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Research Paper

Prevalence and forms of cannabis use in legal vs. illegal recreational cannabis markets

Samantha Goodman (PhD), Elle Wadsworth (MSc), Cesar Leos-Toro (PhD), David Hammond (PhD)*, On behalf of the International Cannabis Policy Study team

School of Public Health and Health Systems, University of Waterloo, Waterloo, ON N2L 3G1, Canada

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ABSTRACT

Background: Recreational or 'non-medical cannabis' has been legalized in several US states, and was legalized federally in Canada in October 2018. There is little comparative data on product use across jurisdictions, particularly with respect to the types of cannabis products used, which differentially impact health.

Methods: Data are from Wave 1 of the International Cannabis Policy Study, collected from Aug 27–Oct 7, 2018. Respondents (n = 27,024) aged 16–65 completed an online survey measuring patterns of cannabis use, quantities and routes of administration. Respondents were recruited from Canada (n = 9976) and US states that had (n = 7362) and had not (n = 9686) legalized non-medical cannabis ('legal' and 'illegal' states, respectively).

Results: Prevalence of at least daily, weekly, and monthly cannabis use were significantly higher in US 'legal' states (11.3%, 18.2%, 25.0%, respectively) than US 'illegal' states (7.4%, 11.6%, 16.8%, respectively; $p < 0.001$) and Canada (8.9%, 14.1%, 19.0%, respectively; $p \leq 0.01$). Dried herb was the dominant form of cannabis reported by past 12-month users across all jurisdictions (77.7%–80.8%). Although the amount of dried herb used per year did not differ by jurisdiction (range: 210.3–229.4 g), those in US 'legal' states were significantly more likely to use dried herb daily or weekly than were those in 'illegal' states and Canada ($p < 0.001$). Use of cannabis concentrates, vaped oils, edibles, and drinks was more prevalent among US 'legal' states than 'illegal' states and Canada ($p \leq 0.001$). Vaping dried herb was more common in both legal and illegal US jurisdictions than in Canada ($p < 0.05$), whereas Canadians were more likely to smoke dried herb with tobacco ($p < 0.001$).

Conclusion: The prevalence of cannabis use—and use of products such as cannabis concentrates, edibles and drinks—was higher in US states that had legalized cannabis. Additional longitudinal research is required to determine whether these differences reflect causal effects of legalization or pre-existing secular trends.

Introduction

The cannabis market is rapidly evolving in North America. Canada's Cannabis Act, which came into effect on October 17, 2018, made Canada the second country after Uruguay to legalize and regulate non-medical cannabis at the federal level (Law; 2018). In the US, although cannabis remains a Schedule I substance at the federal level, 11 states have legalized the possession and sale of recreational cannabis since 2012: Alaska, California, Colorado, Illinois, Maine, Massachusetts, Michigan, Nevada, Oregon, Vermont and Washington, as well as the District of Columbia (National Conference of State Legislatures, 2019).

Given the recency of legalization (and more recently, commercialization) of cannabis in certain US states, the policies and markets in these states remain considerably different (National Conference of State Legislatures, 2019), and there is little evidence of the broader population impact of legalization on prevalence of use or related health outcomes. Traditionally, national drug-monitoring surveys in Canada and the US have been limited by repeat cross-sectional designs and a limited number of questions on cannabis use (Statistics, 2016; Substance Abuse and Mental Health Services Administration. Key substance use and mental health indicators in the United States: Results from the 2017 National Survey on Drug Use and Health HHS Publication No. SMA 18-5068, NSDUH Series H-53. Rockville, MD., 2018; "Canadian Student Tobacco, Alcohol and Drugs Survey CSTADS," 2018) (see Supplementary Materials for a summary of existing surveys that assess cannabis use in Canada and the US). In the wake of non-medical cannabis legalization in Canada, recent efforts to measure cannabis use include the National Cannabis Survey (NCS) and Canadian Cannabis Survey (CCS)

* Corresponding author.
E-mail addresses: samantha.goodman@uwaterloo.ca (S. Goodman), ewadsworth@uwaterloo.ca (E. Wadsworth), cleostor@uwaterloo.ca (C. Leos-Toro), dhammond@uwaterloo.ca (D. Hammond).

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(2018; Statistics, 2019, a). These are the most comprehensive national surveys of cannabis use to date; however, both are cross-sectional, and because data collection only commenced in 2017 (Health, 2017, a; Statistics, 2019, a), detailed data on pre-existing usage trends are limited.

Data from the National Survey on Drug Use and Health (NSDUH) suggest that in 2018, an estimated 10.5% of Americans aged ≥18 years reported using cannabis in the past month (2019). There is emerging evidence of increased prevalence of use among states that have legalized non-medical cannabis, although the extent to which these differences can be attributed to the impact of legalization or broader secular trends remains unclear (Kerr, Bae & Koval, 2018, 2017; Miller, Rosenman & Cowan, 2017; Parnes, Smith & Conner, 2018; 2017, b; Washington State Office of Financial Management, 2016). In Canada, the prevalence of cannabis use has remained fairly stable over the previous decade, although national estimates suggest a modest increase among youth and young adults in the year immediately preceding legalization (Statistics, 2018, Statistics, 2019, b). Prior to legalization in 2018, an estimated 22.2% of Canadians aged ≥16 years reported using cannabis in the past month (2018). However, there is a lack of data across jurisdictions to allow direct comparisons of the effects of non-medical cannabis legalization in Canada and US states. Comparative data is important to understand the impact of regulations and policies that seek to minimize problematic cannabis use, including use among young people and cannabis products that have a higher potential for adverse outcomes (Fischer et al., 2017; Habboushe, Rubin, Liu & Hoffman, 2018; Kroon, Kuhns, Hoch, & Cousijn, 2019).

