areas, resulting in high competition (and reduced prices), while residents in other areas have no physical access to cannabis products.

Edible regulation: To reduce cannabis poisonings (especially among children), restrictions in legal cannabis edibles may be warranted. In Quebec, cannabis-infused chocolates, candies, and desserts are prohibited due to youth appeal. Here, the increase in poisonings was only half as large as in provinces without these restrictions (i.e., a 7.5 fold vs 3.0 fold increase in cannabis poisonings hospitalizations: (3)).

Minimum Legal Age (MLA): Increasing the minimum legal age from 18 to 21 years in Quebec was associated with lower increases of cannabis use rates among adults aged 18-20 (135).

THC Concentration: There has been an increase in THC concentrations of cannabis products being sold legally (see e.g., (184)). Canada does not have a limit on THC concentration; it has taxes on THC content for processed products like oils and edibles, but not for dry cannabis. Quebec has a maximum THC concentration of 30% (185). No comparisons of product strength between Quebec and other jurisdictions are known.

Marketing and Promotion Restrictions: No studies assessing the impact of marketing and promotion restrictions for cannabis are known, but compliance with digital marketing regulations (e.g., age restrictions) appears to be low, especially for social media platforms (186).

Warning Labels and Packaging: Cannabis packaging in Canada has a rotating list of warning labels. Interestingly, warnings that cannabis use is associated with increased risk of psychosis/schizophrenia were removed in April 2019 along with warnings about potential for addiction. Evaluations of warning labels for public health/youth protection are also unknown.

USA

There are no empirical insights on the effectiveness of certain regulations from the US. An expert panel rated state monopoly, physical retail availability restrictions, and taxes as highly effective for protecting health of the general population and youth specifically (187). A Cannabis Policy Scale has been developed to fill this gap in the future (188).

Uruguay

In Uruguay, several regulations are imposed to protect youth. The minimum legal age is 18, only dry cannabis is allowed to be sold, and there are limits of THC concentration on the cannabis sold at pharmacies (9% until December 2022, 15% since then). However, there is no research showing the causal impact of these regulations on consumption.

Theoretical considerations

Based on experience with alcohol and tobacco, factors like physical and temporal availability, pricing, and marketing all impact substance use (189, 190). Restrictions in these domains are effective population-level interventions to minimize adverse public health impacts (191). Also, specialty stores, minimum purchase ages, and limits in location of products within stores have all been shown to be effective at reducing youth use for tobacco and alcohol (192). Applying similar controls and policies to cannabis may be effective ways to reduce use and consequent harms.

4.5. Question 5: Legalization and the illegal market

Question

In legalizing countries, was the illegal market successfully reduced? If yes, to which degree? Is there an association between the degree of reduced illegal market and regulations, such as upper limits for THC concentration, allowing legal sales of edibles, or allowing online purchases?

4.5.1. Expert response

The illegal market appears to have decreased significantly, but the extent is difficult to quantify and varies across legalizing countries, states, and provinces. For example, in Canada 63% of cannabis consumers reported never obtaining their cannabis from illegal sources in 2021 (3 years post-legalization), versus 55% in 2020. There is no specific evidence that potency caps, online purchases, or sales of edibles impact the process of reducing the illegal market. As online purchases currently make up less than 5% of all legal cannabis purchases in Canada, their presence or absence is unlikely to make much difference.

In Uruguay, the legal market share remains well below 50% and there is a considerable grey market. Government-fixed low retail prices have not achieved to reduce the illegal market, because the price is only relevant for users with low socioeconomic status, who are often not registered (prerequisite for legal purchases).

Generally, price, product quality, safety/trust, and convenience are major factors that determine whether users buy cannabis legally or not. Thus, legal cannabis needs to be attractive enough to draw existing users away from illegal suppliers, but not so attractive that it tempts non-users to start consuming, e.g., products particularly attractive to adolescents. It is impossible to do both perfectly, so it is necessary to consider the trade-offs; for examples, see section ***4.9***. Aiming at completely eliminating the illegal market may come at public health costs, i.e., increased use and increased problems from using cannabis. In other words, eliminating the illegal market may to some extent be partially incompatible with public health aims. Moreover, the illegal market cannot be merely eliminated by competition, but it also requires law enforcement activities.

4.5.2. Evidence and reasoning

Canada

In Canada, several sources can be used to assess the extent of the illegal market. Most importantly, survey respondents increasingly reported buying more often from licensed sources and less often from illegal ones (53, 142, 156, 157, 193). Self-reported survey data from Health Canada (the Canadian Cannabis Survey) documented that purchasing from the illicit market has decreased since 2019. In 2021, 63% of cannabis consumers reported never obtaining their cannabis from illegal sources, versus 55% in 2020. In 2021, the main sources reported for sourcing legal cannabis were legal storefront retailers (53%) and websites (11% in 2021 (155). Conversely, the percentage of users saying they bought from “dealers” declined from 18% to 13% (52). Similarly, the percentage saying they bought “some” cannabis legally rose from 23% in early 2018 to 68% in late 2020 (53).

Using self-reported data to estimate illegal sales has limitations because consumers sometimes do not know and/or do not want to admit that their source is illegal. Consequently, respondents sometimes overstated the true legality of their purchases. For example, in 2018, only authorized

medical patients could legally buy cannabis; but the 23% figure mentioned above for 2018 was at least triple the number of such patients, and therefore a vast overestimate (194).

To estimate illegal sales, Statistics Canada uses a combination of surveys and extrapolations: their estimates indicate that illegal sales decreased 53% between 2018 and 2022 and were surpassed by legal sales in 2020 (195). Given the uncertainties in the input data, the specific numbers may be unreliable, but the trend should be an accurate representation of reality.

Unlicensed stores (i.e., "dispensaries") gradually became rare due to police crackdowns, but unlicensed web sites became more common (156, 196, 197). Most online dealers sold through ordinary web sites, though some used restricted-access "dark" sites or social media (198). Some illegal growers might have switched to supplying the U.S. market, as cross-border cannabis seizures increased in frequency and size between 2019 and 2021 (197).

Price, product quality, and safety were the main factors influencing consumers' choice of sources (155, 165, 199), with lower price being the biggest reason for buying illegally (52, 200, 201). Between 2019 and 2021, consumer perceptions of legal products relative to illegal products improved with respect to convenience, safety, and quality, but not price (202).

Prices initially were much higher at private-sector licensed stores than at public-sector ones, which in turn were higher than at illegal dealers (50, 203, 204). But legal prices decreased over time and therefore became more competitive (193, 203, 204).

Regarding product quality, there were many complaints initially about legal dry cannabis products (205), but some smaller licensed producers gradually developed excellent reputations (206). Conversely, illegal products often contained contaminants and much less THC than claimed (207, 208). For edibles, consumers sometimes bought illegal products for their higher THC content (209), or because legal equivalents were unavailable (210).

Convenience was another reason for buying illegally (200). The operating hours (52) and proximity (211) of legal stores mattered, with the latter improving as more stores opened (212).

In provinces with good store coverage, online sales were only a small part of total legal sales. During the first year of legal sales, the online share declined from 43% to 6% as more stores opened (213); it is now around 2% in most provinces. When Prince Edward Island temporarily closed its cannabis stores during the COVID-19 pandemic, only about one third of its store customers switched to buying from its legal web site; the other two thirds presumably returned to illegal sources (214).

USA

The illegal market in some US states has been reduced (overall: (56); Colorado: (215); Washington: (216)), but not others (e.g., California: (217, 218)).

Uruguay

In Uruguay, the illegal market could be reduced and around 30% of users consume legal cannabis. There is less contact with dealers and illegal drugs selling points. Before cannabis legalization, 70% were in contact with the illegal market. In 2017 this share decreased to 50%. Before cannabis legalization, 30% bought cannabis from friends – this increased to 50%. Before cannabis legalization, 66% of frequent cannabis consumers use "prensado" – a product of cannabis leaves and flowers, pressed together and often containing adulterating substances. The use of this product declined considerably with legalization: in 2017 only 14% reported using this product, and people who

continue to use it are mostly people with lower socioeconomic status. In the same period, flower use increased from 33% to 86% (219).

Moreover, preliminary evidence suggests that there is a new “grey market”, which might be the results of not having enough cannabis selling points and the strict regulations (mandatory registration, prohibition to sell to tourists, maximum quantities to purchase, limits to THC potency, no edibles or other products; unpublished study: Mercado ilegal, mercado gris y mercado legal después de la regulación del cannabis en Uruguay). On the other side, the legal cannabis sold at pharmacies has a low price fixed by the government and free of taxes to compete with the illegal market (10 dollars per 5 grams). These two regulations might help to diminish the illegal market, but, preliminary evidence indicates that the low price is mainly important for users of low socioeconomic status, but most of these users don’t consume legal cannabis because they are not registered (unpublished study: Mercado ilegal, mercado gris y mercado legal después de la regulación del cannabis en Uruguay).

Theoretical considerations

One plausible way to reduce diversion from the legal market would be to keep sales limits low, i.e., to disallow people to buy far more than they can actually consume within a short period of time (220). Further, it is possible that illicit retailers may be easier to identify if government monopolies exist (vs. licensing systems) for physical stores and/or for online sales, so this could help reduce illicit markets more efficiently. Moreover, the prominence of the illicit market in the U.S. prior to legalization is a major contributor to various states’ inability to stomp it out. Weak regulation on medical markets allowed too many opportunities for diversion and the like. It is not expected that other markets will have as difficult a time as was seen in the U.S. and Canada, as the medical cannabis programs (adopted prior to legalization) were more highly regulated (if not monopolized).

4.6. Question 6: Legalization and organized crime

Question

How have organized crime activities in relation to cannabis changed in legalizing countries?

4.6.1. Expert response

Evidence specific to the impact on organized crime in the legalizing countries is unknown. There is, however, evidence that cannabis-related arrests have declined, including those for distribution (production, trafficking, importing).

4.6.2. Evidence and reasoning

Canada

Evidence specific to the impact on organized crime in Canada is unknown.

There is some data regarding cannabis-related crime in general. Charges by police for cannabis-related offenses had been falling before legalization and continued falling afterward, making it difficult to know how much was due to legalization.

From 2017 to 2019, the number of adults charged with cannabis possession dropped 92%, while the number charged with cannabis distribution (production, trafficking, importing, etc.) fell 52%; together those represented a 29% decrease in total adult drug charges, i.e., involving cannabis or other drugs (221).

Over the same period, the number of youths aged 12-17 charged with cannabis possession declined 87% while those charged with distribution declined 54%; together those represented a 54% decrease in total youth drug charges (221). Much of the youth decrease occurred during legalization's first three months (60).

Among licensed producers, three licenses were revoked for Cannabis Act violations and six were temporarily suspended (197) (Health Canada, 2022a). A study in 2019 and 2020 found that 86% of producers with online activities, such as web sites or Facebook pages, had potentially violated advertising rules (186). Some retailers were fined for serving underage customers or offering illegal promotions (222).

USA

Evidence specific to the impact on organized crime in the USA is unknown.

Anecdotally, law enforcement in California report that organized crime has played a large role in the California illicit market, including cartels.

Uruguay

Evidence specific to the impact on organized crime in Uruguay is unknown.

Theoretical considerations

Canada's pre-legalization decreases in police charges were presumably due to reduced law enforcement attention. This might partly have been due to police or government leaders deciding that cannabis enforcement should be a lower priority in general, and/or realizing that cannabis would soon be legal.

Legalization incidentally made some aspects of illegal operation easier. For example, police who smell someone smoking cannabis, or see a backyard greenhouse containing cannabis plants, no longer can assume that a crime has occurred.

4.7. Question 7: Illegal market and retail price of legal cannabis

Question

In legalizing countries, is there a quantifiable association between the price of legal recreational cannabis and the share of the illegal market?

4.7.1. Expert response

The difference in price of cannabis on the legal vs. illegal market is a commonly cited determinant for purchasing decisions. However, the association between the price of legal recreational cannabis and the share of the illegal market cannot be quantified in a simple manner based on the available evidence.

4.7.2. Evidence and reasoning

Canada

Surveys consistently have found that price is one of the most important factors affecting where consumers buy their cannabis (e.g., (200)).

During the first year of legal sales in 2018-2019, the relationship between legal price and legal market share was statistically significant, but it explained only a small portion of the differences in shares between provinces (51).

One study analyzed a sample of consumers who were asked to choose between legal and illegal products at various prices (223). It found that consumers preferred legal products and were willing to pay more for them. However, those preferences posed a trade-off for governments: to maximize legal sales revenues (and therefore government tax revenues and corporate profits), they needed to set a high legal price; but to maximize the legal share of the market (and thereby minimize illegal sales), they needed to set a low price.

USA

Evidence on the relationship between the price of legal recreational cannabis and the share of the illegal market is not known.

Uruguay

In Uruguay, not charging taxes and fixing a low price aimed to reduce the illegal market. However, this was not tested in an academic study.

Theoretical considerations

With alcohol and tobacco, governments often impose high taxes and/or set high prices. This can decrease consumption and increase government revenues. However, this is not practical in the short-term or medium-term with cannabis, because the existing illegal market is too well established. A small segment of consumers will pay a large premium to buy legal products, but average consumers will only pay a small premium, and some are unwilling to pay any premium at all.

This implies that at least for the foreseeable future, governments must choose between having high prices for legal cannabis to maximize revenues; or having low prices to maximize legal market share. Initially, Uruguay and Quebec decided to charge low prices and be more competitive; but other Canadian provinces have subsequently done this to varying degrees.

This is also a reason to allow consumers to grow their own cannabis plants, even though only a minority will do so. Consumers who want to really minimize their costs are the ones most likely to buy from cheaper illegal sources; letting them grow their own plants gives them a cheap legal alternative.

4.8. Question 8: Separation of illegal and legal market

Question

Which statutory regulations have been issued to avoid interactions between legal and illegal markets? How did these regulations affect the illegal market? Of particular interest are regulations concerning the documentation of the different steps in the supply chain (from seed to sale) and access to the market (licensing models) in legalizing countries.

4.8.1. Expert response

There are monitoring systems in place, such as the Cannabis Tracking and Licensing System (CTLS) in Canada. This is a federal system, which allows tracking the amounts of cannabis grown and sold across the country in order to minimize diversions to or from the legal system. Similar so-called “seed to sale” systems have been implemented in some US states.

In Canada, there are also security checks for people applying for a producer license. Applicants are allowed to have prior convictions for minor drug crimes but not for being involved in organized crime.

In Uruguay, the selling points (pharmacies) are all registered and monitored. Additionally, users, home-growers and cannabis social clubs must register to legally buy, produce, or share cannabis. There is also a seed register in place, but this is not of practical use.

4.8.2. Evidence and reasoning

Canada

In Canada, the federal government requires cannabis producers to report the amounts of cannabis grown, processed, sold, etc., each month via the CTLS. It also requires retailers to report similar information to their respective provincial cannabis regulatory agencies, which in turn report that to the CTLS (224).

The federal government also requires each producer’s key managers and owners to undergo security checks before the producer can receive a license (225). Such people apparently are allowed to have prior convictions for minor drug crimes like cannabis possession, but not any involving organized crime. Most provinces have similar rules for people seeking retail licenses.

A few producers had their licenses suspended after attempting to illegally increase production. One producer bought dried cannabis from illegal sources and sold it as their own product (226), while another grew plants in a section of the building that had not yet received its license (227).

USA

Seed to sale systems have been the most common form of regulation to monitor the legal supply of cannabis, but the degree of specificity has changed over time and even established states (like WA state) experienced difficulties in implementation of a system when they changed vendors.

Uruguay

The Uruguayan regulation is a highly government-oriented regulation. There is a mandatory registration for users, also for home-growers, and cannabis social clubs. Licenses to produce the cannabis that is sold at pharmacies are given and controlled by the government. There is a seed register, but in practice, no one registers their seeds.

Theoretical considerations

During the first year of legal sales in Canada, when there were shortages of legal products, the main risk of interaction was for illegally grown cannabis to slip into the legal system. But now that there are surpluses of legal products, there are more concerns about legally grown cannabis being diverted into illegal sales.

4.9. Expert notes

To minimize harms, governments should make legal cannabis attractive enough to convince existing users to switch from illegal to legal sources, but not attractive enough to tempt non-users to start consuming it. In practice, many policy questions have no solution that achieves both goals simultaneously; so, regulators must find the "least bad" trade-off. Unfortunately, it can be difficult to predict the net result of such trade-offs: e.g., policies that directly affect legal-versus-illegal market competition can indirectly influence public health, law enforcement, and/or social justice outcomes.

For example, in Canada, federal regulations prevent licensed firms from using advertising to attract new users (225), especially youths; but they also prevent ads from drawing consumers away from illegal sources. Most provincial governments' retailing rules similarly focus on minimizing prevalence growth, rather than minimizing illegal market share (228). So, while these restrictions are appropriate overall, they have some disadvantages.

The federal government's high production standards presumably enhanced product safety, but they also discouraged illegal growers from transitioning into the new legal industry. Provinces with public-sector retail monopolies likewise made it impossible for illegal dealers to become legal. Since those growers and dealers could not join Canada's new legal industry, they presumably competed against it by continuing to operate illegally. To avoid this, it would be good if Germany can somehow encourage people who currently grow or sell illegally to move into the new legal system.

As mentioned for question 2, prevalence increases among adults aged 18-20 were only half as large in Quebec as elsewhere, due to that province increasing its legal age to 21. But the increased legal age pushed all its 18-to-20-year-old cannabis consumers back to illegal suppliers, whereas in other provinces those consumers increasingly bought legal products. So, this policy change presumably increased the health of those Quebecers aged 18-20 who consequently did not start using cannabis but might have decreased the health of those who were already using it.

Cannabis edibles, like gummy candies and cookies, are the most challenging product format to regulate. On the one hand, they are increasingly popular among users, especially new users who do not want to start smoking cannabis; and presumably they pose fewer respiratory health hazards to their users than smoking would. On the other hand, they pose greater risks of accidental consumption by children, pets, and unsuspecting adults. As noted for question 3, cannabis poisoning among children increased substantially after legalization, but Quebec's cannabis candy ban apparently made its increase much smaller.

The Canadian government limits edible products to 10 mg of THC per package (e.g., 5 mg in each of 2 gummies), whereas non-edibles can have 1000 mg of THC per package (e.g., 5 mg in each of 200 capsules), and illegal edibles might contain 100 mg or more per serving (e.g., 100 mg per gummy). On the one hand, the 10 mg per-package limit reduces the risk of accidental overdoses from legal edibles. On the other hand, it increases the likelihood that experienced users will buy illegal products to get the higher potency they want; and those illegal products are often packaged to resemble popular candies like Skittles or M&Ms, increasing the risk of children consuming them.

Competing with the illegal market is one reason to allow consumers to grow their own plants. Many users already do that, despite the illegality; and they are likely to continue doing so after legalization, regardless of what the law allows. In Uruguay, where home growing is legal but people need to register, two thirds of home growers remain unregistered. So, Germany might as well make that activity part of the legal sector rather than part of the illegal one.

One challenge in understanding these trade-offs is that governments disclose little of the cannabis data they collect. This makes it harder for researchers to use interprovincial comparisons to test for links between legal cannabis and health outcomes (229). Meanwhile, for medical studies involving human trials, federal rules require the use of cannabis produced to more stringent standards than what most commercial products provide (230). If Germany legalizes cannabis, it should ensure that data is made publicly available, and that researchers are allowed to test any products that consumers can legally consume.

5. Responses to research questions

5.1. Question 1: Legalization and public health

Question: How did public health indicators (e.g., morbidity, cannabis use disorders, addiction treatment, prevention) change in legalizing countries?

Among adults, the legalization in Canada, USA, and Uruguay had little immediate impact on health indicators. The most consistent short-term impact, defined as being observable within the first two years of establishing legal retail markets, was limited to small increases in health care encounters for acute or chronic cannabis-related problems, as reported in Canada and several US states. For cannabis intoxications that require acute medical care, increases have been observed where cannabis edibles were allowed to sell or where the market expanded greatly. Some of these increases were temporary. Notably, the number of people with CUD seeking specialized care in inpatient or outpatient settings appeared to be unaffected by legalization.

Driving a motor vehicle under the influence of cannabis has increased in most but not all jurisdictions where cannabis was legalized. Cannabis legalization has been linked to a greater number of motor vehicle crashes involving injuries and fatalities in several US states and Uruguay but not in Canada. Finally, legalization appeared to not have any short-term impact on hyperemesis, psychosis, or self-harm among adults, but is linked to a reduction in poison calls for intoxication from synthetic cannabinoids.

To conclude, cannabis legalization per se is not linked to immediate and substantial changes in public health indicators except traffic outcomes. There might be benefits from adult users being more informed about health risks by warning labels and feeling more comfortable to discuss problems concerning cannabis with health care workers. A reduced exposure to synthetic cannabinoids may be offset by a greater number of people experiencing problems from naturally occurring cannabinoids.

