

Research Paper

Trends in the use of cannabis products in Canada and the USA, 2018 – 2020: Findings from the International Cannabis Policy Study

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ABSTRACT

Background and Aims: There is little information on consumption patterns across the diverse range of cannabis product types. This paper examines trends in consumption patterns in Canada and the United States (US) between 2018–2020.

Design: Repeat cross-sectional surveys were conducted as part of the International Cannabis Policy Study online survey in 2018 (n=27,024), 2019 (n=45,426), and 2020 (n=45,180).

Setting: Respondents were recruited from commercial panels in Canada and US states that had and had not legalized non-medical cannabis (US ‘legal’ and ‘illegal’ states, respectively).

Participants: Respondents were male and female participants aged 16–65 years.

Measurements: Data on frequency and consumption amounts were collected for nine types of cannabis products, including dried flower and processed products (e.g., oils and concentrates). Consumers were also asked about mixing cannabis with tobacco. Socio-demographic information was collected.

Findings: Dried flower was the most commonly used product, although use in the past 12 months declined between 2018 and 2020 in Canada (81% to 73%), US legal (78% to 72%) and illegal states (81% to 76%; p<0.05 for all). Prevalence of past 12-month use increased for virtually all other product forms, although prevalence of daily use remained stable across years. In 2020, edibles and vape oils were the most commonly used products after flower. Use of non-flower products was highest in US legal states, although similar trends were observed in all jurisdictions. Males were more likely to report using processed products, and vape oils were the most commonly processed product among 16–20-year-olds. Daily use of cannabis flower increased in US legal and illegal states, and average joint size increased across all jurisdictions over time.

Conclusions: Dried flower remains the dominant product in Canada and the US; however, use of processed cannabis products has increased, with the largest increases observed in legal cannabis markets.

Introduction

The cannabis market in Canada and the US has rapidly diversified since the legalization of medical and non-medical (‘recreational’) cannabis. Although smoking dried flower remains the most common

mode of administration, the consumption of processed cannabis products such as edibles and concentrates has steadily increased over the past decade (Schauer et al., 2016; Spindle et al., 2019).¹ Cannabis edibles, orally consumed oils, and vape oils continue to increase in popularity, particularly in North American jurisdictions with legal cannabis retail markets (Goodman et al., 2020a). As of May 2021, Canada, Uruguay,

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¹ ‘Processed cannabis products’ refers to all forms of cannabis products other than dried flower.

and at least 18 US states have passed laws to legalize non-medical cannabis for adult use, while a broader range of countries and US states have legalized medical cannabis. Preliminary evidence suggests that consumers in jurisdictions with legal non-medical cannabis markets are more likely to use product types other than dried flower (Goodman et al., 2020; Borodovsky et al., 2017). However, the impact of cannabis legalization on forms and frequency of product use remain unclear due to the recency of non-medical cannabis legalization and strong secular trends in products in both legal and illegal cannabis markets.

As with other substances, mode of administration has important implications for cannabis potency, pharmacokinetic effects, and consumer patterns of use. Processed cannabis products have markedly different concentrations of delta-9-tetrahydrocannabinol (THC), the cannabinoid primarily responsible for the psychoactive effects (National Academies of Sciences, Engineering, and Medicine [NASEM], 2017). The THC concentration of dried flower has steadily increased over the past several decades, with typical levels around 20% (Freeman et al., 2021). In contrast, vape oils typically have 70% or greater THC concentration, with even higher levels in 'solid' concentrates, such as wax or shatter, which can be smoked or vaped (Carlini et al., 2017; Caulkins et al., 2018; Mahamad et al., 2020). The THC content of edibles is highly variable, with amounts ranging from several milligrams to several hundred milligrams of THC per product. THC levels may potentially increase the risks of cannabis dependence and adverse outcomes, although evidence on these effects is still emerging (Cinnamon Bidwell et al., 2018; Colorado Department of Public Health & Environment, 2020; Di Forti et al., 2019; Hines et al., 2020; Washington State Prevention Research Subcommittee, 2020).

THC is metabolized differently via different modes of administration, with different pharmacokinetic profiles and intoxicating effects (NASEM, 2017; Spindle et al., 2019). Inhaled forms of cannabis have quicker onset and shorter duration of effects than orally ingested forms. Transdermal products, such as topicals, have the slowest absorption and lowest intoxicating effects (Spindle et al., 2019). The health effects of cannabis can also vary across product forms. In terms of their acute effects, edibles are associated with the greatest difficulty in dosing and highest rate of adverse events from over-consumption and accidental consumption (Hammond, 2019; Monte et al., 2019; Noble et al., 2019; Wang et al., 2016). Health effects of extracts can also vary based on manufacturing standards. Most notably, THC vape oils from illicit sources containing vitamin E acetate were primarily responsible for the e-cigarette or vaping product use-associated lung injury (EVALI) outbreak in the USA in 2019, which claimed the lives of more than 60 consumers and sent several thousand to hospital (Blount et al., 2020; Krishnasamy et al., 2020; US Centers for Disease Control and Prevention, 2021).

The frequency of cannabis consumption is strongly associated with problematic patterns of cannabis use; however, to date, few studies have assessed whether this is also true of the quantity of cannabis consumed in its various forms (Chen et al., 1997; Grant & Pickering, 1998; Hall, 2015; Tomko et al., 2019; Walden & Earleywine, 2008). Therefore, while the number of cigarettes and alcoholic drinks are related to the adverse health effects of tobacco and alcohol use, there is less evidence on the quantity of cannabis consumed because of the challenges in measuring cannabis consumption and different populations considered (Asbridge et al., 2014; Kilmer & Pacula, 2009; Temple et al., 2011). One study estimated dried flower consumption at 2.0 g per day among daily consumers using self-reported data collected in 2013 and 2018 in Washington and New York State (Caulkins et al., 2020). A 2017 survey among US undergraduate students reported averages between 1.0–1.3 g per day (Cuttler & Spradlin, 2017), while a study of UK consumers reported an average of 1.2 g of cannabis among those who used more than three times per week (Pudney et al., 2006). Several studies have also measured joint sizes. Surveys conducted between 2001 and 2010 estimated the average joint size as 0.3–0.5 g (Kilmer & Pacula, 2009). Studies that directly measured joints rolled by consumers over the past decade have

reported average joint weights between 0.3 g among European consumers and approximately 0.6 g among US consumers (Casajuana Kögel et al., 2017; Hindocha et al., 2017; Mariani et al., 2011; Prince et al., 2018).

Given the recent emergence of new cannabis products, there is even less data on the quantity used of product forms other than dried flower. For example, despite the increased popularity of vaping as a mode of administration among young people, we are unaware of any published estimates of typical quantities of vape oils used (Fataar & Hammond, 2019; Hammond et al., 2021; Johnston et al., 2021). Improved measures of consumption for cannabis extracts are important to understand consumer patterns at the population level and to estimate behavioural changes in trials and treatment programs (Loflin et al., 2020).