In addition to influencing who uses cannabis, legalization may also impact the types of cannabis products used. Although dried herb/flower has historically been the predominant cannabis product type used in North America, recent evidence suggests increasing use of alternative cannabis products, including concentrates, edibles and vaped oils, especially in 'legal' markets (Barrus et al., 2016; Borodovsky et al., 2017; Borodovsky, Crosier, Lee, Sargent & Budney, 2016; Daniulaityte et al., 2018; Knapp et al., 2019). Data from Colorado, Oregon and Washington suggest that the use of alternative forms of cannabis increased following legalization (Caulkins et al., 2018; Oregon Liquor Control, 2019; Reed, 2018). The type of product used is important given differences between products in short-term pharmacokinetic effects (Barrus et al., 2016; Loflin & Earleywine, 2014; Newmeyer, Swortwood, Abulseoud & Huestis, 2017) as well as potential differences in longer-term risks associated with the mode of delivery (e.g., smoking) and concerns about high-potency extracts (Borodovsky et al., 2016; Russell, Rueda, Room, Tyndall & Fischer, 2018). To date, most evidence on cannabis products has been derived from sales data, with little evidence from population-based surveys, which rarely collect detailed information on the frequency or quantity of products used at the individual level (e.g., Cuttler & Spradlin, 2017; Health 2017, b; Statistics, 2019, a). There is a need to examine consumer patterns of use for different cannabis products to enhance our understanding of problematic patterns of use and the prevalence of adverse outcomes, as well as to establish safe thresholds of use across modes of delivery (Parnes, Bravo, Conner & Pearson, 2018).

The objective of this study was to examine associations between the legal status of non-medical cannabis and frequency and prevalence of cannabis use, including different forms and routes of administration. These outcomes were examined in Canada, US states that had legalized non-medical cannabis (US 'legal' states) and those that had not (US 'illegal' states), immediately prior to cannabis legalization in Canada. For Canada and any US states that legalize non-medical cannabis in the coming years, these data will serve as baseline estimates against which post-legalization outcomes can be compared. The data may also shed light on the influence of cannabis legalization in US states—including frequency and prevalence of cannabis use and forms of use—and may be used to inform regulatory policies in these or other jurisdictions considering legalization.

Methods

Data are cross-sectional findings from Wave 1 of the International Cannabis Policy Study (ICPS) (Hammond et al., 2018). The ICPS aims to evaluate the population-level impact of non-medical cannabis legalization in Canada and specific US states, including the influence of specific policy measures in regulated cannabis markets (for further detail, see Hammond et al., 2019). Data were collected via self-completed web-based surveys conducted from August 27–October 7, 2018 with respondents aged 16–65. Respondents were recruited through the Nielsen Consumer Insights Global Panel and their partners' panels. Email invitations (with a unique link) were sent to a random sample of panelists (after targeting for age and country criteria); panelists known to be ineligible based on age and country were not invited. Surveys were conducted in English in the US and English or French in Canada (based on the panelist's known language preference). Median survey time was 19.9 min.

Respondents provided consent prior to completing the survey. Respondents received remuneration in accordance with their panel's usual incentive structure (e.g., points-based or monetary rewards, chances to win prizes). The study was reviewed by and received ethics clearance through a University of Waterloo Research Ethics Committee (ORE# 22392/31330). A full description of the study methods can be found in the International Cannabis Policy Study: Technical Report – Wave 1 (2018) (Goodman & Hammond, 2019).

Measures

Socio-demographics—Demographic data included age, sex, ethnicity, highest level of education, and jurisdiction (Canada, US 'illegal' and US 'legal' states).

Other self-reported measures included cannabis use (lifetime, most recent and current frequency of use), age of first using cannabis, time to first use after waking, and quantity of cannabis used.

Cannabis prevalence—A 6-level 'cannabis use status' variable with exclusive categories (Never user; Used >12 months ago; Used in past 12 months; Monthly user; Weekly user; Daily/almost daily user) was derived from three survey questions: lifetime use (Yes; No); most recent cannabis use (More than 12 months ago; More than 3 months ago but less than 12 months ago; More than 30 days ago, but less than 3 months ago; Within the past 30 days); and frequency of use (Less than once per month; One or more times per month; One or more times per week; Every day or almost every day).

Cannabis product types and consumption—Cannabis consumption data were collected using a comprehensive series of measures that assessed frequency of use (Less than monthly, Monthly, Weekly, Daily, Don't know, Refuse) and quantity consumed for nine forms of cannabis: dried herb (smoked or vaped); cannabis oil/liquid taken orally (e.g., drops); cannabis oil/liquid for vaping; edibles (i.e., foods); drinks (e.g., cannabis soda/tea/coffee); concentrates (e.g., wax, shatter, budder); hash or kief; tinctures (e.g., concentrated amounts ingested orally or taken under the tongue); and topical ointments (e.g., skin lotions). Respondents selected their preferred timeframe (usual day/week/month or past 12 months) and unit (g, oz, mL, joints, vape hits, etc.) to report each form of cannabis consumed. Dried herb users could report their consumption in amounts of dried herb (g/oz, lb/kg) or as a number and size of typical joint smoked. Reference images were used to facilitate estimates (see Supplementary Figs. S1–S8). Measures were developed based on extensive pre-testing and cognitive interviewing with cannabis users (Goodman, Leos-Toro & Hammond, 2019; Leos-Toro, 2019). For full item wording, see the ICPS Wave 1 (2018) survey (Hammond et al., 2018).

The survey asked respondents about their current frequency of use in two ways: as a categorical variable (less than once per month, 1+ times per month, 1+ times per week, every day/almost every day) and as an open-ended variable where the respondent entered the number of

days they use cannabis per week/month/in the past 12 months. Where large discrepancies between responses to these two variables existed (e.g., respondent selected "less than once per month" but indicated that they used cannabis on 365 days in the past 12 months), the current frequency of cannabis use was reclassified; this affected 3% of past 12-month cannabis users.

For all product types, the amount reported was multiplied by the timeframe selected by users (usual day/week/month or past 12 months) to calculate average consumption in the past 12 months. For quantities of dried herb, thresholds for plausible values were selected for daily, weekly, monthly, and less than monthly users, and those outside the acceptable range were excluded from this analysis (see Supplementary Table S1). This affected 5.7% of dried herb users. Dried herb consumption amounts reported as joints (range = 0.2–1.2 g, multiplied by number of joints used) or as amount of dried herb (g/oz or kg/lb) were converted to grams and are reported herein for the three jurisdictions. For the remaining forms of cannabis, data are presented in the unit reported by respondents, without outlier removal and with jurisdictions collapsed due to extremely large standard deviations and a lack of data on plausible values for forms of cannabis other than dried herb (see Supplementary Tables S2–S9).