5.2. Question 2: Legalization and cannabis use

Question: What do we know about the development of cannabis use (prevalence) in legalizing countries (compared to pre-legalization)?

Before and after legalization in all legalizing jurisdictions, cannabis use among younger and older adults has been observed to increase and legalization has had little *immediate* impact on this trend. However, studies from Canada and USA with longer observation periods demonstrate that cannabis use has become more common where legal markets have been established. This observation is based on self-report but corroborated with toxicological analyses. As it takes several months if not years for legal markets to grow, it is not surprising that their impact on cannabis use does not occur immediately but only with a certain lag time. It is expected that cannabis use prevalence is growing at a quicker pace if the legal market is attractive to non-users, for example by marketing and a large variety of products offered by a high density of retail outlets.

Importantly, the growth in cannabis use in the adult population observed in Canada, USA, and Uruguay includes both high-risk and low-risk use patterns. With a growing absolute number of users but the share of high-risk use patterns among users remaining constant, cannabis legalization in Canada and US states has likely contributed to an increase in the absolute number of adult users with high-risk use patterns. Increasing cannabis use prevalence over time may also explain the observed increases in some adverse health events (see ***Question 1***).

5.3. Question 3: Legalization and protection of youth

Question: How did the protection of youth (e.g., availability of and exposure to cannabis, use trajectories, prevention, morbidity, cannabis use disorders) change in legalizing countries? Which accompanying measures have been proven successful to protect minors?

Youth aged 17 or younger from Canada, USA, and Uruguay have consistently reported that legalization has made it easier for them to access cannabis. However, cannabis use among adolescents has not consistently increased in these countries. This could be explained by the fact that access to cannabis has hardly changed among those adolescents that are interested in using cannabis. Studies with follow-up periods longer than two years and more robust methodologies, however, show that cannabis legalization in US states has led to increased use among adolescents. This is also corroborated by studies showing that initiation of cannabis use has increased following cannabis legalization. As legal cannabis markets still develop and as cannabis use among adults is becoming more normalized, adolescents living in jurisdictions with legal cannabis markets may be more prone to use cannabis in the future.

Like for adults, the share of high-risk cannabis use patterns among adolescent current users generally has not changed following cannabis legalization. Yet, the risk for CUD among current adolescent users may have increased, although this may be linked to increased willingness to disclose problems. However, cannabis legalization in US states has not led to changes in help-seeking behavior among adolescent cannabis users but is associated with a moderate increase in the number of adolescents showing acute and chronic cannabis-related problems that require medical attention.

For children aged 0-9 years, immediate and considerable increases in (accidental) intoxications among children have been observed in jurisdictions where cannabis edibles were sold legally. Importantly, cannabis intoxications for children remain few in absolute numbers, usually do not require hospitalization and do not have long-term health consequences.

Lastly, cannabis use during pregnancy has increased in legalizing countries/states – parallel to trends observed in the general population. Based on the available literature, generalized conclusions on the impact of cannabis legalization cannot be drawn because of inconsistent findings. However, adverse birth outcomes, such as low birth weight and small for gestational age, have not been negatively impacted by cannabis legalization.

To conclude, cannabis legalization or more specifically the sale of edibles, might lead to immediate increases in accidental intoxications among children. A higher availability of cannabis does not automatically translate into increased use among adolescents, but long-term increases of use and health problems may occur when legal markets expand, and cannabis use is normalized in the general population. Consequently, to protect youth, it will be important to regulate the recreational market effectively, so that adult consumption does not increase, e.g., by capping store density, high taxes, and a ban of marketing. The only empirical measures to protect youth specifically is (the enforcement of) a high minimum legal age (at least 18) as well as ban of cannabis products designed to be attractive to youth.

5.4. Question 4: Best regulations for protecting youth and public health

Question: In legalizing countries, which regulations have had positive effects on protecting youth and public health? Which regulations had negative effects? Of particular interest are limits of THC concentration and minimum legal purchasing age.

Although there is quite a wide range of regulatory models implemented, there are only few empirical comparative evaluations of specific regulations. Those regulations with direct empirical evidence are a) high minimum legal age, b) restricted licensing for retailers, c) restricting edible sales. For a) increasing the minimum legal age in Quebec from 18 to 21 years was associated with attenuated growth of cannabis use among young adults aged 18-20. For b) a strict licensing cap in Ontario was associated with a reduction of the number of cannabis-related acute and chronic problems that require medical attention. For c) restricting the sales of edibles to products that are not designed to be attractive for youth (e.g., candies, gums) was linked to an attenuated growth of (accidental) cannabis intoxications among children.

There is no empirical evidence that can be used to recommend for or against THC concentration caps.

Apart from these regulations with direct empirical evidence, the experiences from regulating alcohol and tobacco suggest that pricing policies, marketing bans, and availability restrictions may be effective measures to minimize cannabis related problems among both youth and adults. Marketing bans, including requirements for discreet storefronts, may also be more important to protect youth than regulations of minimal distance between schools and retailers.

5.5. Question 5: Legalization and the illegal market

Question: In legalizing countries, was the illegal market successfully reduced? If yes, to which degree? Is there an association between the degree of reduced illegal market and regulations, such as upper limits for THC concentration, allowing legal sales of edibles, or allowing online purchases?

There is only indirect evidence on changes in the illegal market. Survey data from Canada suggest that cannabis users are increasingly likely to (exclusively) purchase cannabis products from licensed retailers. In 2021 – three years post legalization – 63% of users reported to never purchase illegally. In the US state of Washington, legal sales grew much faster than THC consumption levels measured in wastewater, which is suggestive of a reduction of the illegal market. In Uruguay, the legal market share remains well below 50% but there is a large grey market, i.e., products that were once sold legally but later shared/resold illegally.

Generally, it seems that a more attractive, less regulated legal market results in a quicker reduction of the illegal market. Often cited determinants for purchasing legal vs. illegal products are price, product quality, safety/trust, and convenience. However, there is no empirical evidence that certain regulations would facilitate the expansion of the legal market. Online purchases unlikely make a difference as they currently only make up 5% of legal purchases in Canada.

Importantly, it needs to be considered that competition itself will not eliminate the illegal market. Thus, making the legal market more competitive can facilitate some users to switch to the legal market but an attractive legal market also comes with the risk of causing non-users to initiate using cannabis – with potential public health costs (see also ***Question 1, 2, and 4***). Consequently, the aim of eliminating the illegal market cannot be achieved by merely creating an attractive, i.e., cheap,

convenient, and advertised legal alternative, which would be incompatible with public health aims. To some extent, reducing illegal market activities will require law enforcement measures.

5.6. Question 6: Legalization and organized crime

Question: How have organized crime activities in relation to cannabis changed in legalizing countries?

There is no specific evidence on changes in organized (drug) crime activities in the context of cannabis legalization in Canada, USA, and Uruguay.

In the US, the arrest rates for possession have declined greatly following cannabis legalization. These make up the vast majority of cannabis-related arrests. In Canada, the arrest rates already declined prior to legalization. For changes in the distribution of cannabis, the evidence is less clear.

There are some studies that point at increased rates of property and violent crimes following cannabis legalization in some US states. The findings are rather heterogeneous and may partially be specific to the US. Thus, increasing crime rates are not to be expected in case of cannabis legalization in Germany.

5.7. Question 7: Illegal market and retail price of legal cannabis

Question: In legalizing countries, is there a quantifiable association between the price of legal recreational cannabis and the share of the illegal market?

The association between the price of legal cannabis products and the share of the illegal market cannot be quantified in a simple manner. While the price preference is a determinant for legal vs. illegal purchases for many users, there are no studies that would allow for a simple quantification of this relationship.

5.8. Question 8: Separation of illegal and legal market

Question: Which statutory regulations have been issued to avoid interactions between legal and illegal markets? How did these regulations affect the illegal market? Of particular interest are regulations concerning the documentation of the different steps in the supply chain (from seed to sale) and access to the market (licensing models) in legalizing countries.

There are monitoring systems in place, such as the Cannabis Tracking and Licensing System (CTLS) in Canada. This is a federal system, which allows tracking the amounts of cannabis grown and sold across the country in order to minimize diversions to or from the legal system. Similar so-called “seed to sale” systems have been implemented in some US states.

In Canada, there are also security checks for people applying for a producer license. Applicants are allowed to have prior convictions for minor drug crimes but not for being involved in organized crime.

In Uruguay, the selling points (pharmacies) are all registered and monitored. Additionally, users, home-growers and cannabis social clubs must register to legally buy, produce, or share cannabis. There is also a seed register in place, but this is not of practical use.

6. Summary and conclusions

This report provides an overview on the effects of legalizing cannabis for recreational purposes in Canada, USA, and Uruguay. In those countries, cannabis use and related problems has become more common before legalization and this trend has continued after legalization. This secular trend, an increasing prevalence of cannabis use and related problems, is also observed in Germany and a possible legalization is very unlikely to reverse this trend. However, continuing the current prohibitive approach is also not expected to make a difference.

To understand the exact impact of cannabis legalization, two important aspects need to be considered.

First, it takes several years for legal markets to expand. This has not only implications for efforts to replace the illegal market, but also for consumption and health. In Canada, the number of legal stores and sales have on average doubled every year since cannabis became legal in 2018 (231). This expansion has important implications for the evaluation of cannabis legalization. If the legal market impacts on consumption or health outcomes, such effects would be more likely to be observed with continued market expansion and consolidation. This is also reflected in the findings of this report, with long-term studies are more consistent in showing changes in consumption and health indicators: in those populations that have access to legal cannabis products, cannabis use increases at a slightly faster pace. This is more consistent for adults, including young adults aged 18-25, but less so for adolescents. The increased prevalence of cannabis use among adults caused by legalization is modest and it should be considered that most cannabis-related health and social risks arise from using cannabis frequently and early in life, i.e., before the age of 18. This does not mean that increased cannabis use prevalence among adults should be overlooked, because legalization has been linked to a modestly increased number of adults admitted to hospitals or EDs for acute and chronic problems, such as intoxications and CUD.

Second, there are many ways to regulate a legal cannabis market and the choice of regulations are crucial for the impact on consumption and health. Here are some examples of regulations that are currently in place:

- In Uruguay, the sale of flowers with up to 15% THC is allowed in a limited number of pharmacies across the country. Here, users aged 18 or older need to register to purchase cannabis legally or to grow their own plants.
- In Alberta – as in many US states and Canadian provinces – the number of private retail licenses is not limited. This results in a high density of outlets (20 per 100,000 in 2022) and above-average access to legal cannabis for the population (231). Here, the minimum legal age is 18 years and growing up to 4 plants is allowed.
- In Quebec, a public model was adopted, which means that legal cannabis is only sold in province-owned retail outlets. Here, the store density is only a fraction of that observed in Alberta (1 per 100,000 in 2022; (231)). As access to legal cannabis in Quebec is slightly below the national average, it is not clear whether the retail density is sufficient for the local population. Here, the minimum legal age is 21 years and home-cultivation remains prohibited.

In private retail models, legal retailers seek to increase revenue and this can be achieved by replacing the illegal market but also by attracting non-users to initiate cannabis consumption. The available evidence supports this reasoning and tentatively suggests that, where legal markets expand greatly, cannabis use and related health problems increase. At the same time, expansion of the legal market is also an effective means in replacing the illegal market.

To summarize, legalizing cannabis with the sole aim of quickly eliminating the illegal market requires a quickly expanding legal market, which may come with public health costs. Conversely, a health-oriented model may not be effective in reducing the illegal market quickly. Consequently, policy makers need to find the balance between these two partially conflicting aims.

For a cautious, public-health oriented approach in legalizing cannabis, a detailed set of recommendations have been developed and published elsewhere. Here, we highlight key measures that are expected to protect the health of adults and youth in a legal cannabis environment:

Protecting the health of adults

Based on the available evidence, the best way to protect the health of adults is to avoid cannabis retail commercialization. Theoretically, this can be best achieved by a public retail model, in which the number and location of retailers are centrally planned to ensure a sufficient access to legal products for the population while avoiding a clustering of outlets. In this model, prices can also be adjusted to be competitive with the illegal market. The next best option would be a private model, in which the number of licenses are capped. There are only few experiences of licensing caps and the optimal threshold may be determined empirically, starting with a low number (e.g., 1 retailer per 100,000 population). Also, allowing non-profit associations that provide quality-controlled cannabis to users (cannabis social clubs) may also be considered to minimize cannabis commercialisation. Regardless of the distribution model, marketing for cannabis products should be banned. This does not only include advertising on traditional media (TV, billboards), but also on the internet (websites, social media). Marketing restrictions may also address the appearance of storefronts, which should be discreet rather than heavily advertised. Lastly, pricing policies should disincentivize purchases of high-THC products. Specifically, an inflation-adjusted THC-based tax and a minimum unit price for the same amount of THC could contribute to minimize price discounts and falling retail prices following legalization.

Protecting the health of youth

To protect the health of youth, it should be avoided that cannabis use among adolescents rises considerably. An increasing normalization of use in the general population could increase consumption among youth in the long term. Additionally, there are few measures that specifically aim to protect the health of youth. First, the minimum legal age should not be below 18 years. Unlike currently practised for tobacco and alcohol, there should be a mandatory age verification and violations should be persecuted. Selling cannabis products to minors should result in a temporary or permanent license suspension. Second, cannabis products should not be designed to be attractive for youth. This specifically includes cannabis edibles, that should not be sold in colourful packages and in forms that are preferred by children, such as candies or gummies. Further, cannabis edibles should be sold in childproof containers and each packaged unit should not exceed 10mg THC to avoid over-intoxication.

Importantly, the effectiveness of these regulations depend on their enforcement. For example, adolescents in Germany currently can easily access alcoholic beverages in supermarkets even if they are below the minimum legal age. When legalizing cannabis, the mistakes in regulating alcohol and tobacco should not be repeated.

Conclusion

Where cannabis was legalized, cannabis use has generally increased before and after legislative changes. Further increases in cannabis use are also expected to happen in Germany – regardless of the proposed legalization. In Canada, USA, and Uruguay, few immediate changes in use and health

outcomes have been observed just after legal cannabis was available. However, as the legal market requires several years to expand and replace the illegal market, long-term impacts are crucial. Where legal cannabis markets grow and legal products become more available, the use of cannabis and related health problems became more common. Importantly, there are several measures that can be implemented to reduce possible adverse consequences of cannabis legalization for adults and youth. These include restrictions in licencing and marketing, and regulations concerning the sale of edibles. By learning from the North American experiences, Germany can legalize cannabis and protect public health.

7. Appendices

Appendix 1: Search strategy

Appendix 2: Questionnaire sent to the experts

Appendix 3: Summary table of all studies

8. References

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Appendix 1

Slight adjustments for the respective databases - see corresponding documentation!

No.	Terms for outcome: **Illegal market**	**No.**	Terms for outcome: **Health protection**	**No.**	Terms for outcome: **Youth protection**	**No.**	**Cannabis terms**	**No.**	**Legalization terms**
1	illegal	8	prevalence	30	youth	38	cannabis	42	legali?ation
2	Illicit	9	health	31	adolescen*	39	marijuana	43	legal
3	“black market”	10	treat*	32	children	40	THC		
4	organi?ed crime	11	“use disorder”	33	student	41	Tetrahydrocannabinol		
5	criminal*	12	addiction	34	p?ediatric				
6	smuggl*	13	dependenc*	35	Prevention				
7	seizure*	14	hospital*	36	legal age				
		15	emergency	37	minimum legal purchas* age				
		16	pregnan*						
		17	intoxicat*						
		18	poison*						
		19	psychos#s						
		20	schizophrenia						
		21	traffic						
		22	accident						
		23	availability						
		24	online purchas*						
		25	“web order”						
		26	“mail order”						
		27	e-commerce						
		28	delivery						
		29	price						

Assignment of search terms to research questions

Nr.	Question	Operationalization/ search terms
1	How did public health indicators (e.g., morbidity, cannabis use disorders, addiction treatment, prevention) change in legalizing countries?	health prevalence use treatment cannabis use disorder addiction dependenc* hospital emergency pregnan* intoxication poisoning psychosis schizophrenia traffic accident
2	What do we know about the development of cannabis use (prevalence) in legalizing countries (compared to pre-legalization)?	prevalence use
3	How did the protection of youth (e.g., availability of and exposure to cannabis, use trajectories, prevention, morbidity, cannabis use disorders) change in legalizing countries? Which accompanying measures have been proven successful to protect minors?	youth adolescen* children student p?diatric prevention legal age minimum legal purchas* age availability exposure prevalence cannabis use disorder

		addiction dependenc* hospital emergency intoxication poisoning psychosis schizophrenia
4	In legalizing countries, which regulations have had positive effects on protecting youth and public health? Which regulations had negative effects? Of particular interest are limits of THC concentration and minimum legal purchasing age.	health youth adolescen* children student p?diatric prevention legal age minimum legal purchas* age hospital emergency pregnan* intoxication poisoning psychosis schizophrenia traffic accident THC tetrahydrocannabinol
5	In legalizing countries, was the illegal market successfully reduced? If yes, to which degree? Is there an association between the degree of reduced illegal market and regulations, such as upper limits for THC concentration, allowing legal sales of edibles, or allowing online purchases?	illegal “black market” organi?ed crime criminal* smuggl*

		seizure* THC tetrahydrocannabinol availability online purchase web order mail order e-commerce delivery
6	How have organized crime activities in relation to cannabis changed in legalizing countries?	organi?ed crime criminal* smuggl*
7	In legalizing countries, is there a quantifiable association between the price of legal recreational cannabis and the share of the illegal market?	price „black market“
8	Which statutory regulations have been issued to avoid interactions between legal and illegal markets? How did these regulations affect the illegal market? Of particular interest are regulations concerning the documentation of the different steps in the supply chain (from seed to sale) and access to the market (licensing models) in legalizing countries.	Illegal “black market”

Search-Syntax:

#1 AND #2 AND #3 AND #4 NOT #5

#1	illegal OR “black market” OR organi?ed crime OR criminal* OR smuggl* OR seizure* OR prevalence OR use OR health OR treatment OR cannabis use disorder OR addiction OR dependenc* OR hospital OR emergency OR pregnan* OR intoxication OR poisoning OR psychosis OR schizophrenia OR traffic OR accident OR availability OR online purchase OR web order OR mail order OR e-commerce OR delivery OR price OR youth OR adolescen* OR children OR student OR p?diatric OR prevention OR exposure OR legal age OR minimum legal purchas* age
#2	cannabis OR marijuana OR THC OR tetrahydrocannabinol
#3	legali?ation OR legal
#4	year 2012 to current
#5	animal OR rat OR mice

Embase

Search performed on 11.01.2023

	Keyword	hits
1	Cannabis* [exp cannabis addiction/ or exp cannabis smoking/ or exp cannabis/ or exp Cannabis sativa/ or exp cannabis-induced psychosis/ or exp "cannabis use"/]	58880
2	Marijuana* [marijuana.mp. or exp cannabis/]	53470
3	THC* [exp cannabis/ or THC.mp. or exp tetrahydrocannabinol/]	56408
	~~Tetrahydrocannabinol~~	
4	legali?ation	3972
5	legal	329537
6	illegal	17949
7	Illicit	34184
8	black market	545
9	organi?ed crime	262
10	criminal*	45674
11	smuggl*	1053
12	seizure*	294787
13	prevalence	1320529
14	health	5015414
15	treat*	10251805
16	disorder	2300926
17	addiction	155803
18	dependenc*	484211
19	hospital*	3247627
20	emergency	667165
21	pregnan*	1226762
22	intoxicat*	288343
23	poison*	161550
24	psychos#s	165802
25	schizophrenia	244996
26	traffic	152121
27	accident	469300
28	availability	344931
29	online purchas*	208
30	web order	2
31	mail order	965
32	e-commerce	888
33	delivery	1025052
34	price	50726
35	youth	109342
36	adolescen*	1983187
37	children	1651949
38	student	464404
39	p?ediatric	685015

40	Prevention	2174874
41	legal age	530
42	minimum legal purchas* age	17
43	1 or 2 or 3	73219
44	4 or 5	332018
45	6 or 7 or 8 or 9 or 10 or 11 or 12	386685
46	13 or 14 or 15 or 16 or 17 or 18 or 19 or 20 or 21 or 22 or 23 or 24 or 25 or 26 or 27 or 28 or 29 or 30 or 31 or 32 or 33 or 34	19080305
47	35 or 36 or 37 or 38 or 39 or 40 or 41 or 42	5694416
48	45 or 46 or 47	21193668
49	43 and 44 and 48	4940
50	limit 49 to yr="2012 -Current"	3707