The current study examined the use of different cannabis products in population-based surveys in Canada and the US. Specifically, the study examined changes over time in the prevalence of use of different cannabis products, the frequency of use and consumption amounts for each product type, mixing cannabis with tobacco, and sociodemographic correlates of consumption.

Methods

Data are cross-sectional findings from the first three annual waves of the International Cannabis Policy Study (ICPS), conducted in Canada and the US. Data were collected from respondents aged 16–65 via self-completed web-based surveys conducted in August–October 2018, and September–October in both 2019 and 2020. A non-probability sample of respondents was recruited through the Nielsen Consumer Insights Global Panel and their partners' panels. The Nielsen panels are recruited using a variety of probability and non-probability sampling methods. For the ICPS surveys, Nielsen draws stratified random samples from the online panels, with quotas based on age and state/province of residence. Upon completion, respondents received remuneration in accordance with their panel's usual incentive structure. Monetary incentives have been shown to increase response rates and decrease response bias in subgroups under-represented in surveys, including disadvantaged subgroups (Groves et al., 2009). The cooperation rate, which was calculated based on AAPOR Cooperation Rate #2 as the percentage of respondents who completed the survey of eligible respondents those who accessed the survey link, was 64.2% in 2018, 62.9% in 2019, and 62.0% in 2020 (American Association for Public Opinion Research, 2016). Surveys were conducted in English in the US and English or French in Canada. Median survey time was 20 minutes in 2018, 25 minutes in 2019, and 21 minutes in 2020.

The study was reviewed by and received ethics clearance through a University of Waterloo Research Ethics Committee (ORE#31330). A full description of the study methods can be found in the Technical Reports and methodology paper (Goodman et al., 2021; Hammond et al., 2020).

Measures

Socio-demographics

Respondents provided demographic information, including sex at birth, age group, ethnicity/race, highest education level, perceived income adequacy, and alcohol and tobacco use. Briefly, perceived income adequacy was assessed with a measure that is associated with objective measures of income and wealth (Litwin & Sapir, 2009), while ethnicity/race was assessed with country-specific measures drawn from the census or benchmark health surveys—see Table 1 for descriptions.

Frequency of cannabis product use

The ICPS surveys (available at www.cannabisproject.ca/methods) include a comprehensive series of questions on patterns of cannabis use. Respondents were asked about their use of nine cannabis products: dried flower (smoked or vaped), cannabis oils/liquids taken orally (e.g., drops

Table 1
International Cannabis Policy Study (ICPS) sample characteristics by jurisdiction and year (n=117,630) [% (n)].

Characteristic	Canada			US illegal states			US legal states ⁺		
	2018 n=9,976	2019 n=15,081	2020 n=15,571	2018 n=9,686	2019 n=10,235	2020 n=12,421	2018 n=7,362	2019 n=20,110	2020 n=17,188
Sex	$\chi^2(2)=0.01, p=0.999$			$\chi^2(2)=0.01, p=0.998$			$\chi^2(2)=0.24, p=0.950$		
Female	49.9% (4,974)	49.8% (7,516)	49.9% (7,766)	50.3% (4,874)	50.3% (5,151)	50.3% (6,245)	49.7% (3,661)	49.7% (10,005)	50.0% (8,591)
Male	50.1% (5,002)	50.2% (7,565)	50.1% (7,805)	49.7% (4,812)	49.7% (5,084)	49.7% (6,176)	50.3% (3,701)	50.3% (10,106)	50.0% (8,597)
Age group	$\chi^2(8)=9.45, p=0.709$			$\chi^2(8)=3.61, p=0.961$			$\chi^2(4)=36.33, p=0.049$		
16-25	18.8% (1,871)	18.6% (2,806)	18.4% (2,867)	19.9% (1,924)	19.8% (2,025)	20.2% (2,509)	19.5% (1,437)	19.7% (3,971)	19.5% (3,351)
26-35	20.6% (2,059)	20.8% (3,142)	21.0% (3,266)	21.4% (2,074)	21.6% (2,206)	20.9% (2,598)	22.9% (1,685)	22.6% (4,547)	22.3% (3,826)
36-45	19.6% (1,956)	19.8% (2,979)	20.0% (3,121)	19.0% (1,837)	19.0% (1,950)	19.3% (2,398)	17.3% (1,276)	19.4% (3,892)	19.7% (3,378)
46-55	20.9% (2,082)	20.0% (3,016)	19.5% (3,040)	20.2% (1,953)	19.9% (2,035)	19.6% (2,431)	21.8% (1,604)	19.4% (3,904)	19.4% (3,328)
56-65	20.1% (2,008)	20.8% (3,138)	21.0% (3,276)	19.6% (1,898)	19.7% (2,019)	19.7% (2,485)	20.0% (1,361)	18.5% (3,796)	19.2% (3,305)
Ethnicity	$\chi^2(2)=112.76, p<0.001$			$\chi^2(2)=0.83, p=0.794$			$\chi^2(2)=0.26, p=0.952$		
White	77.6% (7,743)	73.7% (11,117)	71.7% (11,157)	76.5% (7,410)	76.1% (7,789)	76.0% (9,438)	76.6% (5,643)	76.4% (15,355)	76.4% (13,138)
Other/Mixed/ Unstated	22.4% (2,233)	26.3% (3,964)	28.3% (4,414)	23.5% (2,276)	23.9% (2,446)	24.0% (2,983)	23.4% (1,719)	23.6% (4,755)	23.6% (4,050)
Education level	$\chi^2(6)=0.09, p=1.000$			$\chi^2(6)=152.21, p<0.001$			$\chi^2(6)= 458.73, p<0.001$		
Less than high school	15.6% (1,552)	15.6% (2,355)	15.5% (2,413)	15.2% (1,474)	12.1% (1,240)	11.1% (1,383)	11.8% (870)	5.1% (1,022)	6.4% (1,102)
High school or equivalent	26.8% (2,671)	26.8% (4,035)	26.8% (4,173)	19.5% (1,887)	22.6% (2,313)	24.3% (3,014)	16.0% (1,175)	20.3% (4,092)	20.7% (3,552)
Some college/ technical	32.7% (3,264)	32.7% (4,936)	32.7% (5,103)	38.4% (3,721)	36.5% (3,733)	35.7% (4,434)	42.2% (3,106)	41.9% (8,424)	39.9% (6,864)
Bachelor's degree	24.9% (2,489)	24.9% (3,755)	24.9% (3,882)	26.9% (2,604)	28.8% (2,949)	28.9% (3,589)	30.0% (2,212)	32.7% (6,573)	33.0% (5,670)
Income adequacy	$\chi^2(10)=150.34, p<0.001$			$\chi^2(10)=200.41, p<0.001$			$\chi^2(10)=222.85, p<0.001$		
Very difficult	8.2% (820)	9.6% (1,455)	7.6% (1,176)	9.3% (901)	10.7% (1,093)	9.2% (1,138)	8.8% (650)	10.1% (2,024)	7.9% (1,361)
Difficult	20.1% (2,001)	22.3% (3,364)	18.5% (2,885)	22.2% (2,153)	23.2% (2,375)	18.3% (2,273)	19.6% (1,440)	22.6% (4,548)	18.5% (3,181)
Neither easy nor difficult	36.0% (3,592)	35.1% (5,290)	37.6% (5,855)	31.6% (3,060)	33.1% (3,385)	34.7% (4,307)	32.2% (2,373)	33.2% (6,684)	35.6% (6,121)
Easy	21.4% (2,134)	19.8% (2,986)	22.1% (3,437)	22.0% (2,134)	19.0% (1,950)	22.0% (2,593)	20.9% (1,685)	22.9% (4,007)	21.7% (3,732)
Very easy	11.2% (1,118)	9.6% (1,445)	10.8% (1,675)	12.9% (1,248)	11.6% (1,185)	13.4% (1,664)	13.6% (1,005)	11.1% (2,239)	13.1% (2,253)
Unstated	3.1% (311)	3.6% (542)	3.5% (542)	2.0% (189)	2.4% (247)	3.6% (445)	2.8% (209)	3.0% (608)	3.1% (540)
Alcohol use	$\chi^2(2)=72.70, p<0.001$			$\chi^2(2)=20.45, p<0.001$			$\chi^2(2)=34.86, p<0.001$		
Past 12-month use	80.8% (8,084)	78.3% (11,809)	76.3% (11,873)	66.5% (6,235)	66.2% (6,773)	63.9% (7,936)	70.0% (5,538)	72.5% (14,579)	69.9% (12,019)
Less frequent use/ Unstated	19.2% (1,696)	21.7% (3,272)	23.7% (3,698)	33.5% (3,202)	33.8% (3,462)	36.1% (4,485)	30.0% (2,138)	27.5% (5,532)	30.1% (5,169)
Tobacco cigarette use	$\chi^2(2)=9.83, p=0.073$			$\chi^2(2)=0.01, p=0.996$			$\chi^2(2)=0.26, p=0.947$		
Past 30-day use	19.5% (1,944)	19.4% (2,924)	18.2% (2,830)	18.2% (1,761)	18.1% (1,855)	18.1% (2,253)	17.2% (1,266)	17.2% (3,467)	17.4% (2,993)
Less frequent use/ Unstated	80.5% (8,032)	80.6% (12,157)	81.8% (12,741)	81.8% (7,925)	81.9% (8,380)	81.9% (10,168)	82.8% (6,096)	82.8% (16,643)	82.6% (14,196)
Cannabis use status (exclusive categories)	$\chi^2(10)=203.72, p<0.001$			$\chi^2(10)=217.68, p<0.001$			$\chi^2(10)=302.21, p<0.001$		
Never user	43.4% (4,327)	37.9% (5,716)	39.1% (6,082)	45.3% (4,386)	37.6% (3,845)	42.9% (5,322)	38.5% (2,849)	30.6% (6,158)	36.3% (6,238)
Used >12 months ago	29.0% (2,897)	26.8% (4,045)	26.7% (4,159)	30.9% (2,997)	31.8% (3,256)	29.9% (3,709)	27.3% (2,011)	30.3% (6,096)	28.9% (4,967)
Used in past 12 months	8.6% (856)	11.3% (1,709)	10.2% (1,591)	7.0% (675)	8.2% (836)	6.7% (828)	9.4% (691)	10.1% (2,027)	8.1% (1,398)
Monthly user	4.9% (489)	7.0% (1,053)	6.4% (1,003)	5.2% (506)	6.1% (625)	5.2% (644)	6.8% (500)	6.3% (1,272)	6.7% (1,157)
Weekly user	5.2% (517)	5.7% (853)	5.7% (891)	4.2% (403)	4.7% (85)	4.4% (543)	6.8% (503)	6.3% (1,259)	6.1% (1,057)
Daily/almost daily user	8.9% (891)	11.3% (1,706)	11.8% (1,844)	7.4% (720)	11.6% (1,189)	11.1% (1,375)	11.3% (834)	16.4% (3,298)	13.8% (2,372)