Data analysis

A total of 28,471 respondents completed the survey. After removing 1302 respondents with invalid responses to data quality questions (reported inability to answer questions honestly or select the current month), missing data for education, ineligible country of residence, smartphone use, or residence in District of Columbia (due to inadequate sample size for weighting), 27,042 respondents were retained in the current analytic sample.

Post-stratification sample weights were constructed based on the Canadian and US census estimates. Respondents from Canada were classified into age-by-sex-by-province and education groups. Respondents from the US 'legal' states were classified into age-by-sex-by-legal state, education, and region-by-race groups, while those from the illegal states were classified into age-by-sex, education, and region-by-race groups. Correspondingly grouped population count and proportion estimates were obtained from Statistics Canada (Statistics, 2017, Statistics, 2019, c) and the US Census Bureau (2018). A raking algorithm was applied to the full analytic sample (n = 27,169) to compute weights that were calibrated to these groupings. Raking involves repeatedly calibrating to the variable groupings sequentially until convergence in the weight values is achieved. A SAS macro (2019) was used to conduct this process, also referred to as iterative proportional adjustments of the weights (Battaglia, Izrael & Ball, 2017). Weights were rescaled to the sample size for Canada, US 'illegal' states and US 'legal' states. Estimates are weighted unless otherwise specified.

Separate binary logistic regression models were fitted to examine differences between jurisdictions in frequency of cannabis use (1 = yes; 0 = no for each of: 'Never user'; 'Past 12-month user', 'At least monthly user', 'At least weekly user'; and 'Daily/almost daily user), as well as past 12-month use (1 = past 12-month use; 0 = no past 12-month use) and 'regular' use (0 = less than monthly/monthly use; 1 = weekly/daily use) of each form of cannabis. Linear regression models were used to test for differences between jurisdictions in age at first cannabis use, time to first use after waking, average number of days used per year, mean amount of dried herb used in the past 12 months, and mean percentage of different routes of administration for dried herb and concentrate. The following key socio-demographic variables were entered into models in a single step: age group, sex, education level and ethnicity (see Table 1 for response categories). Adjusted odds ratios (AORs) and unstandardized beta estimates are reported. Analyses were conducted using survey procedures in SAS Studio version 3.6.

Table 1
Weighted sample characteristics of ICPS Wave 1 (2018) respondents, by jurisdiction (n = 27,024).

	Canada (n = 9976)	US 'illegal' states (n = 9686) % (n)	US 'legal' states (n = 7362)
Age group			
16–25	18.8% (1871)	19.9% (1924)	19.5% (1437)
26–35	20.6% (2059)	21.4% (2074)	22.9% (1685)
36–45	19.6% (1956)	19.0% (1837)	17.3% (1276)
46–55	20.9% (2082)	20.2% (1953)	21.8% (1604)
56–65	20.1% (2008)	19.6% (1898)	18.5% (1361)
Age [mean (SD)]	40.7 (14.9)	40.1 (15.1)	40.1 (14.8)
Sex			
Female	49.9% (4974)	50.3% (4874)	49.7% (3661)
Male	50.1% (5002)	49.7% (4812)	50.3% (3701)
Ethnicity			
White	77.6% (7743)	76.5% (7410)	76.6% (5643)
Other/Mixed/ Unstated	22.4% (2233)	23.5% (2276)	23.4% (1719)
Education			
Less than high school	15.6% (1552)	15.2% (1474)	11.8% (870)
High school diploma or equivalent	26.8% (2671)	19.5% (1887)	16.0% (1175)
Some college/ vocational training +	32.7% (3264)	38.4% (3721)	42.2% (3106)
Bachelor's degree or higher	24.9% (2489)	26.9% (2604)	30.0% (2212)

[+] This category includes some college, college certificate/diploma, technical/vocational training, apprenticeship, or some university.

Results

Sample characteristics are shown in Table 1.

Indicators of cannabis use

Table 2 shows various indicators of cannabis use and pairwise contrasts between jurisdictions. Rates of ever trying cannabis were higher in US 'legal' states (61.7%) than in Canada (56.6%) and US 'illegal' states (54.7%). The prevalence of past 12-month, monthly, weekly and daily/almost daily use were also significantly higher in US 'legal' states than in Canada or US 'illegal' states. In addition, the prevalence of past 12-month use and frequency of use were higher in Canada than US 'illegal' states.

As shown in Table 2, age at first use varied significantly by jurisdiction ($F(2, 15{,}848) = 10.83$, $p < 0.001$); respondents in Canada were significantly older at first use than those in US 'illegal' states. Among past 12-month users, the mean number of days cannabis was used per year did not differ significantly by jurisdiction ($F(2,6735) = 1.89$, $p = 0.15$), although those in US 'legal' states tended to use on more days per year than those in Canada ($p = 0.05$). Daily cannabis users in Canada waited longer after waking to use cannabis than those in both US jurisdictions ($F(2, 1763) = 9.71$, $p < 0.001$).

Prevalence of use of different forms of cannabis

Table 3 shows the proportion of past 12-month cannabis users who reported using each form of cannabis in the past 12 months, as well as significant differences by jurisdiction. While the prevalence of use of dried herb and orally ingested cannabis oils did not vary significantly by jurisdiction, US 'legal' states had a significantly higher prevalence of past 12-month use of every other form of cannabis compared to 'illegal' jurisdictions, with the exception of hash or kief, which did not differ significantly between US 'legal' states and Canada.

Table 4 shows the frequency of use of each form of cannabis, and Fig. 1 shows the prevalence of 'regular' (weekly or daily) use of each

Table 2
Indicators of cannabis use among ICPS Wave 1 (2018) respondents, by jurisdiction (n = 27,024).