* „Map term to subject heading“ selected and terms in brackets chosen

Web of Science

Search performed on 12.01.2023

	Keyword	hits
1	Cannabis*	36.195
2	Marijuana*	25.160
3	THC*	21.892
	~~Tetrahydrocannabinol~~	
4	legali$ation	6.183
5	legal	365.515
6	illegal	37.516
7	Illicit	30.086
8	black market	12.332
9	Organi$ed crime	6.730
10	criminal*	162.181
11	smuggl*	4.320
12	seizure*	165.508
13	prevalence	1.153.623
14	health	10.080.451
15	treat*	7.619.778
16	disorder	1.808.402
17	addiction	118.804
18	dependenc*	1.243.583
19	hospital*	2.385.180
20	emergency	636.459
21	pregnan*	635.680
22	intoxicat*	55.194
23	poison*	118.007
24	Psychos$s	79.774
25	schizophrenia	220.977
26	traffic	413.771
27	accident	184.498
28	availability	530.618
29	online purchas*	15.491
30	web order	57.446
31	mail order	10.704
32	e-commerce	32.492
33	delivery	930.717
34	price	490.272
35	youth	498.621
36	adolescen*	702.516
37	children	2.253.801
38	student	1.258.859
39	p$ediatric	963.251
40	Prevention	1.077.677
41	legal age	22.821

42	minimum legal purchas* age	95
43	1 or 2 or 3	67.750
44	4 or 5	369.996
45	6 or 7 or 8 or 9 or 10 or 11 or 12	404.014
46	13 or 14 or 15 or 16 or 17 or 18 or 19 or 20 or 21 or 22 or 23 or 24 or 25 or 26 or 27 or 28 or 29 or 30 or 31 or 32 or 33 or 34	21.068.926
47	35 or 36 or 37 or 38 or 39 or 40 or 41 or 42	5.368.586
48	45 or 46 or 47	23.692.739
49	43 and 44 and 48	4.237
50	limit 49 to yr="2012 -Current"	3.743

Medline and PsycInfo

Search performed on 12.01.2023

	Keyword	
1	exp cannabis addiction/ or exp cannabis smoking/ or exp cannabis/ or exp Cannabis sativa/ or exp cannabis-induced psychosis/ or exp "cannabis use"/	28.152
2	marijuana.mp. or exp cannabis/	51.591
3	exp cannabis/ or THC.mp. or exp tetrahydrocannabinol/	35.083
	~~Tetrahydrocannabinol~~	
4	legali?ation	8.152
5	legal	313.131
6	illegal	33.426
7	Illicit	71.329
8	black market	844
9	organi?ed crime	2.730
10	criminal*	227.404
11	smuggl*	2.345
12	seizure*	241.476
13	prevalence	1.422.176
14	health	8.085.610
15	treat*	8.556.827
16	disorder	1.706.493
17	addiction	336.217
18	dependenc*	648.333
19	hospital*	7.367.661
20	emergency	651.520
21	pregnan*	1.264.347
22	intoxicat*	94.099
23	poison*	197.129
24	psychos#s	224.295
25	schizophrenia	483.681
26	traffic	147.612
27	accident	130.328
28	availability	399.901
29	online purchas*	2.129
30	web order	2
31	mail order	902
32	e-commerce	10.073
33	delivery	909.229
34	price	182.745
35	youth	538.816
36	adolescen*	3.536.358
37	children	2.759.517
38	student	579.754

39	p?ediatric	1.097.403
40	prevention	1.504.465
41	legal age	781
42	minimum legal purchas* age	41
43	1 or 2 or 3	61.237
44	4 or 5	318.176
45	6 or 7 or 8 or 9 or 10 or 11 or 12	550.395
46	13 or 14 or 15 or 16 or 17 or 18 or 19 or 20 or 21 or 22 or 23 or 24 or 25 or 26 or 27 or 28 or 29 or 30 or 31 or 32 or 33 or 34	19.806.359
47	35 or 36 or 37 or 38 or 39 or 40 or 41 or 42	6.852.746
48	45 or 46 or 47	21.843.427
49	43 and 44 and 48	6.372
50	limit 49 to yr="2012 -Current"	5.250

Appendix 2

Effects of cannabis legalisation (ECaLe): Expert survey

Dear expert,

You have been invited to support a short-term (three-month) project that aims to inform the legislation on cannabis for recreational purposes in Germany. Specifically, the German Federal Ministry of Health is interested in the effects of legalising cannabis with respect to protecting youth, public health, and illegal market activities.

You will find a set of 8 questions below, which we kindly ask you to fill out **by January 25, 2023**. To answer the questions, you may first give a general free text response which may reflect empirical and theoretical considerations, but also personal experiences. Subsequently, please indicate any evidence that supports your response. There are three types of evidence that you can specify:

a) direct empirical evidence: empirical studies of any kind (including qualitative/quantitative studies and systematic reviews) that provide direct answers to the question (e.g., time series analyses of changes in consumption dependent on cannabis legalisation),
b) indirect empirical evidence: empirical studies of any kind (including qualitative/quantitative studies and systematic reviews that can be used to infer indirect answers (e.g., studies in the alcohol/tobacco field on price regulation that may inform cannabis policies),
c) Personal experiences, observations or theoretical considerations: hypotheses that are based on your personal experiences or observations, as well as on theoretical reasoning (e.g., use an economic theory to predict how prices impact on illegal cannabis purchases).

In the questionnaire below, there will be a table with three separate cells to provide your answers according to these three evidence types. Whenever you refer to studies, please provide a sufficient amount of information for us to identify the respective studies (e.g., DOI, URL, author/year/title/journal).

Please note that we are conducting a systematic literature review ourselves, so we do not ask you to give a comprehensive overview of all relevant studies. Thus, in addition to citing key papers, we appreciate to be informed of any grey literature, pre-prints, and government documents that you are aware of regarding the outlined questions. If you do not feel you have sufficient expertise to answer a given question, you may just skip it.

Combining both your responses and the identified studies from our parallel literature search, the research team will answer these 8 questions to the best extent possible. Afterwards, we will invite all experts to participate in an online focus group to present the answers to all questions and discuss the answers and any remaining questions in the group. This **online focus group** is expected to be conducted **between 27 February and 10 March**. When returning your responses to this survey, please indicate your general availabilities during these two weeks.

We will protect your privacy by keeping your survey responses on encrypted hard drives. Only the principal investigator (Jakob Manthey) will have access to a document that links your name to the survey responses. This document will not be shared with other members of the research team or with the wider public. For the focus group and for public reports, the survey responses will not be linked to your name. By returning your responses, you consent to participate in this study and the outlined conditions. After participating in the focus group, you will be offered **a compensation of 1,000.00 €** (one thousand Euro).

Thank you again for supporting this important and compact research project! We look forward to your responses and plan to publish the results in an international peer-reviewed journal after completing the project for which you will of course be invited as co-author.

Kind regards,

Jakob Manthey, for the entire research team (Tobias Hayer, Britta Jacobsen, Jens Kalke, Jürgen Rehm, Moritz Rosenkranz, Uwe Verthein)

A note on the term 'legalising countries':

The research questions were compiled by the German Federal Ministry of Health but reflect the interests of various federal ministries involved in preparing the legalisation in Germany. They refer to evidence and insights from countries that have introduced "controlled access or other forms of legalisation of cannabis for recreational purposes" (literal translation). The Ministry of Health has listed Canada, selected US states, the Netherlands, Switzerland, and Uruguay as examples. For simplicity, these jurisdictions will be named "legalising countries" henceforth. At the minimum, the questions below should be answered based on experiences gathered in Canada, select US states, and Uruguay and you may simply provide responses for the jurisdiction you have primary interest/expertise is. However, additional insights from other countries (e.g., Switzerland, the Netherlands) are also welcome!

1. Research question 1:

How did public health indicators (e.g., morbidity, cannabis use disorders, addiction treatment, prevention) change in legalising countries?

Your response (free text):

a) direct empirical evidence	
b) indirect empirical evidence	
c) theoretical considerations	

2. Research question 2:

What do we know about the development of cannabis use (prevalence) in legalising countries (compared to pre-legalisation)?

Your response (free text):

a) direct empirical evidence	
b) indirect empirical evidence	
c) theoretical considerations	

3. Research question 3:

How did the protection of youth (e.g., availability of and exposure to cannabis, use trajectories, prevention, morbidity, cannabis use disorders) change in legalising countries? Which accompanying measures have been proven successful to protect minors?

Your response (free text):

a) direct empirical evidence	
b) indirect empirical evidence	
c) theoretical considerations	

4. Research question 4:

In legalising countries, which regulations have had positive effects on protecting youth and public health? Which regulations had negative effects? Of particular interest are limits of THC concentration and minimum legal purchasing age.

Your response (free text):

a) direct empirical evidence	
b) indirect empirical evidence	
c) theoretical considerations	

5. Research question 5:

In legalising countries, was the illegal market successfully reduced? If yes, to which degree? Is there an association between the degree of reduced illegal market and regulations, such as upper limits for THC concentration, allowing legal sales of edibles, or allowing online purchases?

Your response (free text):

a) direct empirical evidence	
b) indirect empirical evidence	
c) theoretical considerations	

6. Research question 6:

How have organized crime activities in relation to cannabis changed in legalising countries?

Your response (free text):

a) direct empirical evidence	
b) indirect empirical evidence	
c) theoretical considerations	

7. Research question 7:

In legalising countries, is there a quantifiable association between the price of legal recreational cannabis and the share of the illegal market?

Your response (free text):

a) direct empirical evidence	
b) indirect empirical evidence	
c) theoretical considerations	

8. Research question 8:

Which statutory regulations have been issued to avoid interactions between legal and illegal markets? How did these regulations affect the illegal market? Of particular interest are regulations concerning the documentation of the different steps in the supply chain (from seed to sale) and access to the market (licensing models) in legalising countries.

Your response (free text):

a) direct empirical evidence	
b) indirect empirical evidence	
c) theoretical considerations	

Appendix 3

doi	Author	Year	Country	State	Classification of outcome	Other regulation than legalization studied	Outcome	Study design	Deatails study design	Setting of sample	Age of sample	Sex of sample	Representativeness	General result	Result details
10.1016/j.drugpo.2020.103028	Armstrong	2021	Canada	nationwide	illegal market or crime		illegal market	only post measurements	post	illegal market	all ages	all sexes	yes	see text	see text
10.1111/add.15535	Callaghan	2021	Canada	nationwide	illegal market or crime		property crime	pre and post measurements without external control	ITS	nationwide	12-17 years	all sexes	yes	no change	Step function effect males (ώ) estimate: 0.88 95% CI: -13.93; 15.70 p=0.9072 Estimated step effect change, % (SE): 1.0% (8.4%). Step function effect females (ώ) estimate: 0.40 95% CI: -4.05; 4.85 p=0.8588 Estimated step effect change, % (SE): 1.1% (6.5%)
10.1111/add.15535	Callaghan	2021	Canada	nationwide	illegal market or crime		violent crime	pre and post measurements without external control	ITS	nationwide	12-17 years	all sexes	yes	no change	Step function effect males (ώ) estimate: -0.38 95% CI: -8.59; 7.84 p=0.9287 Estimated step effect change, % (SE): -0.4% (4.7%). Step function effect females (ώ) estimate: -1.31 95% CI: -4.15; 1.54 p=0.3677 Estimated step effect change, % (SE): -4.2% (4.7%)
10.3138/jcs-2020-0056	Hathaway	2021	Canada	nationwide	illegal market or crime		illegal market	only post measurements	post	illegal market	all ages	all sexes	yes	see text	see text
10.1111/dar.13069	Mahamad	2020	Canada	nationwide	illegal market or crime		illegal market	only post measurements	post	illegal market	all ages	all sexes	yes	see text	see text
10.25318/82-003-x202000200002-eng	Roterman	2020	Canada	nationwide	illegal market or crime		illegal market	pre and post measurements without external control	pre/post	illegal market	all ages	all sexes	yes	see text	see text
10.25318/82-003-x202100400001-eng	Roterman	2021	Canada	nationwide	illegal market or crime		illegal market	pre and post measurements without external control	pre/post	illegal market	all ages	all sexes	yes	see text	see text
10.1186/s12954-023-00753-6	Wadsworth	2023	Canada	nationwide	illegal market or crime		illegal market	only post measurements	post	illegal market	all ages	all sexes	yes	see text	see text
10.1111/add.14641	Burgard	2019	USA	Washington	illegal market or crime		illegal market	only post measurements	post	illegal market	all ages	all sexes	yes	see text	see text
10.1007/s00168-019-00931-0	Burkhardt	2019	USA	Colorado	illegal market or crime		violent crime	pre and post measurements with external control	DID	Denver, Colorado	unknown	all sexes	yes	no change	-0.008 (0.043)
10.1007/s00168-019-00931-0	Burkhardt	2019	USA	Colorado	illegal market or crime		property crime	pre and post measurements with external control	DID	Denver, Colorado	unknown	all sexes	yes	no change	0.040 (0.025)
10.1080/24751979.2019.1691934	Connealy	2020	USA	Colorado (areas with vs without dispensaries)	illegal market or crime		violent crime	pre and post measurements with external control	synthetic control	not specified	all ages	all sexes	yes	no change	
10.1080/24751979.2019.1691934	Connealy	2020	USA	Colorado (areas with vs without dispensaries)	illegal market or crime		property crime	pre and post measurements with external control	synthetic control	not specified	all ages	all sexes	yes	increase	Difference treated control: 239.69 (+18,8%) (90.52 (7.1%), 404.16 (31.7%))
10.1080/24751979.2019.1691934	Connealy	2020	USA	Colorado (areas with vs without dispensaries)	illegal market or crime		other crime (disorder)	pre and post measurements with external control	synthetic control	not specified	all ages	all sexes	yes	no change	
10.1016/j.jebo.2018.02.005	Dragone	2019	USA	Washington vs. Oregon	illegal market or crime		violent crime	pre and post measurements with external control	DID	Washington; Oregon	unknown	all sexes	yes	no change	ß= -6.53 (6.77)
10.1016/j.jebo.2018.02.005	Dragone	2019	USA	Washington vs. Oregon	illegal market or crime		property crime	pre and post measurements with external control	DID	Washington; Oregon	unknown	all sexes	yes	decrease	ß= –148.06 (44.91); p≤0.01
10.1177/00220426221134107	Harper	2022	USA	Washington	illegal market or crime		violent crime	pre and post measurements with external control	synthetic control	nationwide	all ages	all sexes	yes	no change	
10.1177/00220426221134107	Harper	2022	USA	Colorado	illegal market or crime		violent crime	pre and post measurements with external control	synthetic control	nationwide	all ages	all sexes	yes	no change	
10.1177/00220426221134107	Harper	2022	USA	Washington	illegal market or crime		property crime	pre and post measurements with external control	synthetic control	nationwide	all ages	all sexes	yes	no change	A statistically significant difference between the synthetic trend and actual trend was observed for 2018 and 2019 suggesting that the difference was unusually large and had Colorado not legalized marijuana, Colorado would have experienced about 320 fewer thefts per 100,000 people during these years, which would be about a 16% reduction. Confidence in this finding should be tempered as the average p-value in the post-treatment period was 0.200, and the placebo test shows that the effect was only unusually large at the very end of the post-treatment period.
10.1177/00220426221134107	Harper	2022	USA	Colorado	illegal market or crime		property crime	pre and post measurements with external control	synthetic control	nationwide	all ages	all sexes	yes	increase	
10.1080/07418825.2019.1567807	Hughes	2020	USA	Colorado	illegal market or crime		violent crime	pre and post measurements with external control	DID	grids in Denver, where dispenaries were opened vs. grids where no dispensaries were opened	all ages	all sexes	no	increase	Estimated effects of recreational marijuana dispensaries on crime and disorder from conditional autoregressive Bayesian spatiotemporal Poisson regression models (N=3981 grid cells, N= 4 years). Violent crime (aggravated assault) median (95% CI): 0.395 (0.123 to 0.640)
10.1080/07418825.2019.1567807	Hughes	2020	USA	Colorado	illegal market or crime		property crime	pre and post measurements with external control	DID	grids in Denver, where dispenaries were opened vs. grids where no dispensaries were opened	all ages	all sexes	no	increase	Estimated effects of recreational marijuana dispensaries on crime and disorder from conditional autoregressive Bayesian spatiotemporal Poisson regression models (N=3981 grid cells, N= 4 years). Property crime(burglary) median (95% CI): 0.398 (0.219 to 0.571)

10.1080/07418825.2019.1567807	Hughes	2020	USA	Colorado	illegal market or crime		other crime	pre and post measurements with external control	DID	grids in Denver, where dispenaries were opened vs. grids where no dispensaries were opened	all ages	all sexes	no	increase	Estimated effects of recreational marijuana dispensaries on crime and disorder from conditional autoregressive Bayesian spatiotemporal Poisson regression models (N=3981 grid cells, N= 4 years). Other crime (public disorder) median (95% CI): 0.652 (0.290 to 0.687)
10.1002/bsl.2573	Kan	2022	USA	California vs. Pennsylvania	illegal market or crime		illegal market	pre and post measurements with external control	DID	illegal market	all ages	all sexes	yes	see text	see text
10.1080/07418825.2019.1666903	Lu	2021	USA	Colorado + Washington vs. control states	illegal market or crime		property crime	pre and post measurements with external control	DID	not specified	all ages	all sexes	yes	no change	Table 4+5
10.1080/07418825.2019.1666903	Lu	2021	USA	Colorado + Washington vs. control states	illegal market or crime		violent crime	pre and post measurements with external control	DID	not specified	all ages	all sexes	yes	no change	Table 4+5
10.1177/0091450917708790	Maier	2017	USA	Washington and Colorado (and 9 other law-changing states) vs. control states	illegal market or crime		violent crime	pre and post measurements with external control	DID	nationwide (except District of Columbia)	unknown	unknown	yes	no change	F= 0.05 p= 0.819
10.1177/0091450917708790	Maier	2017	USA	Washington and Colorado (and 9 other law-changing states) vs. control states	illegal market or crime		property crime	pre and post measurements with external control	DID	nationwide (except District of Columbia)	unknown	unknown	yes	no change	F= 3.57 p= 0.065
10.1111/add.15517	Meinhofer	2021	USA	AK, CA, CO, ME, MA, MI, NV, OR, WA vs. control states	illegal market or crime		illegal market	pre and post measurements with external control	DID	illegal market	all ages	all sexes	yes	see text	see text
10.1007/s10940-021-09534-5	Thacker	2021	USA	Washington (communities with vs. w/o dispensaries)	illegal market or crime		property crime	pre and post measurements with external control	synthetic control	Washington (communities with vs. w/o dispensaries)	unknown	all sexes	yes	no change	1.734
10.1007/s10940-021-09534-5	Thacker	2021	USA	Washington (communities with vs. w/o dispensaries)	illegal market or crime		violent crime	pre and post measurements with external control	synthetic control	Washington (communities with vs. w/o dispensaries)	unknown	all sexes	yes	no change	0.113
10.1007/s10940-021-09534-5	Thacker	2021	USA	Washington (communities with vs. w/o dispensaries)	illegal market or crime		other crime	pre and post measurements with external control	synthetic control	Washington (communities with vs. w/o dispensaries)	unknown	all sexes	yes	no change	0.181
10.1007/s12103-022-09696-3	Worrall	2022	USA	Alaska, California, Colorado, Illinois, Maine, Massachusetts, Michigan, Nevada, Oregon, Vermont, Washington, District of Columbia vs. control states	illegal market or crime		illegal market	pre and post measurements with external control	DID	illegal market	all ages	all sexes	yes	see text	see text
10.1016/j.jcrimjus.2020.101742	Wu	2021	USA	Oregon vs. control states	illegal market or crime		violent crime	pre and post measurements with external control	synthetic control	Oregon vs control states (counties in the 19 non-legalized states)	unknown	all sexes	yes	increase	49.435 p = 0.057
10.1016/j.jcrimjus.2020.101742	Wu	2021	USA	Oregon vs. control states	illegal market or crime		property crime	pre and post measurements with external control	synthetic control	Oregon vs control states (counties in the 19 non-legalized states)	unknown	all sexes	yes	increase	365.404 p = 0.021
10.1016/j.drugpo.2021.103528	Wu	2022	USA	Oregon vs control states	illegal market or crime		violent crime	pre and post measurements with external control	DID	Oregon vs control states	unknown	all sexes	yes	no change	48.029 (26.079) p ≤ 0.1
10.1177/0886260521076169	Wu	2022	USA	Oregon vs control states	illegal market or crime		violent crime	pre and post measurements with external control	synthetic control	Oregon vs control states	unknown	all sexes	yes	increase	If OR had not legalised cannabis: on average, a reduction of approximately 120 cases for 2015, 166 cases for 2016, and 271 cases for 2017, per 100,000 population Estimate =132.7 SE= 38.0
10.1177/0022042621134902	Queirolo	2022	Uruguay	Montevideo + Metropolitan area	illegal market or crime		illegal market	only post measurements	post	illegal market	all ages	all sexes	yes	see text	see text
10.1097/ADM.0000000000000747	Auger	2021	Canada	Quebec	ADULT: use or health		CUD (healthcare)	pre and post measurements without external control	pre/post	hospitals in Quebec	all ages	male, female	yes	decrease	0.93 (0.89, 0.98)
10.1097/CXA.0000000000000154	Bahji	2022	Canada	nationwide	ADULT: use or health		use	pre and post measurements without external control	pre/post	not specified	12+	all sexes	yes	increase	There was a significant increase in cannabis past-year prevalence in subgroup meta-analyses (P < 0.0001, Fig. 1) comparing post-legalization [2018–2021: 25.0% (95% CI, 23– 27%), I2 = 96%] to prelegalization [1985–2017: 10% (95% CI, 9%–11%), I2 = 99%].
10.1503/cjs.000620	Ball	2021	Canada	Ontario	ADULT: use or health		use	pre and post measurements without external control	pre/post	single trauma centre	29-70 years	male, female	no	no change	There was no difference in the rate of positive cannabinoid screen results between the 2 periods (25% v. 22%, p = 0.7).
10.1186/s12873-021-00428-0	Baraniecki	2021	Canada	Ontario	ADULT: use or health		poisoning	pre and post measurements without external control	pre/post	Hospital ED	18 - 60 and above, median 27	68% male, 32% female	no	no change	2.44 vs 2.94
10.1056/NEJMsa2109371	Brubacher	2022	Canada	British Colombia	ADULT: use or health		DUI	pre and post measurements without external control	ITS	4 trauma centers	all ages	all sexes	yes	increase	After legalization, there was an increase in the prevalence of moderately injured drivers (...) and with a THC level of at least 2 ng per milliliter (adjusted prevalence ratio, 2.29; 95% CI, 1.52 to 3.45).
10.1016/j.drugalcdep.2021.109008	Callaghan	2021	Canada	Alberta and Ontario	ADULT: use or health		traffic	pre and post measurements without external control	ITS	EDs	mean age: Alberta: 38.8 years, Ontario: 41.3 years	male, female	yes	no change	see Table 1: no significant change according to intervention parameters