χ^2 (df): Chi-test between years, within jurisdiction. ⁺Legal states refer to US states that had legalized non-medical cannabis at the time of data collection in each year.

or capsules), cannabis oil/liquid for vaping, edibles/foods, drinks, solid concentrates (e.g., wax, shatter), hash or kief, tinctures (e.g., concentrated amounts ingested orally or taken under the tongue), and topicals. Respondents reported whether they had used each of nine product types in the past 12 months (No; Yes, but not in past 12 months; Yes, in past

12 months; Don't know). Frequency of use of each product was assessed (Less than once a month; Monthly; Weekly; Daily; Don't know; Refuse to answer). Based on their reported frequency of use, they were asked to enter the average number of days over the past 12 months, days per month, days per week, or times per day, respectively, they used that

product type. Products that were reported as non-THC containing CBD products were not included.

Consumption amounts

For each product used in the past 12 months, respondents reported how much they used over the entire day on the “last day” of use. Respondents were then asked if that represented their usual consumption amount. If not, they were asked to indicate the amount they *usually* used on days when they use it. Images were displayed for each of the nine product categories to improve reporting accuracy. In the case of dried flower, respondents had the option of reporting amounts in joints, grams or ounces. Respondents who opted to report using joints could select their usual joint size from images of six different rolled joint sizes ranging from 0.2–1.2 grams. Respondents selected the usual joint size and indicated how much of each joint they consumed. Respondents who opted to report in grams or ounces could select from 12 different images, ranging from 1/8 gram to more than 1 ounce of dried flower. In all cases, a bottle cap was provided as a reference image. Open-ended responses were provided to respondents who reported purchasing more than one ounce. Images were also shown for the other eight product categories, with reporting units shown in Table 5. These measures were developed and modified based on previously published cognitive interviewing and extensive pilot testing (Goodman et al., 2019; Sikorski et al., 2021).

Dried flower mixed with tobacco

Consumers of dried flower were asked to report the percentage of dried flower that they: smoke mixed with tobacco; smoke without tobacco; vape; or ‘other’ way of consuming dried flower. Consumers were categorized as those that reported consuming dried flower mixed with any versus no tobacco.

Market share of dried flower users

In 2019 and 2020, we calculated the proportion of dried flower consumed by consumers of different usage frequencies by multiplying the number of days consumers used dried flower per year by their usual daily consumption of dried flower (in grams). Results were stratified by frequency of dried flower use.

Legal status of non-medical cannabis in Canada and US states

Legal states refer to those that have implemented non-medical (or ‘recreational’) cannabis laws (2018: Alaska, California, Colorado, Maine, Massachusetts, Nevada, Oregon, Vermont, Washington; Michigan and the District of Columbia were added in 2019; and Illinois was added in 2020). Canada legalized non-medical cannabis at the federal level in October 2018.