	Canada (n = 9976)	US 'illegal' states (n = 9686) % (n)	US 'legal' states (n = 7362)	US 'illegal' states vs. Canada *(ref)*	Canada vs. US 'legal' states *(ref)* AOR (95% CI), p-value	US 'illegal' vs. US 'legal' states *(ref)*
Frequency of cannabis use+ (n = 27,024)						
Never used cannabis	43.4% (4327)	45.3% (4386)	38.3% (2822)	1.08 (1.00, 1.16), 0.06	1.25 (1.13, 1.38), <0.001	1.34 (1.22, 1.48), <0.001
Used >12 months ago	29.0% (2897)	30.9% (2997)	27.3% (2011)	1.11 (1.02, 1.20), 0.014	0.91 (0.82, 1.01), 0.076	1.22 (1.01, 1.35), <0.001
Past 12-month users	27.6% (2752)	23.8% (2303)	34.4% (2529)	0.82 (0.75, 0.89), <0.001	0.72 (0.65, 0.80), <0.001	0.59 (0.53, 0.65), <0.001
At least monthly user	19.0% (1897)	16.8% (1628)	25.0% (1837)	0.87 (0.79, 0.97), <0.01	0.68 (0.61, 0.77), <0.001	0.59 (0.53, 0.67), <0.001
At least weekly user	14.1% (1408)	11.6% (1122)	18.2% (1337)	0.82 (0.73, 0.92), 0.001	0.70 (0.61, 0.80), <0.001	0.57 (0.50, 0.65), <0.001
Daily/almost daily user	8.9% (891)	7.4% (720)	11.3% (834)	0.84 (0.73, 0.97), <0.001	0.73 (0.62, 0.85), <0.001	0.61 (0.52, 0.72), <0.001
		Mean (SD)		***β* (95% CI), *p*-value**		
Age at first use (years) (n = 15,489)++	19.3 (7.9)	18.7 (6.7)[a]	19.1 (7.9)[b]	−0.79 (−1.13, −0.46), <0.001	0.40 (−0.03, 0.83), 0.07	−0.39 (−0.81, 0.03), 0.07
Days used per year (n = 7584)+++	149.3 (145.7)	148.4 (140.9)	156.1 (143.5)	3.97 (−6.67, 14.61), 0.46	−11.55 (−23.23, 0.13), 0.05	−7.58 (−19.30, 4.15), 0.21
Hours after waking until use (n = 2042)++++	4.5 (4.7)	3.5 (4.2)	3.6 (4.3)	−1.23 (−1.84, −0.62), <0.001	1.28 (0.62, 1.94), <0.001	0.18 (−0.54, 0.65), 0.86

+ Sum of categories is greater than population in each jurisdiction because daily, weekly and monthly users are included in past 12-month users;.
++ Asked to 'ever' cannabis users.
+++ Asked to past 12-month cannabis users.
++++ Asked to daily cannabis users.
Significance testing for frequency of cannabis use conducted using binary logistic regression; remaining variables tested using linear regression.
Models adjusted for sex, age group, education and ethnicity. AOR = adjusted odds ratio; β = unstandardized beta estimate; SD = standard deviation; 95% CI = 95% confidence interval.

Table 3
Prevalence of past 12-month use of each form of cannabis among past-12 month cannabis users, by jurisdiction (n = 7584).

Form of cannabis	Canada (n = 2752) % (n)	US 'illegal' states (n = 2303)+	US 'legal' states (n = 2529)	US 'illegal' states vs. Canada *(ref)*	Canada vs. US 'legal' states *(ref)* AOR (95% CI), p-value	US 'illegal' vs. US 'legal' states *(ref)*
Dried herb	80.7% (2222)	80.8% (1859)	77.7% (1964)	1.00 (0.82, 1.22), 1.00	1.19 (0.97, 1.47), 0.10	1.19 (0.96, 1.48), 0.11
Edibles (foods)	37.7% (1036)	37.2% (856)	51.4% (1300)	0.94 (0.81, 1.10), 0.46	0.59 (0.50, 0.71), <0.001	0.56 (0.47, 0.67), <0.001
Hash or kief	25.1% (691)	17.2% (395)	23.8% (602)	0.62 (0.50, 0.75), <0.001	1.04 (0.85, 1.27), 0.72	0.64 (0.51, 0.80), <0.001
Cannabis oil (oral)	22.2% (612)	20.4% (470)	23.8% (601)	0.89 (0.74, 1.08), 0.23	0.94 (0.77, 1.15), 0.55	0.84 (0.68, 1.03), 0.09
Cannabis oil (vaped)	20.9% (575)	30.2% (695)	39.8% (1006)	1.62 (1.35, 1.95), <0.001	0.39 (0.32, 0.47), <0.001	0.63 (0.53, 0.76), <0.001
Concentrates	16.8% (462)	15.4% (354)	22.0% (557)	0.90 (0.73, 1.13), 0.37	0.69 (0.56, 0.86), 0.001	0.63 (0.50, 0.79), <0.001
Topical ointments	9.4% (259)	11.2% (257)	21.1% (534)	1.22 (0.95, 1.56), 0.12	0.40 (0.31, 0.51), <0.001	0.48 (0.38, 0.62), <0.001
Drinks	8.1% (224)	8.7% (201)	17.0% (430)	1.05 (0.78, 1.41), 0.74	0.43 (0.32, 0.56), <0.001	0.45 (0.37, 0.60), <0.001
Tinctures	6.6% (181)	6.7% (154)	13.0% (328)	1.05 (0.76, 1.43), 0.78	0.47 (0.35, 0.63), <0.001	0.49 (0.36, 0.66), <0.001

+ Sample size in US 'illegal' states was 2301 for dried herb and 2303 for all other forms of cannabis. Note that prevalence of using an 'Other' form of cannabis was 0.0% − 0.2% across jurisdictions and significance testing was therefore not performed. Significance testing conducted using binary logistic regression (1 = past 12-month use; 0 = no past 12-month use), and adjusted for sex, age group, education and ethnicity. 95% CI = 95% confidence interval; AOR = adjusted odds ratio.

Table 4
Frequency of use and prevalence of regular use among past 12-month users of each form of cannabis, by jurisdiction.