10.1177/07067437211070650	Callaghan	2022	Canada	Alberta	ADULT: use or health		psychosis/schizophrenia	pre and post measurements without external control	ITS	EDs	all ages	all sexes	yes	no change	0.34, 95% CI: -4.1, 4.8), p=.88
10.1177/07067437211070650	Callaghan	2022	Canada	Ontario	ADULT: use or health		psychosis/schizophrenia	pre and post measurements without external control	ITS	EDs	all ages	all sexes	yes	no change	24.3, 95% CI: -18.3, 67.0) p=.26
10.1136/oemed-2022-108316	Carnide	2022	Canada	British Columbia/Yukon, Alberta, Saskatchewan/Manitoba, Ontario, Quebec, Atlantic Canada	ADULT: use or health		use	pre and post measurements without external control	pre/post	workplace with at least 5 employees	18+	all sexes	yes	increase	There was a statistically significant change in cannabis use status from prelegalisation to postlegalisation (p<0.0001), with fewer respondents reporting former use (40.4% at T1, 33.0% at T2) and a greater proportion of workers reporting past-year use (30.4% at T1, 39.3% at T2).
10.1136/oemed-2022-108316	Carnide	2022	Canada	British Columbia/Yukon, Alberta, Saskatchewan/Manitoba, Ontario, Quebec, Atlantic Canada	ADULT: use or health		frequency	pre and post measurements without external control	pre/post	workplace with at least 5 employees	18+	all sexes	yes	increase	The proportion of respondents reporting daily or almost daily use between the two time points was statistically significantly different (7.0% at T1, 8.0% at T2; p=0.0267).
10.1080/09687637.2022.2117021	Christiano	2022	Canada	nationwide	ADULT: use or health		DUI	pre and post measurements without external control	pre/post	nationwide	16-34 years	all sexes	yes	no change	B=0.025 SE=0.259
10.1097/AOG.0000000000004207	Geoffrion	2021	Canada	British Columbia	ADULT: use or health		use	pre and post measurements without external control	DID	tertiary care clinic for pelvic pain and endometriosis	27-43	female	no	increase	Prelegalization, 366 of 2,760 women were cannabis users (13.3%), compared with 143 of 666 (21.5%) postlegalization (P,.001).
10.1016/j.jsat.2021.108340	Hawke	2021	Canada	Ontario	ADULT: use or health		frequency	pre and post measurements without external control	pre/post	Centre for Addiction and Mental Health, Toronto, Canada	mean age 19.3 (2.5)	male, female, transgender/divers	no	no change	high-frequency cannabis use, i.e., both before legalization (n=33, 35.5%), and after legalization (N = 59, 35.1%),X2=.003, p=.953
10.1016/j.jsat.2021.108340	Hawke	2021	Canada	Ontario	ADULT: use or health		perceived availability	pre and post measurements without external control	pre/post	Centre for Addiction and Mental Health, Toronto, Canada	mean age 19.3 (2.5)	male, female, transgender/divers	no	no change	On a 0 to 4 scale (4 = very easy), participants rated the ease of cannabis access at M = 3.65 (SD = 0.79) prior to legalization and M = 3.75 (SD = 0.60) after legalization; this was not a significant difference: F(1,246) = 2.614, p = .107, partial η2 = 0.011.
10.1186/s12913-020-05756-8	Hawley	2020	Canada	British Colombia	ADULT: use or health		use	pre and post measurements without external control	pre/post	six British Columbia cancer centers (94% of the total numver of cancer patients)	median age 66	male, female, other	no	increase	There was an increase in respondent disclosure of Current Use of cannabis from 23·1% in the pre- legalization cohort to 29·1% in the post-legalization co- hort (p-value <0·01).
10.1016/j.drugpo.2022.103629	Jordan	2022	Canada	New Brunswick	ADULT: use or health		use	pre and post measurements without external control	pre/post	forensics	19+	male, female	yes	no change	Although the proportion of cannabinoid-positive samples was greater post-legalization compared to pre-legalziation (20.6% versus 17.1%, respectively), this did not remain significant following BH correction (Effect size 0.04 (0.00-0.08)
10.1371/journal.pone.0268718	Kim	2022	Canada	Ontario	ADULT: use or health		poisoning	pre and post measurements without external control	ITS	Hospital ED	25-44 years	males and females	yes	increase	e.g. women: 1.140 (1.011 to 1.286), see table 5
10.1371/journal.pone.0268718	Kim	2022	Canada	Ontario	ADULT: use or health		poisoning	pre and post measurements without external control	ITS	Hospital ED	18-24, 65+	males and females	yes	no change	see table 5
10.1371/journal.pone.0268718	Kim	2022	Canada	Ontario	ADULT: use or health	allowing edible sales	poisoning	pre and post measurements without external control	ITS	Hospital ED	18-44 years	males and females	yes	increase	e.g. men 18-24: 1.303 (1.148 to 1.480), see table 5
10.1371/journal.pone.0268718	Kim	2022	Canada	Ontario	ADULT: use or health	allowing edible sales	poisoning	pre and post measurements without external control	ITS	Hospital ED	45-64 years	males and females	yes	no change	see table 5
10.1177/07067437211114785	Kim	2023	Canada	Ontario	ADULT: use or health		CUD (healthcare)	pre and post measurements without external control	ITS	Ontario	18+	all sexes	yes	increase	Difference pre-intervention vs. Phase 1 trend: 2.5% (0.9 to 4.2), p=0.002
10.1177/07067437211114785	Kim	2023	Canada	Ontario	ADULT: use or health	allowing edible sales	CUD (healthcare)	pre and post measurements without external control	ITS	Ontario	18+	all sexes	yes	decrease	Difference Phase 1 (legalization) vs. Phase 2 (edibles) trend: −4.0% (−6.3 to −1.6), p=0.001
10.1001/jamanetworkopen.2022.31937	Myran	2022	Canada	Ontario	ADULT: use or health		hyperemesis	pre and post measurements without external control	ITS	hospitals in Colorado	15+	male, female	yes	no change	net change after legalization: IRR per capita: 0.83, 95% CI: 0.68, 1.02
10.1001/jamanetworkopen.2022.31937	Myran	2022	Canada	Ontario	ADULT: use or health	commercialisation	hyperemesis	pre and post measurements without external control	ITS	hospitals in Colorado	15+	all sexes	yes	increase	net change after commercialization & COVID-19: IRR per capita: 1.32, 95% CI: 1.07, 1.63
10.1111/add.15834	Myran	2022	Canada	Ontario	ADULT: use or health		poisoning	pre and post measurements without external control	ITS	hospital ED	15-105	males and females	yes	decrease	The combined effect at 17 months after RCL (in February2020) was a statistically significant net decrease in the rate of visits of18% (IRR = 0.82, 95% CI = 0.70–0.96) among individuals aged15–105 years, relative to the counterfactual (had RCL not occurred).
10.1111/add.15834	Myran	2022	Canada	Ontario	ADULT: use or health	commercialisation	poisoning	pre and post measurements without external control	ITS	hospital ED	15-105	males and females	yes	increase	The com-bined effect at 15 months after RCC (in May 2021) was a significantnet increase of 22% (IRR = 1.22, 95% CI = 1.04–1.42) in the rate ofcannabis-attributable visits among individuals aged 15–105 years, rel-ative to the counterfactual (had RCC and the pandemic not occurred)
10.1186/s13011-021-00372-z	Rosic	2021	Canada	Ontario	ADULT: use or health		use	pre and post measurements without external control	pre/post	outpatient MAT clinics (MAT with methadone or buprenorphine-naloxone)	group 1: 38.9 years (SD = 10.4) group 2: 39.6 years (SD = 10.8)	all sexes	yes	no change	days of use (past 30 days): ß = -0.42; 95% CI: -2.05, 1.21; p= 0.615
10.1186/s13011-021-00372-z	Rosic	2021	Canada	Ontario	ADULT: use or health		use	pre and post measurements without external control	pre/post	outpatient MAT clinics (MAT with methadone or buprenorphine-naloxone)	group 1: 38.9 years (SD = 10.4) group 2: 39.6 years (SD = 10.8)	all sexes	yes	no change	Percentage of cannabis-metabolite-positive drug screens: 95% CI: 0.99, 1.01; p= 0.638

10.1186/s13011-021-00372-z	Rosic	2021	Canada	Ontario	ADULT: use or health		frequency	pre and post measurements without external control	pre/post	outpatient MAT clinics (MAT with methadone or buprenorphine-naloxone)	group 1: 38.9 years (SD = 10.4) group 2: 39.6 years (SD = 10.8)	all sexes	yes	no change	OR = 0.97; 95% CI: 0.77, 1.21; p= 0.794
10.25318/82-003-x201900600001-eng	Roterman	2019	Canada	nationwide	ADULT: use or health		use	pre and post measurements without external control	pre/post	national	15+	male, female	yes	increase	14.0% (12.7%, 15.4%) to 17.5% (16.1%, 19.0%)
10.25318/82-003-x201900600001-eng	Roterman	2019	Canada	nationwide	ADULT: use or health		frequency	pre and post measurements without external control	pre/post	national	15+	male, female	yes	no change	Conversely, the percentage of Canadians reporting DAD use at each Quarter remained stable between 2018 and 2019 (...)
10.25318/82-003-x202000200002-eng	Roterman	2020	Canada	nationwide	ADULT: use or health		DUI	pre and post measurements without external control	pre/post	national	15+	all sexes	yes	no change	before 14.2% after 13.2%, n.s.
10.25318/82-003-x202000200002-eng	Roterman	2020	Canada	nationwide	ADULT: use or health		use	pre and post measurements without external control	pre/post	national	15+	all sexes	yes	increase	before: 14.9%, after 16.8%, p<0.05
10.25318/82-003-x202000200002-eng	Roterman	2020	Canada	nationwide	ADULT: use or health		frequency	pre and post measurements without external control	pre/post	national	15+	all sexes	yes	no change	before: 5.9%, after 6.0%, n.s.
10.25318/82-003-x202100400001-eng	Roterman	2021	Canada	nationwide	ADULT: use or health		use	pre and post measurements without external control	pre/post	online-based survey	15+	all sexes	yes	increase	Q1 2018: '000= 4,178.8 % = 14.0 (p < 0.05) CI % = 12.7 to 15.4 Q4 2020: '000 = 6,184.3 % = 20.0 CI % = 18.3 to 21.8
10.25318/82-003-x202100400001-eng	Roterman	2021	Canada	nationwide	ADULT: use or health		frequency	pre and post measurements without external control	pre/post	online-based survey	15+	all sexes	yes	increase	Q1 2018: '000= 1,620.0 % = 5.4 (p < 0.05) CI % = 4.6 to 6.3 Q4 2020: '000 = 2,446.9 % = 7.9 CI % = 6.8 to 9.2
10.1016/j.japh.2021.06.023	Steinberg	2021	Canada	British Columbia	ADULT: use or health		use	pre and post measurements without external control	pre/post	patients in pharmacist-led clinic	unknown	all sexes	no	no change	before legalisation: 1% (Panel 1) and 8% (Panel 2) after legalisation: 14% p=0.030; effect size= 0.170
10.1016/j.drugalcdep.2021.108781	Turna	2021	Canada	Ontario	ADULT: use or health		frequency	pre and post measurements without external control	pre/post	existing research registry of ambulatory community adults at St. Joseph's Healthcare Hamilton (Hamilton, ON, Canada)	34.6 ± 13.95	all sexes	no	increase	B= 0.20 SE= 0.03 p<0.001
10.1016/j.drugalcdep.2021.108781	Turna	2021	Canada	Ontario	ADULT: use or health		quantity	pre and post measurements without external control	pre/post	existing research registry of ambulatory community adults at St. Joseph's Healthcare Hamilton (Hamilton, ON, Canada)	34.6 ± 13.95	all sexes	no	increase	B= 0.03 SE= 0.01 p= 0.001
10.1016/j.drugalcdep.2021.108781	Turna	2021	Canada	Ontario	ADULT: use or health		CUD (survey)	pre and post measurements without external control	pre/post	existing research registry of ambulatory community adults at St. Joseph's Healthcare Hamilton (Hamilton, ON, Canada)	34.6 ± 13.95	all sexes	no	increase	B=0.23 SE= 0.08 p= 0.001
10.1177/070674370984684	Vignault	2021	Canada	Quebec	ADULT: use or health		use	pre and post measurements without external control	pre/post	hospital Centre hospitalier universitaire de Sherbrooke (CHUS)	18+	all sexes	no	increase	OR (CI = 95%): 1.81 (1.34 to 2.44) p=0.0001
10.1177/070674370984684	Vignault	2021	Canada	Quebec	ADULT: use or health		CUD (healthcare)	pre and post measurements without external control	pre/post	hospital Centre hospitalier universitaire de Sherbrooke (CHUS)	18+	all sexes	no	no change	OR CI = 95%: 1.37 (0.99 to 1.90) p= 0.061
10.1017/cem.2020.384	Yeung	2020	Canada	Alberta	ADULT: use or health		poisoning	pre and post measurements without external control	pre/post	Urban hospital ED	all ages	males and females	no	increase	absolute level change after legalization: + 43.5 visits per month (Table 2)
10.1017/cem.2020.384	Yeung	2020	Canada	Alberta	ADULT: use or health		poisoning	pre and post measurements without external control	pre/post	Telehealth	all ages	males and females	yes	no change	no significant level change after legalization (Table 2)

10.1017/cem.2020.384	Yeung	2020	Canada	Alberta	ADULT: use or health		poisoning	pre and post measurements without external control	pre/post	Poison Center	all ages	males and females	yes	increase	absolute level change after legalization: + 4.0 visits per month (Table 2)
10.1080/10826084.2022.2034873	Yousufzai	2022	Canada	nationwide	ADULT: use or health		frequency	pre and post measurements without external control	pre/post	online survey	18 to 29 years	all sexes	no	increase	Although there was an increase in smoking frequency at each event, post-hoc analyses for both sexes revealed only a significant increase before and after legalization (p < 0.001) (Table 2).
10.1016/j.aap.2020.105757 (corrigendum)	Aydelotte	2019	USA	Colorado & Washington (vs. Idaho, Kansas, Nebraska, South Dakota)	ADULT: use or health		traffic	pre and post measurements with external control	DID	nationwide	all ages	all sexes	yes	increase	DID: +1.8 (+0.4 to +3.7), Sig. 0.020
10.1111/add.14939	Bae	2020	USA	(almost) nationwide 48 states)	ADULT: use or health		use	pre and post measurements with external control	DID	college	18-26 years	all sexes	yes	increase	Binary 30-day Marijuana Use in Full Sample Beta: 0.210; SE: 0.020; p: <.001; OR: 1.23 CI: 1.19 - 1.28. Adjusted for study covariates (gender, sexual orientation, relationship status, type of residence, race/ethnicity, first year status, legal age status, international student status, membership in the fraternity/sorority, private/public institution, season of survey administration, enrollment size, population, survey administration in odd years)
10.1111/add.14939	Bae	2020	USA	(almost) nationwide 48 states)	ADULT: use or health		frequency	pre and post measurements with external control	DID	college	18-27 years	all sexes	yes	increase	Binary 30-day Frequent Marijuana Use (>= 20 days within past 30 days) Beta: 0.168; SE: 0.038; p=<.001; OR: 1.18; CI: 1.10 - 1.27. Adjusted for study covariates (gender, sexual orientation, relationship status, type of residence, race/ethnicity, first year status, legal age status, international student status, membership in the fraternity/sorority, private/public institution, season of survey administration, enrollment size, population, survey administration in odd years)
10.1111/imj.14164	Bhandari	2019	USA	Colorado	ADULT: use or health		hyperemesis	pre and post measurements without external control	pre/post	hospitals with ED in colorado	all ages	all sexes	yes	increase	There was a 32% increase from 895 in 2012 (the year when recreational use of cannabis was legalised) to 1180 in 2014 after cannabis was legalised for recreational purposes (P < 0.001)."
10.1136/tsaco-2021-000736	Borst	2021	USA	California	ADULT: use or health		DUI	pre and post measurements without external control	ITS	five San Diego County trauma centers	25-56 years	male, female	no	no change	"There was not a significant differential change in the rate of THC+ toxicology after the 2016 legislation, B=0.683, p=0.923 (R2=0.524)."
10.1111/add.14641	Burgard	2019	USA	Washington	ADULT: use or health		use	pre and post measurements without external control	pre/post	Two wastewater treatment plants	all ages	all sexes	no	increase	Wastewater estimates for THC-COOH increased by 9% per quarter (doubling of cannabis consumption from 1.12.2013 to 31.12.2016). A significant linear trend of 0.001 g per calendar day (P<0.0001, R2= 0.165) emerged.
10.1097/ADM.0000000000000480	Calcaterra	2019	USA	Colorado	ADULT: use or health		poisoning	pre and post measurements without external control	ITS	patient care	15+	male, female	yes	increase	Intercept: 28.9 (SE 1.8); Trend change: 1.5 (SE 0.1) p<.0001
10.1097/ADM.0000000000000480	Calcaterra	2019	USA	Colorado	ADULT: use or health		CUD (healthcare)	pre and post measurements without external control	ITS	patient care	15+	male, female	yes	increase	Intercept: 40.4 (SE 5.5); Trend change: 2.7 (SE 0.1) p<.001
10.1080/15389588.2020.1810246	Calvert	2020	USA	Colorado	ADULT: use or health		traffic	pre and post measurements without external control	ITS	nationwide	all ages	all sexes	yes	increase	mean difference: 0.22 (0.05, 0.39)
10.1080/15389588.2020.1810246	Calvert	2020	USA	Washington	ADULT: use or health		traffic	pre and post measurements without external control	ITS	nationwide	all ages	all sexes	yes	no change	
10.1080/15389588.2020.1810246	Calvert	2020	USA	Oregon	ADULT: use or health		traffic	pre and post measurements without external control	ITS	nationwide	all ages	all sexes	yes	no change	
10.1186/s13011-022-00443-9	Carlson	2022	USA	California	ADULT: use or health		use	pre and post measurements without external control	pre/post	state-level computer-assisted telephone interviews	all ages (only available information: 18+)	all sexes	yes	increase	All adults were significantly more likely to report current use of cannabis [1.24 (1.09–1.42)], p<.01
10.1001/jamapsychiatry.2019.3254	Cerda	2020	USA	Colorado,Washington, Alaska, Oregon and control states	ADULT: use or health		use	pre and post measurements with external control	DID	statewide computer-assisted self-interviews	18-25 years	male, female	yes	no change	In the group aged 18 to 25 years, no difference was found after state RML enactment in past-month marijuana use, past- month frequent use, or past-year CUD in the overall sample (Table 2) or among users (Table 3).
10.1001/jamapsychiatry.2019.3254	Cerda	2020	USA	Colorado,Washington, Alaska, Oregon and control states	ADULT: use or health		use	pre and post measurements with external control	DID	statewide computer-assisted self-interviews	26+	male, female	yes	increase	Among respondents aged 26 years or older, past-month marijuana use after RML enactment increased from 5.65% to 7.10% (OR, 1.28; 95% CI, 1.16-1.40) (Table 2).
10.1001/jamapsychiatry.2019.3254	Cerda	2020	USA	Colorado,Washington, Alaska, Oregon and control states	ADULT: use or health		frequency	pre and post measurements with external control	DID	statewide computer-assisted self-interviews	18-25 years	male, female	yes	no change	In the group aged 18 to 25 years, no difference was found after state RML enactment in past-month marijuana use, past- month frequent use, or past-year CUD in the overall sample (Table 2) or among users (Table 3).
10.1001/jamapsychiatry.2019.3254	Cerda	2020	USA	Colorado,Washington, Alaska, Oregon and control states	ADULT: use or health		frequency	pre and post measurements with external control	DID	statewide computer-assisted self-interviews	26+	male, female	yes	increase	Furthermore, past- month frequent use increased from 2.13% to 2.62% (OR, 1.24; 95% CI, 1.08-1.41) (table 2) (...)
10.1001/jamapsychiatry.2019.3254	Cerda	2020	USA	Colorado,Washington, Alaska, Oregon and control states	ADULT: use or health		CUD (survey)	pre and post measurements with external control	DID	statewide computer-assisted self-interviews	18-25 years	male, female	yes	no change	In the group aged 18 to 25 years, no difference was found after state RML enactment in past-month marijuana use, past- month frequent use, or past-year CUD in the overall sample (Table 2) or among users (Table 3).
10.1001/jamapsychiatry.2019.3254	Cerda	2020	USA	Colorado,Washington, Alaska, Oregon and control states	ADULT: use or health		CUD (survey)	pre and post measurements with external control	DID	statewide computer-assisted self-interviews	26+	male, female	yes	increase	(...) and past-year CUD increased from 0.90% to 1.23% (OR, 1.36; 95% CI, 1.08-1.71) (Table 2).
10.1186/s40621-019-0180-4	Chung	2019	USA	Colorado and comparator	ADULT: use or health		use	pre and post measurements without external control	ITS	six trauma centers in three states with RML & three states without RML	all ages	male, female	yes	increase	In activated patients, there was a significant interaction effect for marijuana use: commercialization of recreational marijuana was associated with an increased rate of marijuana detection (interaction p < 0.001)