Data cleaning

Data on consumption amounts were cleaned to replace outliers using Winsorization and specify pre-defined upper and lower limits for each product type (described in Supplemental Table S1) (Caulkins et al., 2020). In 2020, variables were derived to represent the usual daily consumption of each of the nine product types consumed on days used. In some cases, this required converting multiple units to a standard unit (e.g., g or mL); for other product types, the variable represents number of products consumed per day or times used per day (see Table 5). For dried flower, frequency of use was recoded if respondents entered numeric values for daily/weekly/monthly/past 12-month use that were inconsistent with their stated frequency of dried flower use. Thresholds were ≥ 5 days per week or ≥ 1 time per day for daily use, 1-4 times per week for weekly use, 1-15 times per month for monthly use, and 1-30 days per year for less than monthly use.

Data analysis

The final cross-sectional samples comprised 27,169 (2018), 47,735 (2019) and 45,680 (2020) respondents, for a total sample size of 118,584. See Technical Reports for more detail on exclusions (www.cannabisproject.ca/methods). A sub-sample of 117,630 ($n=27,024$ in 2018, 45,426 in 2019, 45,180 in 2020) were analyzed after excluding 954 respondents with missing data on education.

Post-stratification sample weights were constructed based on known population targets. Respondents from Canada were classified into age-by-sex-by-province, education, and, except in 2018, age-by-smoking status groups. Respondents from the US legal states were classified into age-by-sex-by-legal state, region-by-race, education in 2018 and education-by-legal state in 2019 and 2020, and, except in 2018, age-by-smoking status groups. Respondents from the illegal states were classified into age-by-sex, region-by-race, education, and, except in 2018, age-by-smoking status groups. Correspondingly grouped population count and proportion estimates were obtained from Statistics Canada (Statistics Canada, 2020; Statistics Canada, 2016), and the U.S. Census Bureau (U.S. Census Bureau, 2019; 2020). Separately for Canada, US legal states, and US illegal states, a raking algorithm was applied to the cross-sectional analytic sample to compute weights that were calibrated to these groupings. Weights were rescaled to the sample size for Canada, US legal states and US illegal states. Estimates are weighted unless otherwise specified.

Binary logistic regression models were used to test the odds of using each product type in the past 12 months (1=Used in past 12 months; 0=Did not use in past 12 months) and frequency of using each product type (1=Weekly/daily; 0=Less frequently/Unstated; non-consumers were excluded) among past 12-month cannabis consumers. Repeated measures Generalized Estimating Equation (GEE) models were fit to examine differences in the prevalence of daily use across product types stratified by jurisdiction. Logistic regression models were also fit to examine changes in daily use of products across survey years stratified by jurisdiction. Finally, linear regression models were used to test for differences in mean joint size across survey years, within each jurisdiction, as well as differences in mean joint size among those who did versus did not mix dried flower with tobacco, in each jurisdiction and survey year. All models were adjusted for age group, sex, education, ethnicity/race, income adequacy, device type and cannabis use frequency (coded for models as less than monthly use, monthly/weekly use, daily/almost daily use). Analyses were conducted using survey procedures in SAS (SAS version 9.4, SAS Institute Inc., Cary, NC, USA).

Results

Sample characteristics

Sample characteristics are shown in Table 1. Approximately half of respondents were female, and mean age across the three survey years was 40.3 (SE=0.05) years.

Prevalence of different types of cannabis products

Fig. 1 shows the proportion of past 12-month cannabis consumers who reported each type of cannabis product in the past year, with tests of significant differences between 2018-2019 and 2019-2020 indicated with asterisks, as well as shown in Supplemental Table S2. Although dried flower was the most common product form, past 12-month use declined between 2018 and 2020 in all three jurisdictions. Between 2018 and 2020, edible use increased in all jurisdictions, with the largest increase in Canada between 2019 and 2020. In fact, in 2020, cannabis edibles were the second-most prevalent category in all jurisdictions, with the highest levels of edible use in US legal states.

Orally ingested oils increased by approximately 9 percentage points in all jurisdictions between 2018 and 2019, with the largest increases in