	Canada (n = 2133)	US 'illegal' states (n = 1744)	US 'legal' states (n = 1863)	US 'illegal' states vs. Canada *(ref)*	Canada vs. US 'legal' states *(ref)*	US 'illegal' vs. US 'legal' states *(ref)*
	Frequency of use% (n)			Odds of 'regular' use AOR (95% CI)		
Dried herb				1.02 (0.85, 1.21), 0.87	0.78 (0.64, 0.96), 0.02	0.80 (0.65, 0.98), 0.03
<Once a month	27.6% (589)	26.1% (456)	23.6% (440)			
Monthly	15.9% (340)	18.5% (323)	15.8% (294)			
Weekly	23.7% (506)	25.3% (442)	27.7% (517)			
Daily	32.8% (699)	30.0% (523)	32.8% (612)			
Cannabis oil (oral)				1.20 (0.85, 1.71), 0.31	1.88 (1.30, 2.73), <0.001	2.26 (1.52, 3.36), <0.001
<Once a month	28.6% (168)	26.6% (122)	41.5% (237)			
Monthly	22.7% (133)	21.6% (99)	25.5% (146)			
Weekly	25.4% (149)	32.3% (148)	21.7% (124)			
Daily	23.4% (137)	19.4% (89)	11.3% (65)			
Cannabis oil (vaped)				1.55 (1.12, 2.16), <0.01	0.55 (0.39, 0.78), <0.001	0.86 (0.63, 1.17), 0.33
<Once a month	37.7% (211)	33.0% (220)	31.4% (305)			
Monthly	28.7% (161)	23.0% (153)	21.4% (208)			
Weekly	23.4% (131)	28.8% (192)	28.8% (279)			
Daily	10.1% (57)	15.3% (102)	18.3% (178)			
Edibles (foods)				1.25 (0.90, 1.72), 0.19	0.60 (0.44, 0.82), <0.01	0.75 (0.55, 1.03), 0.07
<Once a month	54.1% (547)	51.4% (430)	40.4% (509)			
Monthly	24.6% (249)	24.7% (206)	31.2% (393)			
Weekly	15.0% (152)	18.2% (152)	22.4% (282)			
Daily	6.2% (63)	5.7% (48)	6.1% (76)			
Drinks				1.89 (1.02, 3.49), 0.04	3.21 (1.79, 5.74), 0.07	1.40 (0.60, 3.28), <0.001
<Once a month	33.7% (71)	17.3% (33)	41.6% (171)			
Monthly	28.0% (59)	24.2% (46)	28.4% (117)			
Weekly	29.1% (61)	41.7% (79)	18.9% (78)			
Daily	9.3% (20)	16.8% (32)	11.1% (46)			
Concentrates				1.12 (0.72, 1.75), 0.61	0.73 (0.48, 1.11), 0.14	0.82 (0.52, 1.27), 0.37
<Once a month	38.7% (172)	36.5% (124)	29.9% (158)			
Monthly	22.6% (101)	22.4% (76)	26.4% (139)			
Weekly	20.9% (93)	24.5% (83)	21.1% (112)			
Daily	17.8% (79)	16.6% (57)	22.6% (119)			
Hash or kief				1.31 (0.87, 1.97), 0.19	0.92 (0.61, 1.37), 0.67	1.20 (0.78, 1.85), 0.40
<Once a month	45.3% (303)	37.5% (142)	37.0% (205)			
Monthly	22.3% (149)	25.8% (97)	30.1% (167)			
Weekly	21.6% (144)	22.6% (86)	24.8% (137)			
Daily	10.8% (72)	14.1% (53)	8.0% (44)			
Tinctures				1.52 (0.77, 3.02), 0.23	0.88 (0.48, 1.64), 0.70	1.35 (0.74, 2.46), 0.33
<Once a month	31.9% (55)	17.5% (25)	33.1% (98)			
Monthly	23.8% (41)	30.5% (44)	23.1% (69)			
Weekly	26.2% (45)	26.6% (39)	27.8% (83)			
Daily	18.1% (31)	25.4% (37)	16.0% (48)			
Topical ointments				0.94 (0.58, 1.52), 0.79	1.42 (0.90, 2.23), 0.13	1.33 (0.85, 2.08), 0.22
<Once a month	24.3% (60)	24.1% (57)	31.2% (156)			
Monthly	21.3% (52)	24.6% (58)	23.5% (118)			
Weekly	32.8% (81)	31.2% (74)	24.1% (121)			
Daily	21.6% (53)	20.1% (47)	21.2% (106)			

Significance testing conducted using binary logistic regression (1 = daily or weekly use; 0 = less frequent use), and adjusted for sex, age group, education and ethnicity. 95% CI = 95% confidence interval; AOR = adjusted odds ratio.

form by jurisdiction. Briefly, those in US 'legal' states were significantly more likely than those in Canada and US 'illegal' states to regularly use dried herb, as well as significantly more likely than those in Canada to regularly use vaped oils/liquids and edibles. In contrast, compared to those in US 'legal' states, consumers in both Canada and US 'illegal' states were significantly more likely to regularly use oils/liquids taken orally, and those in US 'illegal' states were significantly more likely to regularly consume cannabis drinks. Finally, those in US 'illegal' states were significantly more likely than those in Canada to use vaped oils/liquids and cannabis drinks (Table 4).

Routes of administration

Past 12-month users of dried herb and concentrates were also asked to report the percentage of dried herb and concentrate administered in different ways (Table 5). The amount of dried herb smoked without tobacco differed significantly by jurisdiction ($F(2, 4958) = 12.51$, $p < 0.001$). This route of administration was more prevalent in US jurisdictions than Canada; conversely, smoking dried herb with tobacco was more common in Canada than US jurisdictions ($F(2, 4958) = 37.46$, $p < 0.001$). Vaping dried herb also differed significantly by jurisdiction ($F(2, 4958) = 9.08$, $p < 0.001$), such that it was most prevalent in US 'legal' states, followed by US 'illegal' states and Canada. There were no differences across jurisdictions in routes of administration of concentrates such as wax or shatter.