10.1093/jat/bku090	Couper	2014	USA	Washington	ADULT: use or health		DUI	pre and post measurements without external control	pre/post	Washington State	all ages	all sexes	yes	increase	"This represents a percentage point increase of 6.1 and 12.8% over the previous time period for THC and carboxy-THC, respectively. Significance was still observed using the normalized data (THC X2 ¼ 140.03, carboxy-THC X2 ¼ 477.93)."
10.1136/bmjopen-2018-027432	Delling	2019	USA	Colorado vs. New York, Oklahoma	ADULT: use or health		traffic	pre and post measurements with external control	DID	hospitals (inpatient health care)	all ages	all sexes	yes	increase	CO vs. NY: RR 1.22, 95% CI: 1.16, 1.28, p<.0005; CO vs. OK: RR 1.18, 95% CI: 1.02, 1.37, p=.026
10.1136/bmjopen-2018-027432	Delling	2019	USA	Colorado vs. New York, Oklahoma	ADULT: use or health		self-harm	pre and post measurements with external control	DID	hospitals (inpatient health care)	all ages	all sexes	yes	increase	CO vs. NY: RR 1.09, 95% CI: 1.93, 1.15, p=.002; CO vs OK: RR 1.26, 95% CI: 1.12, 1.41, p<.0005
10.1136/bmjopen-2018-027432	Delling	2019	USA	Colorado vs. New York, Oklahoma	ADULT: use or health		hyperemesis	pre and post measurements with external control	DID	hospitals (inpatient health care)	all ages	all sexes	yes	no change	CO vs. NY: RR 1.08, 95% CI: 1.06, 1.10, p<.0005; CO vs. OK: RR 0.95, 95% CI: 0.97, 1.01, p<.0005
10.1136/bmjopen-2018-027432	Delling	2019	USA	Colorado vs. New York, Oklahoma	ADULT: use or health		psychosis/schizophrenia	pre and post measurements with external control	DID	hospitals (inpatient health care)	all ages	all sexes	yes	decrease	CO vs. NY: RR 0.84, 95% CI: 0.82, 0.86, p <.0005; CO vs. OK: RR 0.80, 95% CI 0.79, 0.80, p<.0005
10.1136/bmjopen-2018-027432	Delling	2019	USA	Colorado vs. New York, Oklahoma	ADULT: use or health		CUD (healthcare)	pre and post measurements with external control	DID	hospitals (inpatient health care)	all ages	all sexes	yes	increase	Over 2010 to 2014, the change in rates of cannabis abuse admissions after versus before recreational cannabis legalisation in 2012 was greater in CO than in NY and OK (RR 1.27, 95% CI 1.26 to 1.28 and RR 1.16, 95%CI 1.15 to 1.17; both p<0.0005, respectively)
10.1016/j.addbeh.2020.106782	Doran	2021	USA	California	ADULT: use or health		frequency	pre and post measurements without external control	ITS	online surveys in California	18-24 years	male, female	yes	no change	Table 2: Legalization (Coeff. 0.04, Std error 0.20, z-score 0.20, p = .844); post-leg slope (coeff. 0.01, std error 0.06, z-score 0.20, p=.842)
10.1016/j.ypmed.2021.106548	Doucette	2021	USA	Colorado (control states)	ADULT: use or health		self-harm	pre and post measurements with external control	synthetic control	not specified	ten-year categories (15-24, 25-34, etc)	all sexes	yes	no change	
10.1080/15389588.2018.1530769	Eichelberger	2020	USA	Washington	ADULT: use or health		DUI	pre and post measurements without external control	pre/post	stoplight / stopsign in 6 counties in Wahsington	16+	all sexes	no	no change	extract for 1year post legalization: from text a) self-reported past 24h cannabis use (no change) and b) blood/oral fluid THC test (no change)
10.1080/15389588.2018.1530769	Eichelberger	2020	USA	Washington	ADULT: use or health		DUI	pre and post measurements without external control	pre/post	stoplight / stopsign in 6 counties in Wahsington	16+	all sexes	no	no change	extract for 1year post legalization: from text a) self-reported past 24h cannabis use (no change) and b) blood/oral fluid THC test (no change)
10.1001/jamanetworkopen.2022.52689	Elser	2023	USA	nationwide	ADULT: use or health		psychosis/schizophrenia	pre and post measurements with external control	DID	nationwide (except District of Columbia)	16+	male, female	yes	no change	RR, 1.14; 95%CI, 0.89-1.45
10.1001/jamanetworkopen.2022.52689	Elser	2023	USA	nationwide	ADULT: use or health	THC-related dosage restrictions	psychosis/schizophrenia	pre and post measurements with external control	DID	nationwide (except District of Columbia)	16+	all sexes	yes	increase	RR: 1.61 (1.17 – 2.21)
10.2105/AJPH.2019.305191	Everson	2019	USA	Washington	ADULT: use or health		use	pre and post measurements without external control	pre/post	people living in households with telephone numbers (landline/cellular) in Washington	≥18 years	all sexes	yes	no change	current use prevalence more than doubled, increasing from 5.8% in quarter 1 of 2009 to 13.2% in quarter 4 of 2016, but did not significantly change directly after possession was legalized in 2012 availability was controlled for
10.2105/AJPH.2019.305191	Everson	2019	USA	Washington	ADULT: use or health		frequency	pre and post measurements without external control	pre/post	people living in households with telephone numbers (landline/cellular) in Washington	≥18 years	all sexes	yes	no change	frequent use increased from 2.0% in quarter 1 of 2009 to 5.5% 4 of 2016, but did not significantly change directly after possession was legalized in 2012 availability was controlled for
10.15288/jsad.2022.83.494	Farmer	2022	USA	Colorado, Washington, Oregon, California, Nevada vs. control states	ADULT: use or health		traffic	pre and post measurements with external control	DID	nationwide	all ages	all sexes	yes	increase	(…), the combined effect of legalizing use and sales was a 5.8% increase in injury crash rates (i.e., 100 (e0.0631 – 0.0066 – 1)). estimate 0.0565, Effect (%) 5.8; 95% CI: 0.2-11.7, p=.0431
10.15288/jsad.2022.83.494	Farmer	2022	USA	Colorado, Washington, Oregon, California, Nevada vs. control states	ADULT: use or health		traffic	pre and post measurements with external control	DID	nationwide	all ages	all sexes	yes	no change	Estimate 0.0398, Effect (%) 4.1, 95% CI: -3.1, 11.7, p=.2736
10.1186/s13011-021-00352-3	Gali	2021	USA	California	ADULT: use or health		use	pre and post measurements without external control	pre/post	online surveys in California	18+	all sexes	no	increase	OR = 1.28, p = .01
10.1007/s11606-022-07948-w	Goncalves	2022	USA	nationwide	ADULT: use or health		use	pre and post measurements without external control	ITS	households	21-50	male, female	yes	increase	For example, comparing the period after RCL to before RCL, the prevalence of simultaneous use among respondents aged 21–30 increased from 9.20 to 10.40% (aOR=1.15 [95%CI=1.04–1.27]). Similarly, among participants aged 31–40 years and 41–50 years, prevalence increased from 5.12 to 6.12% (aOR=1.21 [1.04–1.41]) and from 2.93 to 4.68% (aOR=1.63 [1.34–1.98]) respectively.
10.1111/add.15472	Goodwin	2021	USA	nationwide	ADULT: use or health		use	pre and post measurements with external control	DID	persons living with children in the household (civilian non-institutionalized persons)	≥18 years	all sexes	yes	increase	RML was associated with significantly higher prevalence of past-month cannabis use (adjusted odds ratio [AOR] = 1.28, 95% confidence interval[CI] = 1.12, 1.46)
10.1111/add.15472	Goodwin	2021	USA	nationwide	ADULT: use or health		frequency	pre and post measurements with external control	DID	persons living with children in the household (civilian non-institutionalized persons)	≥18 years	all sexes	yes	increase	RML was associated with significantly higher prevalence of daily cannabis use (AOR = 1.25, 95% CI = 1.03, 1.51)

10.15288/jsad.2018.79.88	Grant	2018	USA	Washington	ADULT: use or health		use	pre and post measurements without external control	pre/post	Parent–Child Assistance Program (PCAP), a 3-year intensive case management intervention	childbearing age	female	no	increase	odds ratio [OR] = 2.1, p < .0001)
10.1016/j.amjsurg.2019.08.020	Grigorian	2019	USA	California	ADULT: use or health		use	pre and post measurements without external control	pre/post	level-1 adult, level-2 pediatric trauma center	10-41 years	male, female	no	increase	In the pre-legalization period, 86.8% of trauma patients had a urine toxicology and in the post-legalization period, 77.3% did (p < 0.001). The incidence of marijuana-positive patients in the pre-legalization cohort (n=1564) was 9.4% and 11.0% in the post-legalization cohort (n=491) (p < 0.001).
10.1111/add.15895	Gunadi	2022	USA	California, Massachusetts, Nevada and Maine vs. control states	ADULT: use or health		initiation	pre and post measurements with external control	longitudinal w/ control	interviews within the PATH study	21+	male, female	yes	increase	(...) RCL was associated with higher odds of transition from non-users to users when RCL states were compared to non-legalizing states [odds ratio (OR)=2.18, 95% confidence interval (CI)=1.37–3.45, P<0.001] (...)
10.1111/add.15895	Gunadi	2022	USA	California, Massachusetts, Nevada and Maine vs. control states	ADULT: use or health		frequency	pre and post measurements with external control	longitudinal w/ control	interviews within the PATH study	21+	male, female	yes	no change	We also did not find evidence that RCL was associated with transition from non-users to weekly users (...)
10.1002/hec.4573	Gunadi	2022	USA	Colorado	ADULT: use or health		traffic	pre and post measurements with external control	DID	hospitals in Colorado	all ages	all sexes	yes	no change	Table 3: 85.696 (88.214), not significant
10.1002/hec.4573	Gunadi	2022	USA	Colorado	ADULT: use or health		CUD (healthcare)	pre and post measurements with external control	DID	hospitals in Colorado	all ages	all sexes	yes	increase	increase in marijuana-related hospital discharges per 1000 hospitals: +4.765 (p<.01; 1.363)
https://scholarworks.waldenu.edu/cgi/viewcontent.cgi?article=7609&context=dissertations	Hake	2019	USA	Washington vs. 42 control states	ADULT: use or health		traffic	pre and post measurements with external control	DID	traffic (Washington state vs. 42 other states)	all ages	all sexes	yes	no change	
10.1111/acem.13393	Hall	2018	USA	Colorado	ADULT: use or health		poisoning	pre and post measurements without external control	pre/post	hospital ED	25-79	males and females	yes	increase	from 823.5 (95% CI = 756.7–890.2) to 1,146.1 per 100,000 (95% CI = 1,079.4–1,212.8, p < 0.0001)
10.1136/injuryprev-2019-043511	Hall	2021	USA	Colorado	ADULT: use or health		poisoning	pre and post measurements without external control	ITS	hospital ED	not specified (all ages?)	males and females	yes	decrease	interrupted time series model estimate: −0.021 (p<.05)
10.1136/injuryprev-2019-043511	Hall	2021	USA	Colorado	ADULT: use or health		CUD (healthcare)	pre and post measurements without external control	ITS	hospital ED	not specified (all ages?)	all sexes	yes	increase	ED= 0.4559 (p<0.05) hospitalisations= 0.1385 (p<0.05)
10.1111/ecin.12751	Hansen	2020	USA	Colorado & Washington (+ control states)	ADULT: use or health		traffic	pre and post measurements with external control	synthetic control	nationwide	all ages	all sexes	yes	no change	
10.1001/jamapsychiatry.2023.0019	Hasin	2023	USA	AK, CA, CO, DC, IL, MA, ME, MI, NV, OR, VT, WA vs. control states	ADULT: use or health		CUD (healthcare)	pre and post measurements with external control	DID	Veterans Health Administration (VHA) patients	18-75	all sexes	yes	increase	The DiD estimate of the CUD prevalence increase due to changing from MCL only to RCL/MCL was 0.12% (95% CI, 0.10%-0.13%). Relative to the absolute change in MCL/RCL states by 2019 (1.17%;Table 1), 9.8% of the increase in RCL states could be attributed to RCL enactment.
10.1086/721267	Hollingsworth	2022	USA	nationwide, all states	ADULT: use or health		use	pre and post measurements with external control	DID	online-based survey	18+	all sexes	yes	increase	Table 2: 24.61 (p < 0.01)
10.1086/721267	Hollingsworth	2022	USA	nationwide, all states	ADULT: use or health		use	pre and post measurements with external control	DID	online-based survey	18+	all sexes	yes	increase	Table 2: 29.85 (p < 0.01)
10.1086/721267	Hollingsworth	2022	USA	nationwide, all states	ADULT: use or health		initiation	pre and post measurements with external control	DID	online-based survey	18+	all sexes	yes	increase	Table 2: 31.60 (p < 0.01)
10.1086/721267	Hollingsworth	2022	USA	nationwide, all states	ADULT: use or health		use	pre and post measurements with external control	DID	workplace	adults (age not specified)	all sexes	yes	increase	Table 3: 34.75 (p < 0.01)
10.1097/CORR.0000000000000339	Jennings	2019	USA	Colorado	ADULT: use or health		use	pre and post measurements without external control	pre/post	records of patients undergoing primary total joint arthroplasty	users (n=59): 54.2 (SD 10.6) non-users (n=941): 64.5 (SD 10.2)	all sexes	no	increase	Self-reported marijuana use dramatically increased from 1% (four of 500) to 11% (55 of 500) (odds ratio [OR], 15.3 [95% confidence interval, 5.5–42.6]; p < 0.001) after legalization.
10.1016/j.addbeh.2017.08.015	Jones	2018	USA	Colorado	ADULT: use or health		frequency	pre and post measurements without external control	pre/post	colleges in Colorado	mean age 20.1	male, female	no	no change	Surprisingly, no statistically significant differences in the frequency of marijuana use was found over the four data collections in Colorado, which included before and after the legalization of recreational marijuana use.
10.2105/AJPH.2020.305797	Kan	2020	USA	California, Pennsylvania	ADULT: use or health		use	pre and post measurements with external control	DID	youth's home, community (e.g. coffee shop), secure facility (e.g. detention center, jail)	19-22 years	male	no	no change	There was no main effect of time on marijuana use when we controlled for all covariates.Next, we observed a significant site-by- time interaction (c2 = 13.10; P = .001), and we proceeded to probe specific contrasts by rotating the time reference groups. These post hoc analyses revealed no significant changes in marijuana use in California across any of the time contrasts (Figure 2). In California, rates of use at T1 versus T2 (b = −0.010; P = .950), T2 versus T3 (b = −0.046; P = .846), and T1 versus T3 (b = −0.056; P = .848) were not statistically different. However, marijuana use changed significantly over time in Pennsylvania.