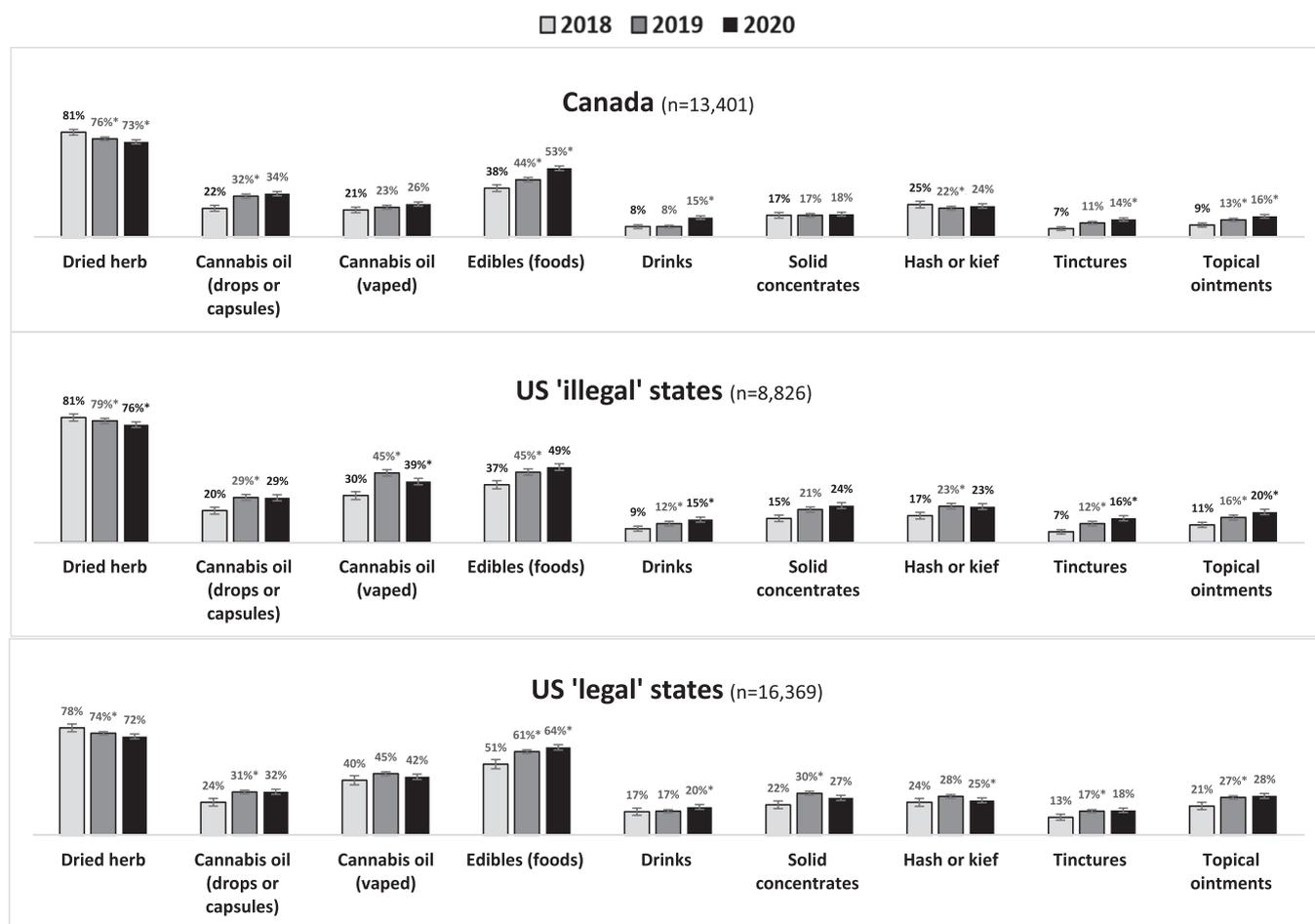


Fig. 1. Prevalence of using specific cannabis products in past 12-months, among all past 12-month cannabis consumers, by jurisdiction and year (weighted) Asterisks on 2019 and 2020 values indicate significant difference with previous year, within each jurisdiction, after adjusting for sex, age group, education, ethnicity, perceived income adequacy, cannabis use status and device type (*p<0.05). +‘Legal’ states refer to states that had legalized non-medical cannabis at the time of data collection in each year.

Canada, before stabilizing in 2020. Trends in vape oils diverged across three jurisdictions: Canada showed modest, but steady increases across the three years, whereas in US legal and illegal states, vape oils declined between 2019 and 2020. Despite these declines, use of vape oils remained substantially higher in US legal and illegal states than in Canada in 2020.

There were substantial increases in the use of solid concentrates in US legal and illegal states but no significant increase in Canada. All other product forms increased, with the notable exception of solid concentrates and hash/kief in Canada, which were stable between 2018 and 2020. By 2020, all three jurisdictions had similar prevalence of use of hash/kief, whereas solid concentrate use was substantially higher in all US states than Canada.

Consumption frequency by product type: Daily and near-daily use

Table 2 shows the frequency of use of each form of cannabis among past 12-month cannabis consumers. Across all three jurisdictions, dried flower had the highest proportion of daily use compared to all other product forms (p<.001 for all contrasts). Other than dried flower, oral liquids and vape oils had the highest prevalence of daily use in Canada, whereas edibles and vape oils had the highest prevalence of daily use in both illegal and legal US states (p<.001 for all contrasts). Across years, no significant changes were observed in daily use of individual product types between 2018 and 2020 in any of the three countries.

Differences by sex at birth and age

Table 3 shows ‘regular’ (weekly or daily/almost daily) consumption by sex at birth and age. In general, males reported greater weekly consumption of most product forms, including hash (Canada and illegal states), capsules (illegal and legal states, vape oils (illegal states), drinks and solid concentrates (legal and illegal states), as well as tinctures (illegal states) and dried flower (Canada). Topicals were the only product that females consistently used more than males across jurisdictions, with the exception of higher use of orally ingested oils among females in Canada.

As Table 3 indicates, regular consumption was highest among 21-35-year-old consumers for most product types. However, regular use of vape oils was equally common among 16-20-year-olds in Canada and US legal states. Indeed, after dried flower, vape oils had the highest prevalence of regular use among young people. One notable difference across jurisdictions was that consumers aged 36-65 in US legal states reported higher levels of regular consumption than in Canada and US illegal states for all product types.

Consumption of dried flower

Table 4 shows the usual joint size reported by past 12-month consumers of dried flower, by year and jurisdiction. Mean joint size increased from 2018 to 2020 by approximately 20% or 0.1 g in each jurisdiction. In 2020, usual joint sizes were highest in legal states (0.82

Table 2
Frequency of use of each form of cannabis among past 12-month cannabis consumers, by jurisdiction and year.