Quantities consumed

Of the past 12-month dried herb users who reported their consumption in joints, the 1.0-g joint was most frequently selected across jurisdictions (M = 0.66 g, SD = 0.32 g). Response frequencies for the six joint sizes were: 1.2-g: 8.1%; 1.0-g: 21.7%; 0.8-g: 16.2%; 0.6-g: 16.7%;

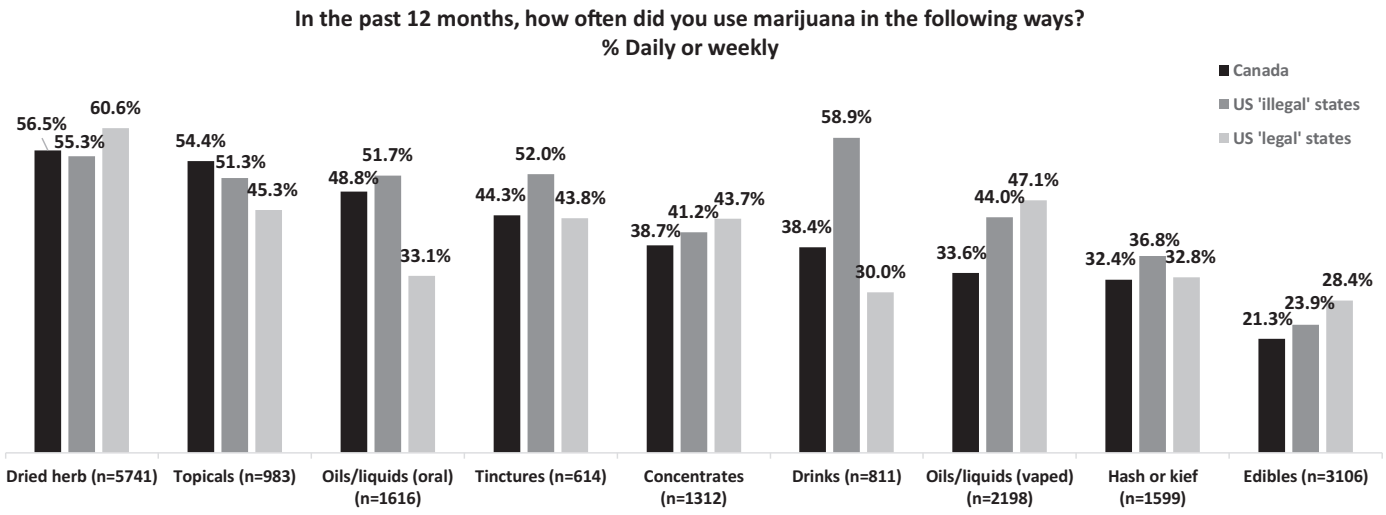

Fig. 1. Regular (daily and weekly) use of cannabis products among past 12-month cannabis users.

0.4-g: 18.2%; 0.2-g: 19.1%. The total amount of dried herb used in the past 12 months (reported in g/oz/kg/lb or number of joints) did not vary significantly by jurisdiction, $F(2,4966) = 0.08$, $p = 0.92$. Mean quantities used were as follows: Canada: $M = 229.4$ g, SD = 437.5; US 'illegal' states: $M = 210.3$ g, SD = 399.8; US 'legal' states: $M = 218.8$ g, SD = 381.1. The amount of dried herb used in the past year increased with frequency of dried herb use (Fig. 2).

Quantities of use among past 12-month users for the remaining forms of cannabis are shown in Supplementary Tables S2–S9. Amounts consumed and units used for reporting varied widely. Due to large ranges and standard deviations, medians and modes are reported in addition to means.

Discussion

The cannabis market is rapidly evolving in both 'legal' and 'illegal' jurisdictions in North America. There has been an emergence of new, higher potency cannabis products, along with changes in retail outlet density and pricing, including a price differential between licit and illicit cannabis in legal markets (Borodovsky et al., 2016; Caulkins et al., 2018; Chandra et al., 2019; Daniulaityte et al., 2018; Mahamad & Hammond, 2019; Mahamad, Wadsworth, Rynard, Goodman, & Hammond, 2019; Smart, Caulkins, Kilmer, Davenport, & Midgette, 2017; Statistics, 2019, d). While an in-depth discussion of these contextual factors is beyond the scope of the current paper, the findings suggest that both the prevalence and frequency of cannabis use is higher in US states that have legalized non-medical cannabis compared to Canada and US 'illegal' states. This finding is consistent with national US data suggesting a higher prevalence of use in 'legal' states. Indeed, in 2016–2017, the prevalence of past 12-month use among adults ≥18 years in all 'legal' states was higher than the national average of 14.7%, with 8 of 10 legal states reporting rates above 20% (2017, a). However, at least some of these differences are due to pre-existing trends in which most states that have legalized non-medical cannabis had higher-than-national prevalence rates prior to legalization (2012, 2013). Indeed, while most state-specific estimates increased post-legalization (2017, b), data from Colorado and Washington suggest no increases in the prevalence of cannabis use before and after legalization, particularly among younger populations (Brooks-Russell et al., 2019; Cerda et al., 2017; Harpin, Brooks-Russell, Ma, James & Levinson, 2018; Jones, Jones & Peil, 2018; Mason et al., 2016). Cross-sectional differences between 'legal' and 'illegal' states thus have the potential to obscure secular or pre-existing differences. The longitudinal nature of the ICPS study will allow for monitoring of these trends over time.

Among 'illegal' jurisdictions, more frequent cannabis use was more common in Canada compared to US 'illegal' states. These differences may reflect increased cannabis use in Canada shortly before legalization in October 2018. Recent data from government surveillance surveys also suggest increases in initiation rates, prevalence of weekly and occasional use, and prevalence of past 3-month use in certain subgroups (males and 45–64-year-olds) (Statistics, 2019, a). Longitudinal studies in both Canada and US legal states will be critically important to

Table 5
Routes of cannabis administration for dried herb and concentrates among past 12-month users, by jurisdiction.