10.1002/bsl.2573	Kan	2022	USA	California, Pennsylvania	ADULT: use or health		DUI	pre and post measurements with external control	longitudinal w/ control	Orange County California; Philadelphia, Pennsylvania	12-17 years	male	no	decrease	Then, results indicated that there was a significant site by time interaction (X 2 = 4.600, p = 0.032).
10.1002/bsl.2573	Kan	2022	USA	California, Pennsylvania	ADULT: use or health		frequency	pre and post measurements with external control	longitudinal w/ control	Orange County California; Philadelphia, Pennsylvania	mean age post legalization: 22 years	male	no	decrease	In this analysis, there was a significant site by time interaction (X 2 = 36.65, p < 0.001) and specific contrasts were probed. These post-hoc analyses indicated that there was a significant increase in cannabis use from pre-legalization to post-legalization in California (b = 0.588, p < 0.001) and Pennsylvania (b = 1.299, p < 0.001), but the increase was greater in Pennsylvania (Figure 3)
10.1111/add.13906	Kerr	2017	USA	Oregon vs control states	ADULT: use or health		use	pre and post measurements with external control	DID	7 colleges	18-26 years	male, female, transgender/other	yes	no change	In the analysis of combined data, the positive association between RML and 30-day marijuana use was not statistically significant (OR=1.21, p=0.48) in the presence of a significant time effect (OR=1.42, p=0.0026), indicating an increasing secular trend of marijuana use.
10.15288/jsad.2018.79.495	Kerr	2018	USA	Washington	ADULT: use or health		use	pre and post measurements without external control	pre/post	Washington	≥18 years	all sexes	yes	no change	1.2%, [95% CI]
10.15288/jsad.2018.79.495	Kerr	2018	USA	Washington	ADULT: use or health		frequency	pre and post measurements without external control	pre/post	Washington	≥18 years	all sexes	yes	no change	0.9%, [95% CI]
10.1037/adb0000385	Kerr	2018	USA	Oregon vs control states	ADULT: use or health		use	pre and post measurements with external control	DID	university in Washington	18–26	all sexes	no	increase	RML predicting 30-day Marijuana Use: aOR 1.29; CI: 1.13 - 1.48; p=.0002
10.1037/adb0000385	Kerr	2018	USA	Oregon vs control states	ADULT: use or health		frequency	pre and post measurements with external control	DID	university in Washington	18–26	all sexes	no	increase	significant, positive association between RML and frequency of marijuana use (OR 1.25, p .0008),
10.1016/j.drugalcdep.2020.108364	Kim	2021	USA	nationwide (AK, CA, CO, DC, MA, ME, MI, NV, OR, VT, WA vs control)	ADULT: use or health		use	pre and post measurements with external control	DID	national	12+	male, female	yes	no change	The association between RML enactment and past-month use of cannabis only was not significant overall (aOR = 1.131, 95% CI: 0.968–1.320), (..)
10.1016/j.drugalcdep.2020.108364	Kim	2021	USA	nationwide (AK, CA, CO, DC, MA, ME, MI, NV, OR, VT, WA vs control)	ADULT: use or health		use	pre and post measurements with external control	DID	national	12+	male, female	yes	increase	Overall, RML enactment was associated with increased past-month cannabis-alcohol poly use (aOR = 1.246, 95% CI: 1.140–1.362).
10.1080/15563650.2022.2099887	Klein	2022	USA	nationwide	ADULT: use or health		other (poisoning of synthetic cannabinoids)	pre and post measurements with external control	ITS	nationwide	all ages	all sexes	yes	decrease	Association between annual synthetic cannabinoid exposures and policy, all US states, 2016–2019. States with permissive state cannabis policy (Ref: restrictive): IRR 0.63; 95% CI: 0.50–0.79; p<0.001
10.1111/add.14536	Lane	2019	USA	Colorado, Washington, Oregon	ADULT: use or health		traffic	pre and post measurements without external control	ITS	Colorado, Washington, Oregon vs. nine neighbouring jurisdictions (control)	all ages	all sexes	yes	increase	Pooled results for legalizing states: Step change (95% CI) 0.90 (0.43 to 1.37); p< 0.001. Trend change (95% CI) -0.05 (-0.08 to -0.01) p=0.007
10.1097/MPA.0000000000001830	Lara	2021	USA	Colorado and Washington vs. Florida and Arizona	ADULT: use or health		use	pre and post measurements with external control	DID	All adult patients hospitalized in Arizona, Florida, Colorado, or Washington during 2011 or 2015	18+	all sexes	yes	increase	increased significantly in all states from 2011 to 2015, 2.2 times in the legalized states compared with 1.83 times in the non-legalized states. The percentage of subjects who used cannabis before legalization in 2011 was clinically similar between Colo/Wash and Ariz/Fla, 1.62% and 1.41%, respectively. However, after cannabis legalization in 2015, the number of users was significantly higher in Colo/Wash (3.58%) than in Ariz/Fla (2.48%) (P < 0.001).
10.1016/j.jth.2018.05.017	Lee	2018	USA	16 states	ADULT: use or health		traffic	pre and post measurements with external control	DID	nationwide	all ages	all sexes	yes	increase	Medical Legalization to full legalization - CMF (crash increase or reduction percentage) 1.312 (+31.2%), SE 0.120, p = .010; De-criminalization & Medical Legalization to full legalization - CMF (crash increase or reduction percentage) 1.631 (+63.1%), SE 0.131, p <.001
10.1016/j.amjmed.2018.11.002	Lo	2019	USA	Washington	ADULT: use or health		use	pre and post measurements without external control	pre/post	two large academic medical centers in Seattle, WA, high risk patients	median 49	all sexes	no	increase	pre-legalization period THC positivity: 30% Post-legalization THC positivity: 36% (p=0.0003)
10.1001/jamanetworkopen.2021.27002	Martins	2021	USA	nationwide	ADULT: use or health		use	pre and post measurements with external control	DID	annual households, noninstitutionalized population aged 12 and older	>20 years old	all sexes	yes	increase	After vs before RCL, aOR (95%CI) Non-Hispanic Black: 1.13 (0.93-1.39) Hispanic: 1.43 (1.22-1.69) [Past-year cannabis use e-value: aOR, 1.68; lower limit 95% CI, 1.44] Other:.1.43 (1.20-1.70) [Past-month cannabis use e-value: aOR, 1.68; lower limit 95% CI, 1.42] Non-Hispanic White: 1.24 (1.13-1.35) [Past-month cannabis use e-value: aOR, 1.47; lower limit 95% CI, 1.32]
10.1001/jamanetworkopen.2021.27002	Martins	2021	USA	nationwide	ADULT: use or health		frequency	pre and post measurements with external control	DID	annual households, noninstitutionalized population aged 12 and older	>20 years old	all sexes	yes	no change	After vs before RCL, aOR (95%CI) Non-Hispanic Black: 1.15 (0.79-1.66) Hispanic: 1.16 (0.85-1.56) Other: 1.08 (0.79-1.49) Non-Hispanic White: 1.02 (0.87-1.19)

10.1001/jamanetworkopen.2021.27002	Martins	2021	USA	nationwide	ADULT: use or health		CUD (survey)	pre and post measurements with external control	DID	annual households, noninstitutionalized population aged 12 and older	>20 years old	all sexes	yes	no change	After vs before RCL, aOR (95%CI) Non-Hispanic Black: 1.00 (0.70-1.44) Hispanic: 1.16 (0.88-1.52) Other: 1.45 (1.07-1.95) [Past-year DSM-5 cannabis use disorder e-value: aOR, 1.69; lower limit 95% CI, 1.22] Non-Hispanic White: 0.92 (0.79-1.07)
10.1001/jamanetworkopen.2021.1955	Matthay	2021	USA	Alaska, Colorado, Nevada, Oregon, Washington vs control states	ADULT: use or health		self-harm	pre and post measurements with external control	DID	health care registry data	15+	all sexes	yes	no change	self-harm, recreational dispensaries: aRR, 1.15; 95%CI, 0.89-1.50
10.1001/jamanetworkopen.2021.1955	Matthay	2021	USA	Alaska, Colorado, Nevada, Oregon, Washington vs control states	ADULT: use or health		other (assault)	pre and post measurements with external control	DID	health care registry data	15+	all sexes	yes	no change	assault, recreational dispensaries: adjusted rate ratio [aRR], 1.27; 95%CI, 0.79-2.03
10.1001/jamanetworkopen.2021.1955	Matthay	2021	USA	Alaska, Colorado, Nevada, Oregon, Washington vs control states	ADULT: use or health	THC-related dosage restrictions	self-harm	pre and post measurements with external control	DID	health care registry data	15+	all sexes	yes	no change	THC dose restrictions: eFigure 4: no impact
10.1001/jamanetworkopen.2021.1955	Matthay	2021	USA	Alaska, Colorado, Nevada, Oregon, Washington vs control states	ADULT: use or health	THC-related dosage restrictions	other (assault)	pre and post measurements with external control	DID	health care registry data	15+	all sexes	yes	no change	THC dose restrictions: eFigure 4: no impact
10.1016/j.addbeh.2022.107552	Mennis	2023	USA	nationwide	ADULT: use or health		use	pre and post measurements with external control	DID	nationwide, USA	18-25 years	all sexes	yes	increase	0.034 (p <0.0005) [0.026, 0.041]; CI 95%
10.1016/j.addbeh.2022.107552	Mennis	2023	USA	nationwide	ADULT: use or health		CUD (healthcare)	pre and post measurements with external control	DID	nationwide, USA	18-25 years	all sexes	yes	no change	−0.624 (p =0.562) [−2.738, 1.490]; CI 95%
10.1016/j.ssmph.2017.08.001	Miller	2017	USA	Washington	ADULT: use or health		use	pre and post measurements with external control	DID	college	mean age 20.5 (2.9) (age starts probably from 19+)	all sexes	no	increase	Controlling for a predicted increase of about 1.2 percentage points each year, we find that marijuana use among WSU students increased between 2.0 and 3.5 percentage points (or 12– 22 percent) after RML and remained higher through 2015. Each estimate across specification is statistically different from zero with at least 95-percent confidence.
10.1016/j.ssmph.2017.08.001	Miller	2017	USA	Washington	ADULT: use or health		frequency	pre and post measurements with external control	DID	college	mean age 20.5 (2.9) (age starts probably from 19+)	all sexes	no	increase	In 2014, we find an increase of about 0.5 days in the past 30 days (40 percent over the pre-2014 average) above a linear trend of between 0.13 and 0.16 days per year
10.1111/1556-4029.15047	Neiswenter	2022	USA	Nevada	ADULT: use or health		use	pre and post measurements without external control	pre/post	n/a	n/a	male, female, unknown	no	increase	In contrast, the proportion of Δ9THC was significantly different between 2015–2016 compared to 2017–2019 with roughly 2% more subjects testing positive after legalization of marijuana (p < 0.001). before: 8.60%, after: 10.7%
10.14309/ajg.0000000000001182	Nemer	2021	USA	Colorado and Washington	ADULT: use or health		CUD (healthcare)	pre and post measurements without external control	pre/post	inpatient setting	18+	all sexes	yes	increase	2.2 times increase in legalized states compared with 1.8 times in non-legalized states. In 2011, there were 12,123 cannabis users in CO/WA and 36,591 in AZ/FL, which increased to 26,833 in CO/WA and 66,845 in AZ/FL, respectively (P< 0.001 for both).
10.14309/ajg.0000000000001182	Nemer	2021	USA	Colorado and Washington	ADULT: use or health		hyperemesis	pre and post measurements with external control	DID	inpatient setting	18+	all sexes	yes	no change	There was no significant interaction between state and period (P 5 0.108), implying that the trend in hyperemesis admissions was not different in states that legalized and states that did not legalize cannabis. However, irrespective of the period, patients in CO and WA had significantly higher odds of presentation with hyperemesis compared with those of patients in AZ and FL (OR 1.28, 95% CI 1.23, 1.33, P , 0.001)
10.1016/j.drugpo.2018.03.011	Parnes	2018	USA	Colorado	ADULT: use or health		use	pre and post measurements without external control	pre/post	college	18-58 years	all sexes	no	no change	However, pre- or post-legalization status did not predict differences in past 30-day use (pre- M=12.00, SD=44.47; post- M=11.21, SD=26.91).
10.1093/crocol/otac015	Pusateri	2022	USA	Colorado, Washington	ADULT: use or health		use	pre and post measurements without external control	pre/post	inpatient community hospitals	18+	male, female	no	increase	Of these, 107 (1.22%) were cannabis users in 2011 and 413 (4.21%) in 2015 (P < .001).
10.1111/eip.13153	Ristanovic	2022	USA	Colorado	ADULT: use or health		use	pre and post measurements without external control	pre/post	youth-parent dyads recruited at the Adolescent Development and Preventive Treatment Programat the University of Colorado Boulder	Mean years (SD) clinical high-risk (CHR): 18.34 (1.99) healthy controls (HC): 17.47 (2.84)	all sexes	no	no change	Pre-legalization, CHR and HC groups significantly differed in cannabis use (χ2 [1,N=52]=5.44, p=.02). Post-legalization, the difference was not significant (χ2 [1,N=35]=.96, p=.33). Non-significant decline was observed in the CHR group (χ2 [1,N=44]=.53 ,p=.47) and a non-significant increase in the HC group (χ2 [1,N=43]=.11,p=.73).
10.1080/15563650.2021.2006212	Roth	2022	USA	California	ADULT: use or health		poisoning	pre and post measurements without external control	ITS	Poison Control Center	>=13	males and females	yes	no change	age-stratified results only reported in text
http://www.nber.org/papers/w29038	Sabia	2022	USA	nationwide	ADULT: use or health		violent crime	pre and post measurements with external control	DID	national	18-20 years	male, female	yes	no change	Our findings show no evidence of significant increases in violent, property, or total arrests for either those under or over age 21 or for males or females
http://www.nber.org/papers/w29038	Sabia	2022	USA	nationwide	ADULT: use or health		violent crime	pre and post measurements with external control	DID	national	21+	male, female	yes	no change	Our findings show no evidence of significant increases in violent, property, or total arrests for either those under or over age 21 or for males or females
http://www.nber.org/papers/w29038	Sabia	2022	USA	nationwide	ADULT: use or health		property crime	pre and post measurements with external control	DID	national	18-20 years	male, female	yes	no change	Our findings show no evidence of significant increases in violent, property, or total arrests for either those under or over age 21 or for males or females
http://www.nber.org/papers/w29038	Sabia	2022	USA	nationwide	ADULT: use or health		property crime	pre and post measurements with external control	DID	national	21+	male, female	yes	no change	Our findings show no evidence of significant increases in violent, property, or total arrests for either those under or over age 21 or for males or females

http://www.nber.org/papers/w29038	Sabia	2022	USA	nationwide	ADULT: use or health		use	pre and post measurements with external control	DID	national	18+	all sexes	yes	increase	In our most conservative specification, which includes state-specific linear time trends (column 3), we uncover an RML-induced 1.6 percentage-point increase in marijuana use, an effect that is statistically distinguishable from zero at the 5 percent level
http://www.nber.org/papers/w29038	Sabia	2022	USA	nationwide	ADULT: use or health		CUD (healthcare)	pre and post measurements with external control	DID	national	all ages	all sexes	yes	no change	We do not find any meaningful effects of marijuana legalization on flows into treatment facilities, associated with marijuana, cocaine, amphetamines, opioids or alcohol (Table 8).
10.1001/jamainternmed.2020.1757	Santaella-Tenorio	2020	USA	Colorado vs. control states	ADULT: use or health		traffic	pre and post measurements with external control	synthetic control	traffic	all ages	all sexes	yes	increase	1.46 deaths per 1 billion VM, MSPE: 25.00
10.1001/jamainternmed.2020.1757	Santaella-Tenorio	2020	USA	Washington vs. control states	ADULT: use or health		traffic	pre and post measurements with external control	synthetic control	traffic	all ages	all sexes	yes	no change	
10.1111/add.15019	Shi	2020	USA	nationwide	ADULT: use or health		poisoning	pre and post measurements with external control	DID	Poison Centers	>21	males and females	yes	increase	Coefficient of linear regression (95% CI): 3.83*(0.93, 6.72), Estimated percentage change: 77.40%
10.1037/adb0000508	Stormshak	2019	USA	Oregon	ADULT: use or health		use	pre and post measurements without external control	lagged longitudinal	three Middle Schools in North and Northeast Portland	14-24 years	male, female	yes	increase	Adjusted odds ratios at Wave 2 from the logistic regression models (see Table 2) revealed that PAL 2 participants had 1.78 times the odds of reporting marijuana use than did PAL 1 participants, a significant effect (OR 1.78, 95% CI: 1.35, 2.36, p<.001). Self-reported use at Wave 3 decreased for PAL 1 participants (33%) and increased for PAL 2 participants (51%). Adjusted odds ratios at Wave 3 showed PAL 2 participants had 2.12 times the odds of reporting marijuana use than did PAL 1 participants, a significant effect (OR 2.12, 95% CI: 1.65, 2.72, p<.001). Thus, all patterns of use between Waves 2 and 3 show greater 30-day marijuana use when marijuana use was legal (i.e., for PAL 2) than when marijuana use was illegal (i.e., for PAL 1).
10.1093/aje/kwab184	Tefft	2021	USA	Washington	ADULT: use or health		DUI	pre and post measurements without external control	ITS		unknown	all sexes	yes	increase	PR: 2.3 95% CI: 1.3, 4.1
10.1080/15563650.2021.2012576	Tolan	2022	USA	Massachusetts	ADULT: use or health		poisoning	pre and post measurements without external control	pre/post	hospital ED	all ages	males and females	no	increase	MED DISP to REC DISP (p=.013) at BHW; MED DISP and REC DISP (p=.002) at MGH
10.1080/15563650.2021.2012576	Tolan	2022	USA	Massachusetts	ADULT: use or health		use	pre and post measurements without external control	pre/post	hospital ED	all ages	all sexes	no	increase	p <0.0001 monthly positivity rates for each legalization time period increased from 18.0% in DEC (n=716) to 18.3% in MED BD (n=2327) to 21.4% in MED DISP (n=1629) to 23.2% (n=1220) in REC BD to 25.1% (n=1049) in REC DISP. Similiar increase between hospitals: 22.0% (n=1393) in DEC to 22.6% (n=4706) in MED BD to 24.9% (4875) in MED DISP to 27.4% (n=3947) in REC BD to 29.4% (n=3673) in REC DISP (Figure 1(B)
10.1080/16066359.2019.1622003	Wallace	2020	USA	Colorado	ADULT: use or health		frequency	pre and post measurements without external control	DID	colleges	Colorado: 22.41 (SD 5.44) National: 20.25 (SD 6.13)	all sexes	yes	increase	sign. higher use frequency in 2015 than 2011 sample (Median =1, SD= 1.91; p<0.0001)
10.1080/16066359.2019.1622003	Wallace	2020	USA	Colorado vs nationwide	ADULT: use or health		frequency	pre and post measurements with external control	DID	colleges	Colorado: 22.41 (SD 5.44) National: 20.25 (SD 6.13)	all sexes	yes	no change	no significant difference between Colorado (mean increase between years = 0.08, change in median response = 0, SD= 2.73) and national level (change in median response = 0) between 2013 and 2015 (V= 99084, p=0.19). Effect sizes between the Colorado and national samples were negligible for magnitudes of change between 2011 and 2013 (Cohen's d = 0.03) and between 2013 and 2015 (Cohen's d =0.03). Both national and Colorado use frequency increased between 2011 and 2015, and Colorado use frequencies did not increase faster than nationally.
10.1016/j.ypmed.2017.03.022	Wang	2017	USA	Colorado	ADULT: use or health		poisoning	pre and post measurements without external control	pre/post	Hospitals ED	not specified	not specified	yes	increase	text: The rates of ED visits significantly increased [...] from 2013 to 2014 (p=0.0005);
10.1016/j.ypmed.2017.03.022	Wang	2017	USA	Colorado	ADULT: use or health		poisoning	pre and post measurements without external control	pre/post	Poison Center	not specified	not specified	yes	increase	text: calls significant increased by 79.7%, from 123 to 221 (p<0.0001).
10.1016/j.ypmed.2017.03.022	Wang	2017	USA	Colorado	ADULT: use or health		CUD (healthcare)	pre and post measurements without external control	pre/post	hospital	all ages	all sexes	yes	increase	see text: There was a marginal statistically significant increase in rates from 2013 to 2014 (p=0.006).
10.1136/injuryprev-2019-043360	Wang	2019	USA	Colorado	ADULT: use or health		poisoning	pre and post measurements without external control	pre/post	Colorado Regional Posion Center	not specified (overall)	males and females	yes	increase	11.2 cases/year
10.1016/j.drugpo.2022.103685	Wang	2022	USA	Colorado	ADULT: use or health		psychosis/schizophrenia	pre and post measurements without external control	pre/post	hospitals & healthcare systems in Colorado	all ages	male, female	yes	increase	(...) we do find an overall positive association between the number of recreational dispensaries per 10,000 and the rate of psychosis ED visits (IRR 1.23, CI 1.03, 1.49). The combined IRRs (table 2) reveal that the positive association between recreational dispensaries per capita and rates of psychosis were primarily driven by counties with either a high baseline rate (IRR = 1.238, p-value = 0.028, suggesting a 24% increase in psychosis visits per capita) and counties with no prior baseline exposure (IRR = 1.100, p-value = 0.00, indicating a 10% increase in psychosis visits per capita).