	Canada			US illegal states			US legal states ⁺		
	2018 n=2,752	2019 n=5,320	2020 n=5,329	2018 n=2,303	2019 n=3,134	2020 n=3,389	2018 n=2,529	2019 n=7,856	2020 n=5,984
Dried flower									
No past 12-month use	22.5%	26.4%	28.8%	24.3%	24.6%	26.3%	26.3%	28.1%	30.8%
<Once a month	21.4%	22.7%	20.3%	19.8%	20.8%	15.3%	17.4%	18.2%	15.9%
Monthly	12.3%	12.9%	11.2%	14.0%	12.6%	13.8%	11.6%	11.5%	11.1%
Weekly	18.4%	14.8%	15.7%	19.2%	18.7%	17.4%	20.4%	15.6%	17.0%
Daily	25.4%	23.2%	23.9%	22.7%	23.3%	27.3%	24.2%	26.6%	25.2%
Cannabis oil (drops)*									
No past 12-month use	78.7%	79.9%	81.1%	80.1%	82.1%	83.5%	77.4%	81.6%	82.0%
<Once a month	6.1%	7.5%	7.2%	5.3%	6.1%	4.9%	9.4%	7.5%	6.5%
Monthly	4.8%	4.3%	3.5%	4.3%	3.1%	4.3%	5.8%	3.9%	3.6%
Weekly	5.4%	4.0%	3.8%	6.4%	4.7%	4.6%	4.9%	3.8%	4.7%
Daily	5.0%	4.3%	4.3%	3.9%	4.0%	2.8%	2.6%	3.2%	3.2%
Cannabis oil (capsules)*									
No past 12-month use	–	91.3%	90.0%	–	91.6%	91.2%	–	91.5%	90.6%
<Once a month	–	3.5%	4.4%	–	2.4%	2.4%	–	3.0%	2.8%
Monthly	–	2.2%	2.1%	–	2.1%	2.7%	–	2.4%	2.7%
Weekly	–	1.5%	2.1%	–	2.8%	2.5%	–	2.1%	2.7%
Daily	–	1.5%	1.4%	–	1.1%	1.2%	–	1.0%	1.2%
Cannabis oil (vaped)									
No past 12-month use	79.6%	78.8%	77.5%	71.0%	58.0%	63.6%	61.6%	58.4%	60.8%
<Once a month	7.7%	10.7%	9.9%	9.6%	16.8%	13.4%	12.1%	16.1%	14.5%
Monthly	5.9%	4.1%	4.9%	6.7%	8.8%	8.3%	8.2%	7.4%	8.3%
Weekly	4.8%	4.1%	4.7%	8.3%	9.6%	8.2%	11.0%	10.4%	8.8%
Daily	2.1%	2.3%	3.1%	4.4%	6.8%	6.5%	7.0%	7.7%	7.7%
Edibles (foods)									
No past 12-month use	63.3%	58.0%	50.4%	63.7%	57.0%	54.2%	50.2%	42.6%	39.2%
<Once a month	19.9%	27.0%	29.0%	18.7%	24.9%	24.8%	20.1%	33.0%	30.2%
Monthly	9.0%	8.7%	10.6%	9.0%	10.7%	10.7%	15.5%	12.2%	14.4%
Weekly	5.5%	4.3%	7.5%	6.6%	6.2%	7.0%	11.1%	9.0%	12.0%
Daily	2.3%	1.9%	2.6%	2.1%	2.7%	3.3%	3.0%	3.2%	4.3%
Drinks									
No past 12-month use	92.3%	93.1%	87.0%	91.8%	90.3%	88.1%	83.7%	85.4%	82.3%
<Once a month	2.6%	3.2%	7.5%	1.4%	3.8%	4.1%	6.8%	8.7%	9.2%
Monthly	2.1%	1.6%	2.8%	1.9%	2.3%	3.4%	4.6%	2.7%	3.3%
Weekly	2.2%	1.2%	2.0%	3.4%	1.8%	2.4%	3.1%	2.2%	3.0%
Daily	0.7%	0.9%	0.7%	1.4%	1.8%	2.0%	1.8%	1.0%	2.2%
Solid concentrates									
No past 12-month use	83.9%	85.0%	85.3%	85.2%	81.8%	79.2%	79.2%	73.2%	76.4%
<Once a month	6.2%	8.0%	7.2%	5.4%	9.3%	9.6%	6.2%	11.9%	9.2%
Monthly	3.7%	2.7%	2.9%	3.3%	3.6%	5.0%	5.5%	5.3%	4.5%
Weekly	3.4%	2.4%	2.5%	3.6%	3.4%	3.2%	4.4%	4.6%	5.3%
Daily	2.9%	1.9%	2.1%	2.5%	1.9%	3.0%	4.7%	4.9%	4.6%
Hash or kief									
No past 12-month use	75.7%	80.8%	79.2%	83.6%	80.5%	80.8%	78.1%	76.5%	79.2%
<Once a month	11.0%	10.9%	11.0%	6.2%	10.3%	8.8%	8.1%	13.8%	11.1%
Monthly	5.4%	4.5%	4.7%	4.2%	4.0%	4.6%	6.6%	4.9%	4.7%
Weekly	5.2%	2.2%	3.1%	3.7%	3.3%	3.1%	5.4%	3.0%	3.2%
Daily	2.6%	1.6%	1.9%	2.3%	1.8%	2.8%	1.8%	1.8%	1.9%
Tinctures									
No past 12-month use	93.8%	90.9%	89.4%	93.7%	90.0%	87.7%	88.2%	86.0%	85.3%
<Once a month	2.0%	4.9%	5.2%	1.1%	3.5%	4.8%	3.9%	7.2%	7.0%
Monthly	1.5%	1.3%	1.9%	1.9%	2.0%	3.0%	2.7%	2.5%	2.9%
Weekly	1.6%	1.4%	2.1%	1.7%	2.5%	2.2%	3.3%	2.5%	2.6%
Daily	1.1%	1.5%	1.4%	1.6%	2.0%	2.3%	1.9%	1.9%	2.2%
Topical ointments									
No past 12-month use	91.1%	88.7%	86.5%	89.8%	86.3%	83.8%	80.2%	76.3%	74.8%
<Once a month	2.1%	5.2%	5.2%	2.5%	5.1%	5.1%	6.2%	10.2%	9.7%
Monthly	1.9%	2.4%	3.3%	2.5%	2.6%	4.2%	4.7%	4.8%	4.8%
Weekly	2.9%	2.3%	3.3%	3.2%	2.9%	3.9%	4.8%	4.9%	7.0%
Daily	1.9%	1.5%	1.7%	2.1%	3.0%	3.0%	4.2%	3.7%	3.7%

⁺ ‘Legal’ states refer to states that had legalized non-medical cannabis at the time of data collection in each year. *In 2018, item wording was “cannabis oils or liquids taken orally (e.g., drops)”; in 2019 and 2020, this category was split into “drops” and “capsules”. Prevalence of using drops but not capsules is shown for 2018; caution should be taken when comparing years for this category, as some capsule consumers may be included in the 2018 value for drops.

Table 3

Prevalence of weekly or daily/almost daily consumption of each cannabis product type by jurisdiction and age group, among past 12-month cannabis consumers, 2020.

		Dried flower	Cannabis oil (drops)	Cannabis oil (capsules)	Cannabis oil (vaped)	Edibles (foods)	Drinks	Solid concentrates	Hash or kief	Tinctures	Topical ointments
Canada n=5,329	Sex										
	Female (<i>ref</i>)	36.1%	9.8%	3.2%	7.5%	10.3%	2.1%	4.0%	3.5%	3.6%	6.5%
	Male	42.8 %*	6.7%***	3.8%	8.0%	9.8%	3.3%	5.2%	6.3%**	3.5%	3.7%***
	Age										
	16-20 years (<i>ref</i>)	31.7%	1.3%	1.3%	8.8%	5.8%	1.0%	3.9%	6.2%	1.3%	2.3%
	21-35 years	41.4%	6.9%**	3.1%	9.6%	12.0%*	4.4%	6.8%	6.0%	3.4%	5.0%
	36-65 years	40.3%*	10.5%***	4.3%	6.4%*	9.8%	2.1%	3.4%	4.1%	4.1%*	5.7%
US illegal states n=3,389	Sex										
	Female (<i>ref</i>)	42.4%	6.2%	1.9%	11.9%	8.5%	1.9%	5.2%	3.2%	2.8%	7.1%
	Male	46.6%	8.4%	5.2%*	17.2%*	11.8%	6.6%**	7.0%	8.2%***	6.0%*	6.7%
	Age										
	16-20 years (<i>ref</i>)	34.7%	3.3%	1.2%	13.4%	8.6%	1.7%	7.3%	6.3%	1.7%	4.3%
	21-35 years	45.8%	8.9%	5.7%	20.6%	14.1%	7.5%	7.8%	8.7%	7.0%	8.1%
	36-65 years	46.4%	7.4%	2.9%	11.1%*	8.1%	3.0%	4.7%***	3.9%*	3.5%	6.8%
US legal states⁺ n=5,984	Sex										
	Female (<i>ref</i>)	39.8%	6.8%	1.9%	15.1%	15.2%	2.5%	6.4%	3.9%	4.4%	12.0%
	Male	44.4%	9.0%	5.7%***	17.8%	17.2%	7.7%**	13.1%***	6.1%	5.1%	9.5%**
	Age										
	16-20 years (<i>ref</i>)	28.4%	2.3%	1.9%	19.4%	6.8%	1.1%	10.6%	4.1%	0.9%	3.8%
	21-35 years	44.4%**	8.6%*	5.6%	19.4%	15.3%	6.7%	13.2%	6.6%	5.1%*	10.9%*
	36-65 years	42.6%**	8.3%*	3.0%	13.9%**	18.3%*	4.7%	7.4%*	4.0%	5.1%*	11.6%*

Ref, reference group. Asterisks indicate significant difference (*p<0.05.