Route of administration	Canada	US 'illegal' states	US 'legal' states	US 'illegal' states vs. Canada *(ref)*	Canada vs. US 'legal' states *(ref)*	US 'illegal' vs. US 'legal' states *(ref)*
	Mean (SD)% used			β (95% CI), *p*-value		
Dried herb	(*n* = 2078)	(*n* = 1711)	(*n* = 1825)			
Smoke without tobacco	68.4 (41.1)	76.5 (35.3)	73.4 (35.9)	8.48 (5.15, 11.80), <0.001	−5.12 (−8.88, −1.35), <0.01	3.36 (−0.23, 6.96), 0.07
Smoke with tobacco	21.1 (36.6)	9.7 (23.0)	10.4 (23.5)	−11.55 (−14.26, −8.83), <0.001	10.73 (7.78, 13.68), <0.001	−0.82 (−3.23, 1.60), 0.51
Vape	9.1 (23.0)	11.3 (22.4)	14.3 (24.4)	1.97 (0.04, 3.90), 0.04	−4.95 (−7.24, −2.67), <0.001	−2.99 (−5.30, −0.67), 0.01
Other	1.4 (9.8)	2.4 (13.9)	2.0 (12.5)	1.10 (−0.06, 2.26), 0.06	−0.66 (−1.72, 0.40), 0.22	0.44 (−0.95, 1.83), 0.53
Concentrate	(*n* = 351)	(*n* = 274)	(*n* = 428)			
Smoke	65.9 (39.9)	62.3 (34.9)	66.4 (34.4)	−0.24 (−8.66, 8.18), 0.96	−2.99 (−10.83, 4.85), 0.45	−3.23 (−11.08, 4.62), 0.42
Vape	30.4 (39.0)	34.5 (34.2)	30.3 (33.0)	1.85 (−6.49, 10.18), 0.66	3.94 (−3.72, 11.60), 0.31	3.94 (−3.72, 11.60), 0.31
Other	3.7 (14.8)	3.2 (14.4)	3.3 (15.6)	−1.61 (−4.54, 1.32), 0.28	0.92 (−1.85, 3.68), 0.51	−0.70 (−4.21, 2.82), 0.70

Significance testing conducted using linear regression. Models adjusted for sex, age group, education and ethnicity. β = unstandardized beta estimate; 95% CI = 95% confidence interval; SD = standard deviation.

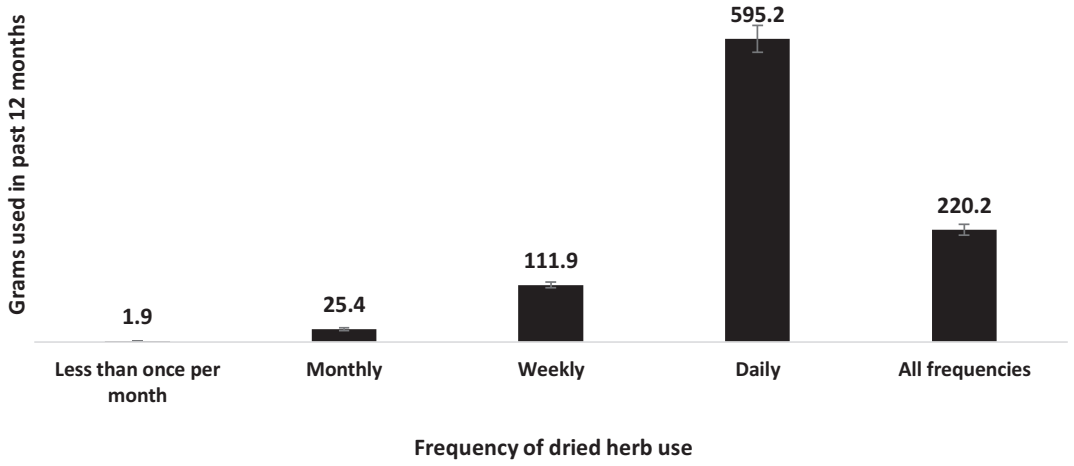

Fig. 2. Mean amount of dried herb used in past 12 months by frequency of use, among past 12-month users of dried herb (n = 5431). Error bars represent standard error of the mean. Mean amount per year did not differ significantly by jurisdiction ($p > 0.05$); the three jurisdictions are therefore collapsed.

establishing whether increases observed shortly before and after legalization are sustained.

In terms of quantity, although consumers in US 'legal' states reported using dried herb more frequently than those in 'illegal' jurisdictions, the amount of dried herb used over the past year was similar across jurisdictions. One possibility is that while frequency of consumption may increase in a legal market, the total amount used may be diffused over multiple sessions. The few other surveys that have measured cannabis consumption have reported quantity used on a 'typical day'. The CCS, a population-based survey of Canadians aged ≥16 years, reported a mean of 1.0 g dried flower/leaf per day among past 12-month users (2018), and a survey of US cannabis users aged 18–46 and 18–36 years reported means of 0.99 g and 1.32 g marijuana per day, respectively (Cuttler & Spradlin, 2017). By comparison, the current study provides lower consumption estimates: past 12-month users reported consuming an average of 0.60 g of dried herb per day. Differences in mean amounts used may relate to differences in response options: in the CCS, response options ranged from '1/20th g' to 'more than 28 g', with no reference images (Health, 2017, a) and a joint was assumed to be 0.33 g, based on work by Ridgeway and Kilmer (2016). The US survey allowed open-ended responses but showed images of dried herb ranging from 1/8th g to 28 g (Cuttler & Spradlin, 2017). In contrast, response options in the ICPS ranged from 1/8th g to 'more than ¼ oz', with additional response options for those who had consumed the highest amount. However, it is more likely that differences are attributable to the population sampled: the US survey surveyed undergraduate students (mean age 20 years), an age group known to have higher rates of cannabis use compared to the general population (2018; 2019). Finally, given the fact that not every cannabis user consumes dried herb daily, reporting average quantity per day is potentially misleading. Reporting consumption amounts by frequency of use provides a fuller picture: as shown in Fig. 2, daily users used about 1.63 g per day, or about 2.7 times more dried herb per day than the sample mean.

Consumption of cannabis concentrates, edibles and other product types was also more common in US states with a legal non-medical cannabis market. This is likely due to increased availability of a variety of product types in legal markets, and may be evidence of a transition from dried herb to other, more processed product types (Caulkins et al., 2018; Daniulaityte et al., 2018; Loflin & Earleywine, 2014; Smart, Caulkins, Kilmer, Davenport, & Midgette, 2017). The odds of using high-potency concentrates and cannabis edibles in the past year were 1.4–1.8 times higher in US legal states, after adjustment for socio-demographic factors. More striking differences were found in past 12-month use of vaped oils and cannabis-infused drinks, which were 1.5–2.5 times more prevalent in legal markets. These findings are consistent with data from the first states to legalize non-medical cannabis, which suggest a growing popularity of high-potency extracts and edibles in a legal market. In Washington, wax/shatter/resin/dabs accounted for 55% of the extract market in 2016, and vape cartridges for 34% (Caulkins et al., 2018). The average potency level of these products can be remarkably high: 2016 data from Washington indicated an average potency of 70% THC across extract categories (Caulkins et al., 2018). The increasing popularity of high potency products has been highlighted as a public health concern, although the potential health effects remain unclear (Brown, 2019; 2019; Ontario Public Health, 2019). Finally, the findings also indicate that consumers in legal markets are almost twice as likely to consume cannabis products often classified as 'medicinal', such as tinctures and topical ointments. The diversification of cannabis products, and the range of uses for which products are consumed, warrant greater attention in future studies, particularly with respect to understanding the factors that guide product selection for both medical and non-medical use. Indeed, previous research suggests that products such as high-potency concentrates are growing in popularity even among medical users (Loflin & Earleywine, 2014).