10.1016/j.drugpo.2022.103685	Wang	2022	USA	Colorado	ADULT: use or health		psychosis/schizophrenia	pre and post measurements without external control	pre/post	hospitals & healthcare systems in Colorado	all ages	male, female	yes	no change	While we find no statistical association between the number of recreational dispensaries per 10,000 residents and the rate of schizophrenia cases (IRR 0.95, CI 0.69, 1.30), (...)
10.1111/add.15795	Weinberger	2022	USA	Alaska, California, Colorado, DC, Massachusetts, Maine, Michigan, Nevada, Oregon, Vermont, Washington vs. control states	ADULT: use or health		use	pre and post measurements with external control	DID	Alaska, California, Colorado, DC, Massachusetts, Maine, Michigan, Nevada, Oregon, Vermont, Washington vs. control states	12+	all sexes	yes	increase	RCL aOR (95% CI): 1.206 (1.088, 1.336)
10.1111/add.15795	Weinberger	2022	USA	Alaska, California, Colorado, DC, Massachusetts, Maine, Michigan, Nevada, Oregon, Vermont, Washington vs. control states	ADULT: use or health		use	pre and post measurements with external control	DID	Alaska, California, Colorado, DC, Massachusetts, Maine, Michigan, Nevada, Oregon, Vermont, Washington vs. control states	12+	all sexes	yes	no change	RCL aOR (95% CI): 1.016 (0,955, 1.178)
10.9778/cmajo.20200155	Windle	2021	USA	Alaska, California, Colorado, Massachusetts, Nevada, Oregon, Washington (only states with retail sales period)	ADULT: use or health		traffic	pre and post measurements without external control	ITS	traffic	all ages	all sexes	yes	increase	1.18 (1.06–1.32)
10.9778/cmajo.20200155	Windle	2021	USA	Alaska, California, Colorado, Massachusetts, Nevada, Oregon, Washington (only states with retail sales period)	ADULT: use or health		traffic	pre and post measurements without external control	ITS	traffic	all ages	all sexes	yes	increase	1.18 (1.06–1.32)
https://rex.libraries.wsu.edu/esploro/outputs/doctoral/THE-EFFECTS-OF-CANNABIS-AND-THE/99900581816601842	Woo	2020	USA	Washington	ADULT: use or health		traffic	pre and post measurements without external control	ITS	traffic	all ages	all sexes	yes	increase	b=0.062 (0.483, 1.156)
10.1017/S0033291722003762	Zellers	2023	USA	Colorado vs. control states	ADULT: use or health		frequency	pre and post measurements with external control	twin	community twin samples	24-49	all sexes	no	increase	increase by 0.11 standard deviations S.E. = 0.03, p = 1.3 x 10^−3
10.1017/S0033291722003762	Zellers	2023	USA	Colorado vs. control states	ADULT: use or health		CUD (survey)	pre and post measurements with external control	twin	community twin samples	24-49	all sexes	no	no change	no change
10.1111/add.16016	Zellers	2023	USA	Colorado vs Minnesota	ADULT: use or health		use	pre and post measurements with external control	twin	community twin samples	24-47	all sexes	no	increase	B=0.33, p=.017
10.1111/add.16016	Zellers	2023	USA	Colorado vs Minnesota	ADULT: use or health		frequency	pre and post measurements with external control	twin	community twin samples	24-47	all sexes	no	no change	"When examining the effect of legalization on frequency only in recent users, the individual (B = 0.12, P = 0.258) and within-pair effect of legalization (B = 0.21, P = 0.290) were greatly attenuated. This suggests that the effect of recreational legalization on mean cannabis frequency is driven by more individuals using, rather than by increasing frequency within users."
10.1111/add.14994	Nazif-Munoz	2020	Uruguay	Montevideo and 4 rural provinces/cities?	ADULT: use or health		traffic	pre and post measurements without external control	ITS	Uruguay	all ages	all sexes	yes	increase	For the driver fatality rate the relative change was an increase of 52.4% (95% CI: 11.6, 93.3, p = 0.012) (Table 3).
10.1111/add.15913	Rivera-Aguirre	2022	Uruguay	urban areas	ADULT: use or health		use	pre and post measurements with external control	DID	secondary schools	18-21	male, female	yes	no change	PD -4.6 (95% CI: -10.2, 1.0)
10.1111/add.15913	Rivera-Aguirre	2022	Uruguay	urban areas	ADULT: use or health		risky use	pre and post measurements with external control	DID	secondary schools	18-21	male, female	yes	no change	PD 10.3 (95% CI: -0.3, 20.9)
10.1111/add.15913	Rivera-Aguirre	2022	Uruguay	urban areas	ADULT: use or health		frequency	pre and post measurements with external control	DID	secondary schools	18-21	male, female	yes	no change	PD -2.6 (95% CI: -15.0, 9.8)
10.1097/ADM.0000000000000747	Auger	2021	Canada	Quebec	YOUTH: use or health		CUD (healthcare)	pre and post measurements without external control	pre/post	hospitals in Quebec	15-19	male, female	yes	no change	0.91 (0.75, 1.09)
10.1016/j.jogc.2021.02.119	Bayrampour	2021	Canada	British Colombia	YOUTH: use or health		use during pregnancy	pre and post measurements without external control	pre/post	any pregnant person ≥19 years old at any gestational age residing in British Columbia	Age, mean (SD), years: pre-legalization sample 31.7 (4.2), post-legalization 31.9 (4.1)	female	no	no change	Although cannabis use during pregnancy increased from 3.64% (95% CI 2.32% -5.69%) to 4.62% (95% CI 2.82% -7.47%) after legalization, the difference was not statistically significant. Legalization was not associated with a significant change in the odds of cannabis use during pregnancy (aOR 1.66; 95% CI 0.75–3.65) after adjsting for pre-pregnancy–related risk factors, including maternal age, ethnicity, income, education, relationship status, and history of any mental health disorder. Also adjusted for confounders during pregnancy, including gravidity, unplanned pregnancy, pregnancy complications, antenatal anxiety symptoms, and antenatal depressive symptoms.
10.1016/j.drugalcdep.2021.109008	Callaghan	2021	Canada	Alberta and Ontario	YOUTH: use or health		traffic	pre and post measurements without external control	ITS	EDs	Alberta: 14-17; Ontario: 16-18	male, female	yes	no change	see Table 1: no significant change according to intervention parameters

10.1080/15563650.2021.1939881	Cohen	2022	Canada	Ontario	YOUTH: use or health		poisoning	pre and post measurements without external control	pre/post	hospital/emergency room	0-18 years	males and females	no	no change	2.1 vs 1.7
10.1016/j.jogc.2022.03.014	Drabkin	2022	Canada	Ontario	YOUTH: use or health		use during pregnancy	pre and post measurements without external control	pre/post	hospital in Ontario	30.7 ± 5.4 years	female	no	no change	Urine drug screen: no significant difference; 7/74 (9.5%) and 8/75 (10.7%) patients tested positive for cannabis in the prelegalization and postlegalization (P¼ samples, respectively 0.99).
10.1016/j.drugalcdep.2020.108505	Hammond	2021	Canada	nationwide	YOUTH: use or health		use	pre and post measurements without external control	pre/post	online youth sample	16-19 years	all sexes	yes	increase	change 2017 - 2019: past 12 months: AOR 1.28, 95 % CI 1.15–1.43; p < 0.0001
10.1016/j.drugalcdep.2020.108505	Hammond	2021	Canada	nationwide	YOUTH: use or health		use	pre and post measurements without external control	pre/post	online youth sample	16-19 years	all sexes	yes	increase	change 2017 - 2019: past 30 days: AOR 1.48, 95 % CI 1.29–1.69; p < 0.0001
10.1016/j.drugalcdep.2020.108505	Hammond	2021	Canada	nationwide	YOUTH: use or health		frequency	pre and post measurements without external control	pre/post	online youth sample	16-19 years	all sexes	yes	increase	change 2017 - 2019: daily use: AOR 2.49, 95 % CI 1.81–3.41; p < 0.0001
10.1001/jamahealthforum.2022.5041	Myran	2023	Canada	Ontario, Quebec, Alberta, British Columbia	YOUTH: use or health		poisoning	pre and post measurements without external control	ITS	hospital	0-9	males and females	yes	increase	2.71 (2.06-3.55)
10.1001/jamahealthforum.2022.5041	Myran	2023	Canada	Ontario, Quebec, Alberta, British Columbia	YOUTH: use or health	allowing edible sales	poisoning	pre and post measurements with external control	DID	hospital	0-9	males and females	yes	increase	increase in provinces legalizing edibles, not in control province: exposed: 2.16 (1.68-2.80), control: 1.18 (0.71-1.97)
10.1001/jamanetworkopen.2022.17648	Nguyen	2022	Canada	Quebec and control provinces	YOUTH: use or health	minimum legal age	use	pre and post measurements with external control	DID	Quebec and control provinces	15-20	all sexes	yes	decrease	95% CI: -6.1 (-12.1 to -0.1)
10.1016/j.jadohealth.2022.09.003	Nguyen	2023	Canada	nationwide	YOUTH: use or health		use	pre and post measurements without external control	ITS	nationwide, Canada	15-18	all sexes	yes	no change	Past 12-month cannabis use prevalence: Change after legalization (95% CI): 0.3 pp (-1.5-2.0); p=.76
10.1016/j.jadohealth.2022.09.003	Nguyen	2023	Canada	nationwide	YOUTH: use or health		initiation	pre and post measurements without external control	ITS	nationwide, Canada	15-18	all sexes	yes	increase	Past 12-month cannabis initiation rate: Change after legalization (95% CI): 2.7 percentage points (pp) (1.7-3.7), p<.02
10.1016/j.jadohealth.2022.09.003	Nguyen	2023	Canada	nationwide	YOUTH: use or health		perceived availability	pre and post measurements without external control	ITS	nationwide, Canada	15-18	all sexes	yes	increase	Ease of accessing cannabis 7.7 pp (5.3-10.0); p<.01
10.25318/82-003-x202000200002-eng	Roterman	2020	Canada	nationwide	YOUTH: use or health		use	pre and post measurements without external control	pre/post	national	15-17	all sexes	yes	decrease	before: 19.8%, after 10.4%, significantly different from reference category or Rest of Canada for provincial comparisons (e.g., Ontario compared with other nine provinces combined)(p<0.05)
10.1177/0706743720984684	Vignault	2021	Canada	Quebec	YOUTH: use or health		use	pre and post measurements without external control	pre/post	hospital Centre hospitalier universitaire de Sherbrooke (CHUS)	12-17	all sexes	no	no change	trend toward an increasing active use of cannabis from 17.9% to 25.5% (p = 0.40)
10.1177/0706743720984684	Vignault	2021	Canada	Quebec	YOUTH: use or health		CUD (healthcare)	pre and post measurements without external control	pre/post	hospital Centre hospitalier universitaire de Sherbrooke (CHUS)	12-17	all sexes	no	no change	number of SUDs involving cannabis (mixed or not) increased from 4.8% to 12.8% (p = 0.20)
10.1017/cem.2020.384	Yeung	2020	Canada	Alberta	YOUTH: use or health		poisoning	pre and post measurements without external control	pre/post	Urban hospital ED	0-14 years	males and females	no	increase	40% increase post legalization (Table 3)
10.1542/peds.2020-045922	Yeung	2021	Canada	Alberta	YOUTH: use or health		poisoning	pre and post measurements without external control	ITS	hospital ED	0-17 years	males and females	no	no change	IRR=1.01, 95% CI: 0.92 to 1.10
10.1016/j.pmedr.2021.101351	Zuckermann	2021	Canada	Alberta, BC, ON, Quebec,	YOUTH: use or health		use	pre and post measurements without external control	lagged longitudinal	high school	~14-18 years	all sexes	no	no change	Current use vs ever- and never-use, Cohort 3 (Grade 9 (ref)), AOR (95% CI): Grade 10: 1.51 (0.97, 2.37) p=0.0682 Grade 11: 1.34 (0.85, 2.11) p=0.2039 Grade 12: 1.44 (0.91, 2.28) p=0.1188
10.1016/j.pmedr.2021.101351	Zuckermann	2021	Canada	Alberta, BC, ON, Quebec,	YOUTH: use or health		frequency	pre and post measurements without external control	lagged longitudinal	high school	~14-18 years	all sexes	no	no change	Regular use vs occasional use, Cohort 3 (Grade 9 (ref)), AOR (95% CI): Grade 10: 1.68 (0.81, 3.50) p=0.1655 Grade 11: 1.51 (0.74, 3.09) p=0.2541 Grade 12: 1.60 (0.79, 3.26) p=0.1946
10.1016/j.amepre.2020.04.008	Bailey	2020	USA	Washington, Oregon	YOUTH: use or health		use	pre and post measurements without external control	pre/post	Seattle area elementary schools	10-20 years	male, female	yes	increase	nonmedical marijuana legalization predicted a higher likelihood of self-reported past-year marijuana (AOR=6.85, p=0.001)
10.1016/j.amepre.2022.09.019	Bailey	2022	USA	Oregon and Washington vs. New York	YOUTH: use or health		use	pre and post measurements with external control	longitudinal w/ control	children of men in the longitudinal Oregon Youth Study (OYS)	13-18	all sexes	yes	no change	SE= 0.358 (0.493) Standardized estimate b(stdY) (SE)=0.151 (0.210) p= 0.470
10.1016/j.amepre.2022.09.019	Bailey	2022	USA	Oregon and Washington vs. New York	YOUTH: use or health		frequency	pre and post measurements with external control	longitudinal w/ control	children of men in the longitudinal Oregon Youth Study (OYS)	13-18	all sexes	yes	no change	SE= 0.306 (0.472) Standardized estimate b(stdY) (SE)= 0.128 (0.199) p= 0.519

10.1016/j.jadohealth.2020.03.039	Barker	2021	USA	Washington, Wisconsin	YOUTH: use or health		use	pre and post measurements with external control	DID	University (college?)	17-19 years	all sexes	no	increase	Among participants who had ever used marijuana ..., the proportion that reported using in the last 28 days rose significantly faster in Washington after RML than it did in Wisconsin. This occurred, despite the fact that the proportion of ever users reporting use in the last 28 days was similar in both states at all time points. Difference in immediate effect at the time of legalization between WA versus WI Coefficient: -1.4 .p= 002. Difference between pre- and post-legalization slopes in WA versus WI ,i.e., difference in differences of the slopes: Coefficinet 11.5; p<.001
10.1016/j.acap.2021.07.018	Bennett	2022	USA	nationwide	YOUTH: use or health		poisoning	pre and post measurements with external control	DID	52 Childrens' hospitals	<6	males and females	no	no change	1.26 (0.85-1.87, p=.24)
10.1177/1178221818815491	Blevins	2018	USA	Washington	YOUTH: use or health		use	pre and post measurements without external control	pre/post	six seattle high schools	12-17 years	not specified	no	no change	(pre-/post policy mean, std): 36.71 (15.89) vs. 36.05 (14.83)
10.1177/1178221818815491	Blevins	2018	USA	Washington	YOUTH: use or health		CUD (survey)	pre and post measurements without external control	pre/post	six seattle high schools	12-17 years	not specified	no	increase	cannabis symptoms (pre-/post policy mean, std): 3.08(2.47) vs 4.42(2.64)**
10.1177/1178221818815491	Blevins	2018	USA	Washington	YOUTH: use or health		CUD (survey)	pre and post measurements without external control	pre/post	six seattle high schools	12-17 years	not specified	no	increase	cannabis problems (pre-/post policy mean, std): 1.50 (.37) vs. 1.70 (.47)**
10.1007/s11121-018-0933-2	Brooks-Russel	2018	USA	Colorado	YOUTH: use or health		use	pre and post measurements without external control	pre/post	high school	~14-18 years	all sexes	yes	no change	2013 % (95%): 20.9 (19.8–22.0) 2015 % (95%): 21.2 (19.8–22.7) The Rao-Scott X^2: 0.07 p=0.79
10.1007/s11121-018-0933-2	Brooks-Russel	2018	USA	Colorado	YOUTH: use or health		frequency	pre and post measurements without external control	pre/post	high school	~14-18 years	all sexes	yes	decrease	2013 % (95%): 33.2 (30.8–35.5) 2015 % (95%): 26.8 (24.0–29.5) The Rao-Scott X^2: 8.46 p<0.01
10.1001/jamapediatrics.2016.3624	Cerda	2017	USA	Colorado vs. control states	YOUTH: use or health		use	pre and post measurements with external control	DID	students	8th/10th grade	all sexes	yes	no change	Difference-in-difference Colorado vs non-RML: grade 8: 1.3 (3.3); p=.72 and grade 10: -2.6 (2.4); p=.30
10.1001/jamapediatrics.2016.3624	Cerda	2017	USA	Washington vs. control states	YOUTH: use or health		use	pre and post measurements with external control	DID	students	8th/10th grade	all sexes	yes	increase	Difference-in-difference Washington vs non-RML: grade 8: 3.2 (1.5); p=.03 and grade 10: 5.0 (1.9); p=.01
10.1001/jamapediatrics.2016.3624	Cerda	2017	USA	Colorado & Washington vs. control states	YOUTH: use or health		use	pre and post measurements with external control	DID	students	12th grade	all sexes	yes	no change	Grade 12, Difference-in-difference (vs non-RML): Colorado -1.7 (3.0); p=.57; Washington 0.8 (2.8); p=.79
10.1001/jamapsychiatry.2019.3254	Cerda	2020	USA	Colorado,Washington, Alaska, Oregon and control states	YOUTH: use or health		use	pre and post measurements with external control	DID	statewide computer-assisted self-interviews	12-17 years	male, female	yes	no change	Among the 12- to 17-year-old respondents, the prevalence of past-month marijuana use (...) did not change in the overall sample (...).
10.1001/jamapsychiatry.2019.3254	Cerda	2020	USA	Colorado,Washington, Alaska, Oregon and control states	YOUTH: use or health		frequency	pre and post measurements with external control	DID	statewide computer-assisted self-interviews	12-17 years	male, female	yes	no change	Among the 12- to 17-year-old respondents, the prevalence of (...) past-month frequent use following state RML enactment did not change in the overall sample (...)
10.1001/jamapsychiatry.2019.3254	Cerda	2020	USA	Colorado,Washington, Alaska, Oregon and control states	YOUTH: use or health		CUD (survey)	pre and post measurements with external control	DID	statewide computer-assisted self-interviews	12-17 years	male, female	yes	increase	However, after RML enactment, past-year CUD prevalence increased slightly among all 12- to 17-year-old respondents (2.18% to 2.72%; OR, 1.25; 95% CI, 1.01-1.55). This increase was 25% higher than that for participants in the same age group in states with no RML enactment. Among the past-year users, CUD increased from 22.80% to 27.20% (OR, 1.27; 95% CI, 1.01-1.59).
10.1016/j.jadohealth.2020.10.019	Coley	2021	USA	Alaska, California, Colorado, Massachusetts, Maine, Nevada vs. control states	YOUTH: use or health		use	pre and post measurements with external control	DID	school	11-17	all sexes	yes	no change	OR (95% CI)= 1.037 (0.803 - 1.340)
10.1016/j.jadohealth.2020.10.019	Coley	2021	USA	Alaska, California, Colorado, Massachusetts, Maine, Nevada vs. control states	YOUTH: use or health		frequency	pre and post measurements with external control	DID	school	11-17	all sexes	yes	decrease	OR (95% CI)= 0.844 (0.720 - 0.989); p ≤ 0.05
10.1080/10826084.2016.1200623	Estoup	2016	USA	Washington	YOUTH: use or health		CUD (survey)	pre and post measurements without external control	pre/post	high schools in greater Seattle area	13-19	male, female	no	increase	B=32.81, p<.001, 95% CI: 19.23, 46.40; pre legalisation: mean 49.47 p<.01; post legalization: mean 80.17 p<.01
10.1080/10826084.2016.1200623	Estoup	2016	USA	Washington	YOUTH: use or health		frequency	pre and post measurements without external control	pre/post	high schools in greater Seattle area	13-19	male, female	no	no change	pre: mean 13.00; post: mean:13.36
10.1080/10826084.2020.1858104	Garcia-Ramirez	2021	USA	Oregon	YOUTH: use or health		use	pre and post measurements without external control	pre/post	High school (11th grade)	16-17 years	all sexes	yes	no change	2018 vs. pre-legalization (OR (95% CI)): 0.92 (0.67, 1.26)
10.1080/10826084.2020.1858104	Garcia-Ramirez	2021	USA	Oregon	YOUTH: use or health		perceived availability	pre and post measurements without external control	pre/post	High school (11th grade)	16-17 years	all sexes	yes	increase	Perceived availability of marijuana B (SEb): -0.12 (p≤0.05)
10.1007/s11606-022-07948-w	Goncalves	2022	USA	nationwide	YOUTH: use or health		use	pre and post measurements without external control	ITS	households	12-20	male, female	yes	no change	0.90 (0.79, 1.04)
10.1016/j.amjsurg.2019.08.020	Grigorian	2019	USA	California	YOUTH: use or health		use	pre and post measurements without external control	pre/post	level-1 adult, level-2 pediatric trauma center	16-18 years	male, female	no	no change	The incidence of marijuana-positive patients in the pre-legalization cohort (n=119) was 39.3% and 46.4% in the post-legalization cohort (n=39) (p =0.24).
10.1111/add.15895	Gunadi	2022	USA	California, Massachusetts, Nevada and Maine vs. control states	YOUTH: use or health		initiation	pre and post measurements with external control	longitudinal w/ control	interviews within the PATH study	12-21 years	male, female	yes	no change	Figure 3: OR 1.07 (not significant)