** p<0.01

*** p<0.001) between males and females, and between ages 21-35 and 36+ and age 16-20, within each jurisdiction, after adjusting for sex, age group, education, ethnicity, perceived income adequacy, cannabis use status and device type. ⁺'Legal' states refer to states that had legalized non-medical cannabis at the time of data collection in each year.

Table 4
Usual dried flower consumption among past 12-month consumers of dried flower, by jurisdiction and year.

Usual joint size (g) among those who reported consumption in joints [†] , % (n)									
	Canada			US illegal states			US legal states ^{††}		
	2018 (n=1,453)	2019 (n=2,958)	2020 (n=2,823)	2018 (n=1,131)	2019 (n=1,687)	2020 (n=1,674)	2018 (n=1,059)	2019 (n=3,549)	2020 (n=2,631)
0.2 g	23.3%	13.5%	10.7%	17.6%	15.4%	11.9%	14.7%	11.3%	9.0%
0.4 g	21.1%	19.1%	19.3%	16.7%	14.9%	16.6%	16.0%	12.5%	11.3%
0.6 g	16.0%	17.1%	15.8%	17.3%	12.3%	13.1%	17.0%	12.9%	13.8%
0.8 g	16.7%	15.8%	17.3%	15.6%	13.5%	13.8%	16.1%	11.9%	11.0%
1.0 g	17.3%	24.9%	26.9%	22.0%	25.8%	25.5%	27.2%	31.8%	34.2%
1.2 g	5.6%	8.8%	10.1%	10.8%	18.1%	19.1%	8.9%	19.5%	20.7%
Mean g (SD)	0.60 (0.32)	0.69 (0.32) ^{***}	0.72 (0.31) ^{**}	0.68 (0.33)	0.75 (0.35) ^{***}	0.76 (0.34)	0.70 (0.32)	0.80 (0.33) ^{***}	0.82 (0.32) [*]
Median	0.60	0.60	0.80	0.60	0.80	0.80	0.80	1.00	1.00
Usual amount (g) of dried flower consumed per day, on days used, reported in joints or weight (g/oz), among past 12-month dried flower consumers ^{†††}									
	Canada			US illegal states			US legal states		
	2018	2019 (n=3,946)	2020 (n=3,812)	2018	2019 (n=2,394)	2020 (n=2,495)	2018	2019 (n=5,634)	2020 (n=4,176)
All past 12-month consumers									
Mean (SD)	–	0.98 (1.25)	1.12 (1.43)	–	1.37 (1.62)	1.41 (1.66)	–	1.27 (1.56)	1.35 (1.64)
Median		0.50	0.60		0.80	0.80		0.60	0.75
< once a month									
Mean (SD)	–	0.45 (0.73)	0.48 (0.79)	–	0.80 (1.26)	0.70 (1.20)	–	0.57 (0.95)	0.64 (1.04)
Median		0.20	0.20		0.25	0.25		0.20	0.25
Monthly									
Mean (SD)	–	0.75 (0.93)	0.76 (0.83)	–	1.15 (1.55)	1.15 (1.40)	–	0.98 (1.22)	0.97 (1.24)
Median		0.43	0.50		0.50	0.60		0.50	0.50
Weekly									
Mean (SD)	–	0.87 (0.99)	0.94 (1.00)	–	1.25 (1.39)	1.12 (1.42)	–	1.13 (1.43)	1.13 (1.34)
Median		0.50	0.60		0.80	0.60		0.60	0.60
Daily/almost daily									
Mean (SD)	–	1.65 (1.56)	1.93 (1.79)	–	2.00 (1.82)	1.96 (1.82)	–	1.90 (1.80)	2.05 (1.94)
Median		1.00	1.20		1.20	1.20		1.20	1.20

[†] Joint sizes were measured using the same response options in both years; however, wording was changed from 'Please choose the joint that is closest to the size you normally smoke' in 2018 to 'Think of the LAST DAY you smoked a joint. Please choose the joint that is closest to the size you smoked' in 2019. ^{††}'Legal' states refer to states that had legalized non-medical cannabis at the time of data collection in each year. ^{†††}Dried flower consumption was measured differently in 2018 vs. 2019/2020. As such, 2018 data have been suppressed. Asterisks on 2019 and 2020 values indicate significant differences (*p<0.05

** p<0.01

*** p<0.001) between 2018 vs. 2019 and 2019 vs. 2020, respectively, within each jurisdiction, after adjusting for sex, age group, education, ethnicity, perceived income adequacy, cannabis use status and device type.

g), followed by illegal (0.76 g) and Canada (0.72 g). One gram was the most popular joint size in all jurisdictions in 2020.

In 2020, joint sizes were smaller among Canadian consumers who reported mixing any dried flower with tobacco versus those who did not mix dried flower with tobacco (mean=0.66 g vs. 0.73 g; $t=4.12$, $p=0.042$). No differences were observed among those who did versus did not mix with tobacco in US illegal (0.73 g vs. 0.77 g; $p=0.373$) or legal states (0.84 g vs. 0.82 g; $p=0.828$); see Supplemental Table S3.

Table 4 also shows usual amount of dried flower consumed on days used. In 2020, the overall amount of dried flower consumed (reported in either weight or joint size) was somewhat higher in US legal (1.35 g) and illegal states (1.41 g) than Canada (1.12 g). Typical consumption amounts increased as the frequency of consumption increased, with daily consumers reporting three to four times the consumption of less than monthly consumers. We estimated that 87.1% of all dried flower was consumed by daily/almost daily consumers, after accounting for frequency of cannabis use (i.e., days per year) and consumption amounts during days of use. This compared to 9.7% for weekly consumers, 3.0% for monthly consumers (3.0%) and 0.3% for less than monthly con-

sumers in 2020. The same values for 2019 differed by less than 1 percentage point for each usage category (data not shown).

Consumption of processed cannabis products

Table 5 shows consumption patterns for products other than dried flower in 2020. Overall, the amounts consumed were generally higher in US illegal states than US legal states and Canada. Canada has the lowest levels of use of oral and vaped cannabis oils. With only a few exceptions, amounts consumed per day for of all product types were higher among daily/almost daily than past-year consumers.

Discussion

The current study provides one of the most comprehensive assessments of cannabis consumption at the population level in Canada and the US to date. The findings highlight the rapidly evolving nature of the cannabis product market, including notable shifts in the types of cannabis products used by consumers. Although dried flower continues to be the dominant cannabis product in the US and Canada, the findings

Table 5
Usual daily consumption amounts among past 12-month consumers of non-flower cannabis products, 2020.