Routes of cannabis administration are not typically measured in national surveys or are assessed using different response options across surveys, making cross-country data difficult to compare. In our study, vaping dried herb or cannabis oils/liquids was less prevalent in Canada compared to US jurisdictions. Previous studies also point to higher rates of vaping in the US compared to Canada. Recent Canadian data suggest that 14% and 26% of past 12-month cannabis users had used vaporizers and vape pens, respectively (2018), and a recent study of US adolescents found that about 33% and 30% had ever vaped cannabis plant material (i.e., dried herb) and concentrates, respectively (Knapp et al., 2019). Previous US studies reported that 51% of past 12-month young adult users had vaped cannabis (Jones, Hill, Pardini & Meier, 2016) and that 61% of adults had *ever* vaped cannabis (Lee, Crosier, Borodovsky, Sargent & Budney, 2016). The distinction between vaping dried herb and concentrates is likely to be important. Vaped concentrates (i.e., THC vape oils) typically have substantially higher levels of THC than dried herb and are associated with greater impairment (2019, a; Loflin & Earleywine, 2014; Russell et al., 2018). Manufactured vape oils may also present greater acute health risks, as illustrated by the recent outbreak of vaping-related lung injuries in the US, which have been primarily related to THC vape oils as opposed to nicotine e-cigarettes (2019). Future iterations of the Lower-Risk Cannabis Use Guidelines, which encourage consumers to avoid smoking cannabis products (Fischer et al., 2017) may need to be updated in light of these data

suggesting that vaping may not represent a safe alternative to smoking.

Finally, the findings highlight the challenge of assessing consumption amounts across the diversity of cannabis products. Although the survey was cognitively tested with regular cannabis users (Goodman et al., 2019), the wide range of consumption quantities provided by respondents (see Supplementary Tables S2–S9) suggests that users have difficulties quantifying forms of cannabis other than dried herb. Few published studies have reported on consumption amounts of cannabis products other than dried herb (Callaghan et al., 2019; Cuttler & Spradlin, 2017), and while this data is collected in the NCS (Statistics, 2019, a), these results have not been included in public data summaries (e.g., Statistics, 2019, e, Statistics, 2019, f). Finally, public reports of consumption data from the CCS have been limited to a few sentences on consumption amounts on a typical usage day, and lack details on data cleaning (2017, 2018), making detailed comparisons with our data challenging. The subsequent wave of the current survey has been updated with enhanced images, standard units and consumption of each product type on the last or 'typical' usage day (see www.cannabisproject.ca/methods). These enhancements may facilitate future comparisons to national data. Overall, refinements in measuring consumption of alternative cannabis products in population-based surveys are urgently needed given the increasing popularity of these products.

Limitations

This study is subject to limitations common to survey research. Respondents were recruited using non-probability-based sampling; therefore, the findings do not provide nationally representative estimates. The data were weighted by age group, sex, region and education in all jurisdictions, and race in the US. However, the study samples were somewhat more highly educated than the national population in the US. In both countries, the ICPS sample had poorer self-reported general health compared to the national population, which is a feature of many non-probability samples (Fahimi, 2018). Rates of cannabis use in the US were also somewhat higher those from NSDUH, which are collected via face-to-face household interviews (2019). Given that cannabis remains an illicit substance federally in the US, the higher cannabis use and poorer self-reported health reported in the ICPS may be due partly due to the use of web surveys, which provide greater perceived anonymity than in-person or telephone-assisted interviews often used in national surveys (Hays, Liu & Kapteyn, 2015; Richman, Kiesler, Weisband & Drasgow, 1999; Tipping et al., 2010). Moreover, research has shown that estimates of cannabis use in the US tend to be lower from NSDUH compared to the National Health and Nutrition Examination Survey (Alshaarawy & Anthony, 2017). Finally, as described in the Measures section, multiple questions were used to provide an in-depth assessment of prevalence and frequency of cannabis use. In some cases, respondents provided conflicting responses (e.g., a minority of users reported using cannabis 'within the past 30 days' but using 'less than monthly'). This highlights the complexities of measuring cannabis use and the importance of measuring both prevalence and frequency.

Conclusions

While the amount of dried herb used did not differ across jurisdictions, both higher prevalence and frequency of cannabis use—including greater use of products such as cannabis edibles, drinks and high-potency concentrates—were observed in US 'legal' states. Compared to dried herb, these products have different properties (e.g., delayed onset and in many cases, higher potency), which should be highlighted in public health messaging in legal cannabis markets. As more jurisdictions continue to legalize non-medical cannabis, policies should address the growing use of higher potency products. In particular, more intuitive labeling of THC and potency is required to facilitate consumers in titrating their dose (Goodman & Hammond, 2020; Hammond, 2019; Leos-Toro, Fong, Meyer & Hammond, 2019). The impact of novel policy measures to restrict THC content also should be examined. These include the federal limit of 10 mg THC per package of cannabis edibles in Canada, as well as the 5 mg THC limit per unit of edibles and 30% THC limit on all other cannabis products in the Province of Quebec (2019, b; "Gazette officielle du québec," 2019). More generally, greater surveillance of the diversity of cannabis products and their consumption is required for adequate assessment of the impact of cannabis legalization and problematic patterns of use.

Declaration of Competing Interest

None.

CRediT authorship contribution statement

Samantha Goodman: Investigation, Formal analysis, Writing - original draft, Project administration. **Elle Wadsworth:** Investigation, Writing - review & editing. **Cesar Leos-Toro:** Writing - review & editing. **David Hammond:** Conceptualization, Methodology, Investigation, Writing - review & editing, Supervision, Funding acquisition.

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Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.drugpo.2019.102658.

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