10.1111/add.15895	Gunadi	2022	USA	California, Massachusetts, Nevada and Maine vs. control states	YOUTH: use or health		frequency	pre and post measurements with external control	longitudinal w/ control	interviews within the PATH study	12-21 years	male, female	yes	no change	Figure 3: OR 0.89 (non significant)
10.1080/10826084.2017.1334069	Harpin	2018	USA	Colorado	YOUTH: use or health		use	pre and post measurements without external control	pre/post	middle and high school	~11-18 (6th to 12th grade)	all sexes	yes	no change	2013: 23.8% 2014: 24.0% p=0.80
10.1080/10826084.2017.1334069	Harpin	2018	USA	Colorado	YOUTH: use or health		perceived availability	pre and post measurements without external control	pre/post	middle and high school	~11-18 (6th to 12th grade)	all sexes	yes	increase	2013: 46.5% 2014: 52.1% p<0.0001 2014, post-retail stores opening: OR= 1.21 95% CI= 1.09 – 1.34
10.7759/cureus.23493	Harvey	2022	USA	California	YOUTH: use or health		poisoning	pre and post measurements without external control	pre/post	Hospital ED	<18	males and females	no	increase	71% of cases presented after legislation
10.1086/721267	Hollingsworth	2022	USA	nationwide, all states	YOUTH: use or health		use	pre and post measurements with external control	DID	online-based survey	12-17	all sexes	yes	increase	Table 2: 10.11 (p < 0.01)
10.1086/721267	Hollingsworth	2022	USA	nationwide, all states	YOUTH: use or health		use	pre and post measurements with external control	DID	online-based survey	12-17	all sexes	yes	increase	Table 2: 14.79 (p < 0.01)
10.1086/721267	Hollingsworth	2022	USA	nationwide, all states	YOUTH: use or health		initiation	pre and post measurements with external control	DID	online-based survey	12-17	all sexes	yes	increase	Table 2: 14.04 (p < 0.01)
10.1007/s11121-022-01475-0	Kerr	2022	USA	Oregon and Washington	YOUTH: use or health		use	pre and post measurements without external control	pre/post	Oregon and Washington	13-20	all sexes	no	no change	adolescents were not significantly more likely to use cannabis at assessments occurring when RCL was in effect than they were when it was not (OR (95% CI) = 2.48 [0.95–6.47])
10.1177/10105395211044917	Lee	2022	USA	Alaska vs. Hawaii	YOUTH: use or health		use	pre and post measurements with external control	DID	Alaska, Hawaii	Hawaii: 15.84 (SD = 1.22) Alaska: 16.05 (SD = 1.25)	all sexes	yes	increase	1.33 (1.11-1.61), p<0.01
10.1177/10105395211044917	Lee	2022	USA	Alaska vs. Hawaii	YOUTH: use or health		initiation	pre and post measurements with external control	DID	Alaska, Hawaii	Hawaii: 15.84 (SD = 1.22) Alaska: 16.05 (SD = 1.25)	all sexes	yes	increase	1.29 (1.10-1.51), p<0.01
10.1080/14767058.2020.1765157	Lee	2022	USA	California	YOUTH: use or health		use during pregnancy	pre and post measurements without external control	pre/post	referral clinic serving a patient population with public insurance; pregnant		female	no	increase	6 to 11% (p= 0.05)
10.1038/s41372-019-0416-8	Lockwood	2019	USA	Colorado	YOUTH: use or health		birth outcomes	pre and post measurements without external control	ITS	hospital, only singleton births to mothers with residence in the state of Colorado	0 years	female	yes	decrease	Difference in the intercepts pre-/post-legalization indicating an immediate effect (risk of SGA birth at the start of the post-legalization: 7% less than that at the end of the pre-legalization cohort (p=0.04)). (Effect estimate (95% CI): 0.93 (0.87, 0.998) p=0.04)
10.1001/jamanetworkopen.2021.27002	Martins	2021	USA	nationwide	YOUTH: use or health		use	pre and post measurements with external control	DID	annual households, noninstitutionalized population aged 12 and older	12-20 years	all sexes	yes	no change	After vs before RCL, aOR (95%CI) Non-Hispanic Black: 0.97 (0.69-1.35) Hispanic: 1.10 (0.85-1.39) Other: 1.09 (0.81-1.47) Non-Hispanic White: 0.95 (0.82-1.11)
10.1001/jamanetworkopen.2021.27002	Martins	2021	USA	nationwide	YOUTH: use or health		frequency	pre and post measurements with external control	DID	annual households, noninstitutionalized population aged 12 and older	12-20 years	all sexes	yes	no change	After vs before RCL, aOR (95%CI) Non-Hispanic Black: 1.01 (0.51-2.02) Hispanic: 1.22 (0.77-1.92) Other: 0.95 (0.54-1.67) Non-Hispanic White: 0.87 (0.65-1.16)
10.1001/jamanetworkopen.2021.27002	Martins	2021	USA	nationwide	YOUTH: use or health		CUD (survey)	pre and post measurements with external control	DID	annual households, noninstitutionalized population aged 12 and older	12-20 years	all sexes	yes	no change	After vs before RCL, aOR (95%CI) Non-Hispanic Black: 0.87 (0.48-1.56) Hispanic: 1.16 (0.79-1.70) Other: 1.47 (0.90-2.41) Non-Hispanic White: 0.93 (0.73-1.20)
10.1080/08897077.2015.1071723	Mason	2016	USA	Washington	YOUTH: use or health		use	pre and post measurements without external control	pre/post	three middle schools in Tacoma, Washington	mean age 13.37 (0.51)	male, female	no	no change	adjusted OR 2.80, 95% CI: 0.94-8.34)
10.1016/j.jadohealth.2021.07.028	Masonbrink	2021	USA	California, Colorado, DC, Massachusetts, Washington vs. control states	YOUTH: use or health		hyperemesis	pre and post measurements without external control	pre/post	tertiary care children's hospitals across 33 states + Washington D.C.	11-17 years	all sexes	yes	increase	There was also an increase in adolescent hospitalizations with a diagnosis of cannabinoid hyperemesis, with states [...] with NMCLs increasing from 124 (.0%) prepolicy to 179 (.1%) postpolicy (p-value<.001 for both).
10.1016/j.jadohealth.2021.07.028	Masonbrink	2021	USA	California, Colorado, DC, Massachusetts, Washington vs. control states	YOUTH: use or health		CUD (healthcare)	pre and post measurements with external control	DID	tertiary care children's hospitals across 33 states + Washington D.C.	11-17 years	male, female	yes	increase	In states with NMCLs, the odds of a cannabis-related hospitalization pre-NMCL policy change increased 5.3% every year (OR 1.053, 95% CI 1.021e1.085, p 1< .001), and post-NMCL policy change increased 15.2% every year (OR 1.152, 95% CI 1.105e1.200, p < .001).
10.1016/j.jhealeco.2021.102537	Meinhofer	2021	USA	Alaska, Colorado, DC, Maine, Massachusets, Nevada, Oregon, Vermont, Washington vs. control states	YOUTH: use or health		use during pregnancy	pre and post measurements with external control	DID	hospitals in the US	15-44 years	all sexes	yes	increase	Table 2: DID(m) estimate of RML: +0.003 (.001)

10.1016/j.jhealeco.2021.102537	Meinhofer	2021	USA	Alaska, Colorado, DC, Maine, Massachusets, Nevada, Oregon, Vermont, Washington vs. control states	YOUTH: use or health		birth outcomes	pre and post measurements with external control	DID	hospitals in the US	0 years	all sexes	yes	no change	see Table 3; There is no statistically significant effect of MMLs on the proportion of newborn hospitalizations with prenatal exposure to noxious substances, neonatal drug withdrawal syndrome, fetal alcohol syndrome, slow growth, respiratory conditions, feeding problems, congenital abnormalities, low gestational age, low birth weight, or very low birth weight. Likewise, RMLs appear to have no effect on these outcomes.
10.1016/j.jhealeco.2021.102537	Meinhofer	2021	USA	Alaska, Colorado, DC, Maine, Massachusets, Nevada, Oregon, Vermont, Washington vs. control states	YOUTH: use or health		birth outcomes	pre and post measurements with external control	DID	hospitals in the US	0 years	all sexes	yes	no change	see Table 3; There is no statistically significant effect of MMLs on the proportion of newborn hospitalizations with prenatal exposure to noxious substances, neonatal drug withdrawal syndrome, fetal alcohol syndrome, slow growth, respiratory conditions, feeding problems, congenital abnormalities, low gestational age, low birth weight, or very low birth weight. Likewise, RMLs appear to have no effect on these outcomes.
10.1016/j.drugalcdep.2020.107960	Mennis	2020	USA	Colorado, Washington, 41 control states	YOUTH: use or health		CUD (healthcare)	pre and post measurements with external control	DID	nationwide	12-17 years	all sexes	yes	decrease	Model 3, adjusted DiD: -7.671 (-38.798, 23.456)
10.1016/j.addbeh.2022.107552	Mennis	2023	USA	nationwide	YOUTH: use or health		use	pre and post measurements with external control	DID	nationwide, USA	12-17 years	all sexes	yes	increase	0.009 (p <0.0005) [0.006, 0.012]; CI 95%
10.1016/j.addbeh.2022.107552	Mennis	2023	USA	nationwide	YOUTH: use or health		CUD (healthcare)	pre and post measurements with external control	DID	nationwide, USA	12-17 years	all sexes	yes	no change	−1.216 (p =0.617) [−5.991, 3.559]; CI 95%
10.1016/j.jadohealth.2022.10.010	Orsini	2022	USA	nationwide	YOUTH: use or health		use	pre and post measurements with external control	longitudinal w/ control	nationwide, USA	12-17	all sexes	yes	increase	Criminalized vs. legal (Ref. cat.): OR (CI) 0.648 (0.435, 0.964), p<.05. The odds of past-month use are 35.2% (p < .05) lower during years when recreational possession was criminalized compared to years when the state had legalized possession
10.1016/j.amepre.2019.09.020	Paschall	2020	USA	Oregon	YOUTH: use or health		use	pre and post measurements without external control	pre/post	students (6th - 11th grade)	~ 11-17 years	all sexes	no	increase	2016 versus prelegalization OR (95% CI): 1.20 (1.10, 1.31) 2018 versus prelegalization OR (95% CI): 1.19 (1.04, 1.36), *p<0.05.
10.1016/j.amepre.2019.09.020	Paschall	2020	USA	Oregon	YOUTH: use or health		perceived availability	pre and post measurements without external control	pre/post	students (6th - 11th grade)	~ 11-17 years	all sexes	no	increase	2016 versus prelegalization beta (SE): 0.07 (0.01), p<0.01 2018 versus prelegalization beta (SE): 0.08 (0.01), p<0.01
10.15288/jsad.2021.82.103	Paschall	2021	USA	California	YOUTH: use or health		use	pre and post measurements without external control	ITS	school	~12-17 (7th, 9th and 11th grade)	all sexes	yes	increase	OR= 1.23 [1.21, 1.25]; p < 0.01
10.1016/j.amepre.2021.06.003	Paschall	2022	USA	California	YOUTH: use or health		use	pre and post measurements without external control	pre/post	Middle and High School (7th-,9th-, and 11th-grade)	~12-17 years	all sexes	yes	increase	6% increase in the odds of alcohol and marijuana co-use RML Pre-post (Multilevel Logistic Regression Analyses, OR (95% CI)) Total sample (n=3,319,329): 1.06 (1.05, 1.07) Nonheavy drinkers(n=251,835): 1.58 (1.54, 1.62) Heavy drinkers (n=281,938): 1.25 (1.21, 1.29) Marijuana users (n=386,116): 0.76 (0.74, 0.78)
10.1016/j.amepre.2021.06.003	Paschall	2022	USA	California	YOUTH: use or health		frequency	pre and post measurements without external control	pre/post	Middle and High School (7th,9th, and 11th grade)	~12-17 years	all sexes	yes	increase	significant increase in the frequency of past 30−day marijuana use (b=0.36, SE=0.07, p<0.001)
10.1186/s42238-019-0002-0	Peters	2019	USA	Colorado	YOUTH: use or health		frequency	pre and post measurements with external control	DID	high schools in Colorado	secondary students (probably 11-18y)	all sexes	yes	no change	Comparing between years, the results are within the margin of error and do not represent a statistically significant difference from 2013 to 2015
10.1186/s42238-019-0002-0	Peters	2019	USA	Colorado	YOUTH: use or health		perceived availability	pre and post measurements with external control	DID	high schools in Colorado	secondary students (probably 11-18y)	all sexes	yes	no change	Comparing between years, the results are within the margin of error and do not represent a statistically significant difference from 2013 to 2015.
10.1007/s10995-020-03010-5	Pflugeisen	2020	USA	Washington	YOUTH: use or health		use during pregnancy	pre and post measurements without external control	pre/post	1 Hospital in WS state	mean age 28.5 ± 5.6 years	female	no	no change	no increase in test positivity strictly among those tested, with 22.7% of the pre-accessibility, 23.4% of the interim, and 23.3% of the post-legalization cohorts testing positive for cannabinoids during pregnancy p= 0.91. (Percentages calculated by number of women tested). Concomitant aORs: (reference group: pre-legalization): interim aOR: 1.09 CI: 0.99-1.18-; p: .05. Post accessibility aOR: 1.37 CI: 1.26-1.48; p<.001
https://www.proquest.com/openview/15aa48d4951693d9737b2b6e1e36eede/1?pq-origsite=gscholar&cbl=18750&diss=y	Pigeon	2021	USA	Colorado	YOUTH: use or health		use	pre and post measurements without external control	pre/post	middle and high school	~14-18 (9th to 12th grade)	all sexes	yes	no change	2013 (19.7%) vs. 2017 (19.4%): X^2=0.56; 95% CI= (-)0.48% to 1.09%; DF= 1; no sign.
10.1016/j.ypmed.2022.107297	Roberts	2022	USA	Washington vs. Alaska, California, Nevada	YOUTH: use or health	warning labels	birth outcomes	pre and post measurements with external control	DID	health care registry data	0 years	female		increase	mandatory warning signs (MWS) and not legalization was studied. Impact of MWS an low birthweight b (CI)=0.003 (0.000-0.006); p=0.041
10.1080/15563650.2021.2006212	Roth	2022	USA	California	YOUTH: use or health		poisoning	pre and post measurements without external control	ITS	Poison Control Center	<13	males and females	yes	increase	text: Cannabis exposures in those under thirteen increased significantly both after recreational legalization (1.04 [CI: 0.38, 1.70]) and after the opening of the retail sales market (0.73 [CI: 0.34, 1.12])
10.1037/adb0000327	Rusby	2018	USA	Oregon	YOUTH: use or health		frequency	pre and post measurements without external control	lagged longitudinal	middle schools	13-14	male, female	yes	no change	Intercept: 1.28, 95% CI: 0.79, 2.08; Slope: 0.87, 95% CI: 0.74, 1.03

10.1037/adb0000327	Rusby	2018	USA	Oregon	YOUTH: use or health		use	pre and post measurements without external control	lagged longitudinal	middle schools	13-14	male, female	yes	no change	Intercept: 0.76, 95% CI: 0.33, 1.72; Slope: 1.17, 95% CI: 0.92, 1.48
10.1111/add.15019	Shi	2020	USA	nationwide	YOUTH: use or health		poisoning	pre and post measurements with external control	DID	Poison Centers	<21	males and females	yes	increase	Coefficient of linear regression (95% CI): 8.39**(3.87, 12.90), Estimated percentage change: 61.48%
10.1002/bdr2.1680	Siega-Riz	2020	USA	Colorado, Washington	YOUTH: use or health		birth outcomes	pre and post measurements without external control	ITS	any (vital certificates from both states)	0 years	female	yes	no change	Time*post Colorado: estimate=−0.02; standard error= 0.01; p=0.10 Washington: estimate= 0.01; standard error= 0.01; p=0.47
10.1001/jamanetworkopen.2021.0138	Skelton	2021	USA	Alaska, Maine vs New Hampshire, Vermont	YOUTH: use or health		use during pregnancy	pre and post measurements with external control	DID	hospital (women who delivered live-born infants)	<17->35 years	female	yes	no change	Risk difference and risk ratio in prenatal period not significant (risk difference, 0.0070 [95% CI, −0.0120 to 0.0260];P= .47; risk ratio, 1.11054 [95% CI, 0.8467 to1.4432];P= .46)
10.1055/s-0039-1694793	Straub	2021	USA	Washington	YOUTH: use or health		use during pregnancy	pre and post measurements without external control	pre/post	hospital	26.76 ±5.64	female	no	no change	Cohort T1: 23.17% (n=373) Cohort T2: 24.02% (n=363) Cohort T3: 23.94% (n=532) Total: 23.73% (n=1,268) χ2= 0.4; p=0.815
10.1055/s-0039-1694793	Straub	2021	USA	Washington	YOUTH: use or health		birth outcomes	pre and post measurements without external control	pre/post	hospital	0 years	all sexes	no	no change	T3 OR: 1.36 SE: 0.27 z: 1.56 p= 0.118 95% CI: 0.93, 1.99
10.15585/mmwr.mm6839a3	Ta	2019	USA	Washington	YOUTH: use or health		use	pre and post measurements without external control	pre/post	public school	~11-18 years	male	no	decrease	Among male students in grade 10, past 30–day marijuana use increased from 17.6% in 2004 to 21.4% in 2010 and subsequently declined to 13.5% in 2016 (Figure 2).
10.15585/mmwr.mm6839a3	Ta	2019	USA	Washington	YOUTH: use or health		use	pre and post measurements without external control	pre/post	public school	~11-18 years	female	no	no change	Among female students in grade 10, there was no change in the prevalence of past 30–day use, which remained approximately 16% during this period.
10.1016/j.jemermed.2019.01.004	Thomas	2019	USA	Washington	YOUTH: use or health		poisoning	pre and post measurements without external control	ITS	Poison Center	<9 years	males and females	yes	increase	call rate increased 2.3 times after opening of retail shops
10.1097/PEC.0000000000001703	Thomas	2021	USA	Washington	YOUTH: use or health		poisoning	pre and post measurements without external control	pre/post	single tertiary care pediatric hospital ED or transferrals	<9 years	males and females	no	increase	1.19 cases per year vs. 3.88 cases per year
10.1001/jamapediatrics.2016.0971	Wang	2016	USA	Colorado	YOUTH: use or health		poisoning	pre and post measurements with external control	DID	Poison Center	<10 years	males and females	yes	increase	34%(95% CI, 22%-47%;P< .001) increase in Colorado per year vs 19% in rest of US (95% CI, 12%-27%,P< .001). Difference significant (p=.04)
10.1016/j.jadohealth.2017.12.010	Wang	2018	USA	Colorado	YOUTH: use or health		poisoning	pre and post measurements without external control	pre/post	childrens' hospital in Colorado	13-21 years	males and females	no	increase	only comparison 2009 - 2015/linear time trend reported: 1.8/1000 visits in 2009 to 4.9/1000 in 2015
10.1136/injuryprev-2019-043360	Wang	2019	USA	Colorado	YOUTH: use or health		poisoning	pre and post measurements without external control	pre/post	Colorado Regional Posion Center	0-8 years	males and females	yes	increase	after legalization: increase 10.3 cases/year, pre: +1,3
10.1016/j.ypmed.2022.106993	Wang	2022	USA	Colorado	YOUTH: use or health		use during pregnancy	pre and post measurements without external control	pre/post	hospitals in Colorado	childbearing age	female	yes	increase	IRR [95% CI]: 8.44 [3.90,18.27], p at 0.01% level
10.1111/add.15795	Weinberger	2022	USA	Alaska, California, Colorado, DC, Massachusetts, Maine, Michigan, Nevada, Oregon, Vermont, Washington vs. control states	YOUTH: use or health		use	pre and post measurements with external control	DID	Alaska, California, Colorado, DC, Massachusetts, Maine, Michigan, Nevada, Oregon, Vermont, Washington vs. control states	12-17	all sexes	yes	decrease	RCL aOR (95% CI): 0.737 (0.624, 0.871) p< 0.001
10.1111/add.15795	Weinberger	2022	USA	Alaska, California, Colorado, DC, Massachusetts, Maine, Michigan, Nevada, Oregon, Vermont, Washington vs. control states	YOUTH: use or health		use	pre and post measurements with external control	DID	Alaska, California, Colorado, DC, Massachusetts, Maine, Michigan, Nevada, Oregon, Vermont, Washington vs. control states	12-17	all sexes	yes	decrease	RCL aOR (95% CI): 0.645 (0.513, 0.810) P_int: < 0.001
10.1016/j.drugpo.2020.102748	Laqueur	2020	Uruguay	nationwide vs Chile	YOUTH: use or health		use	pre and post measurements with external control	synthetic control	schools in urban settings	~13-17 (8th, 10th and 12th grade)	all sexes	no	no change	2.53% (placebo test: 10/15)
10.1016/j.drugpo.2020.102748	Laqueur	2020	Uruguay	nationwide vs Chile	YOUTH: use or health		use	pre and post measurements with external control	synthetic control	schools in urban settings	~13-17 (8th, 10th and 12th grade)	all sexes	no	no change	2.31% (placebo test: 10/15)
10.1016/j.drugpo.2020.102748	Laqueur	2020	Uruguay	nationwide vs Chile	YOUTH: use or health		frequency	pre and post measurements with external control	synthetic control	schools in urban settings	~13-17 (8th, 10th and 12th grade)	all sexes	no	no change	1.76% (placebo test: 13/15)
10.1016/j.drugpo.2020.102748	Laqueur	2020	Uruguay	nationwide vs Chile	YOUTH: use or health		perceived availability	pre and post measurements with external control	synthetic control	schools in urban settings	~13-17 (8th, 10th and 12th grade)	all sexes	no	increase	6.31% (placebo test: 2/15)

10.1111/add.15913	Rivera-Aguirre	2022	Uruguay	urban areas	YOUTH: use or health		use	pre and post measurements with external control	DID	secondary schools	12-17	male, female	yes	decrease	PD -5.2 (95% CI: -7.4, -3.1)
10.1111/add.15913	Rivera-Aguirre	2022	Uruguay	urban areas	YOUTH: use or health		risky use	pre and post measurements with external control	DID	secondary schools	12-17	male, female	yes	no change	PD 4.4 (95% CI: -2.1, 11.0)
10.1111/add.15913	Rivera-Aguirre	2022	Uruguay	urban areas	YOUTH: use or health		frequency	pre and post measurements with external control	DID	secondary schools	12-17	male, female	yes	no change	PD -2.7 (95% CI: -10.4, 4.9)