	Canada			US illegal states			US legal states ⁺		
	n	Mean (SD)	Median	n	Mean (SD)	Median	n	Mean (SD)	Median
Cannabis oil – drops (mL/day)									
All past 12-month consumers	827	2.34 (4.87)	1.00	440	4.25 (7.75)	1.00	828	3.23 (6.53)	1.00
Daily/almost daily consumers	201	2.16 (3.93)	1.00	70	4.80 (8.19)	1.00	166	4.04 (7.17)	1.00
Cannabis oil – capsules (#/day)									
All past 12-month consumers	447	2.71 (2.73)	2.00	228	3.29 (3.17)	2.00	448	2.86 (2.57)	2.00
Daily/almost daily consumers	61	2.61 (2.35)	2.00	28	4.84 (3.33)	5.00	52	4.58 (3.79)	3.00
Cannabis oil – vaped (times/day)									
All past 12-month consumers	902	3.05 (2.85)	2.00	986	3.87 (3.20)	3.00	1,862	3.66 (3.05)	3.00
Daily/almost daily consumers	124	3.77 (3.39)	2.00	188	5.66 (3.57)	5.00	377	5.02 (3.59)	4.00
Edibles/foods (#/day)									
All past 12-month consumers	2,627	1.37 (1.30)	1.00	1,513	1.53 (1.43)	1.00	3,595	1.49 (1.39)	1.00
Daily/almost daily consumers	134	1.80 (1.62)	1.00	104	2.26 (1.90)	2.00	248	1.92 (1.56)	1.00
Drinks (#/day)									
All past 12-month consumers	664	0.92 (0.43)	1.00	392	1.04 (0.65)	1.00	1,061	0.92 (0.50)	1.00
Daily/almost daily consumers	25	0.95 (0.52)	1.00	62	1.00 (0.58)	1.00	126	1.17 (0.90)	1.00
Concentrates (g/day)									
All past 12-month consumers	482	1.23 (1.61)	0.50	466	1.25 (1.58)	0.83	987	1.18 (1.60)	0.50
Daily/almost daily consumers	70	1.76 (1.99)	1.00	65	2.08 (2.17)	1.00	233	1.26 (1.59)	0.50
Hash or kief (g/day)									
All past 12-month consumers	699	1.08 (1.32)	0.73	393	1.41 (1.50)	1.00	766	1.10 (1.33)	0.50
Daily/almost daily consumers	56	1.04 (1.26)	0.50	51	2.46 (1.73)	2.00	78	2.01 (1.57)	2.00
Tinctures (mL/day)									
All past 12-month consumers	402	4.50 (8.77)	1.00	296	6.24 (10.51)	1.00	608	4.58 (9.19)	1.00
Daily/almost daily consumers	57	2.51 (6.59)	1.00	64	8.09 (11.52)	1.10	94	4.06 (6.81)	1.00
Topical ointments (mL/day)									
All past 12-month consumers	472	1.20 (0.96)	0.88	369	1.52 (1.27)	1.12	1,070	1.31 (1.06)	0.88
Daily/almost daily consumers	58	1.45 (1.07)	1.12	67	2.17 (1.47)	1.76	157	1.65 (1.25)	1.12

⁺ ‘Legal’ states refer to states that had legalized non-medical cannabis at the time of data collection in each year.

indicate a potential shift from dried flower to other forms of cannabis. The use of dried flower declined between 5 to 8 percentage points over the three-year period of study, in parallel with a rise in the use of processed cannabis products. The findings also indicate changes to the size of joints, which are the most common form of smoking dried flower. Among Canadian consumers, 0.2 g was the most prevalent joint size in 2018, compared to 1.0 g in 2020, with a similar increase among US consumers. In 2020, the average joint size across all jurisdictions was 0.72–0.82 g, considerably higher than estimates from previous studies, which ranged between 0.3–0.5 g of cannabis (Hindocha et al., 2016; Ridgeway & Kilmer, 2016). The increased joint size may reflect the popularity of ‘pre-rolled’ joints, which are typically sold in 0.5-g and 1.0-g sizes (Ontario Cannabis Store, 2020). Despite increases in the average joint size, the average amount of dried flower used by consumers was relatively stable across years, apart from modest increases among Canadian consumers. Future research should examine whether changes in joint size are associated with changes in intake among consumers, or whether cannabis consumers ‘compensate’ for changes in product

forms in the same way that tobacco smokers compensate for changes in cigarette to maintain a consistent nicotine intake (U.S. Department of Health and Human Services, 2014). These findings also have implications for studies that rely upon a ‘standard’ joint size to estimate individual consumption or overall market size (Callaghan et al., 2019; Health Canada, 2019; Zeisser et al., 2022). Previous studies that assume smaller joint sizes may underestimate aggregate estimates of cannabis consumption. In addition, the wide variability in joint size reported by consumers suggests that using a single ‘standard’ joint size to predict individual consumption may be subject to considerable measurement error.

Consumption data highlights the importance of daily cannabis consumers as a priority group for cannabis policy. Daily consumers accounted for 87% of all dried flower consumed due to more frequent consumption and higher consumption amounts on days of use compared to non-daily consumers, consistent with prior studies (Caulkins et al., 2018; Caulkins et al., 2020; Zeisser et al., 2022). Thus, although daily consumers account for only one third of all cannabis consumers, they

play a dominant role in dictating market trends in terms of aggregate demand and product-specific trends. Daily consumers may be particularly influential in determining the effectiveness of cannabis regulations in legal markets. For example, research from Canada indicates that daily consumers were slower to transition to legal retail sources following legalization of Canada (Wadsworth et al., 2022). More generally, the markedly higher consumption levels among daily consumers places them at greater risks of adverse health effects and warrant special consideration in public education messaging (NASEM, 2017).

The use of all processed cannabis products increased between 2018 and 2020, with the exception of hash and solid concentrates in Canada, and hash in US illegal states. Edibles and oils were the most commonly used cannabis-derived products. Edibles had the highest annual prevalence of use of any derived product, but were only the second or third most popular product used daily after vape oils (all jurisdictions), oral oils (Canada), and solid concentrates (US legal states). These findings suggest that edibles may be consumed to a greater extent for specific occasions, in contrast to vape oils which are more often used daily. Vape oils are known for their convenience, are more discrete, and provide rapid onset similar to smoked products; in addition, vape oils typically have very high THC levels, similar to solid concentrates.

The extent to which cannabis legalization has influenced the types of products used by consumers remains an important policy question. Differences in the product trends between jurisdictions provide several indications that cannabis legalization may have increased the use of processed cannabis products. First, US legal states had a higher prevalence of use for all processed products, and lower use of dried flower. Notably, edible use was substantially higher in US legal states: 64% of consumers reported past 12-month use in 2020, approaching the 72% level that reported dried flower use. Product trends in Canada are also consistent with the dates in which specific products became legally available following non-medical legalization in October 2018. During the first 12 months after legalization in October 2018, only dried flower and some oral oils were available in legal retail stores. This is reflected in the data, in which the largest increase in oral oils occurred in Canada between 2018 and 2019. All remaining cannabis-derived products, including edibles and vape oils, were legally available for sale in Canada in early 2020, the period with the largest increase in the use of cannabis edibles and drinks. In contrast, use of vape oils increased steadily in Canada between 2018 and 2020, but with no greater increase post-legalization between 2019 and 2020. These findings may reflect the popularity of vape oils prior to legalization and consumers' concerns about the EVALI outbreak, which occurred in late 2019. The use of vape oils in US legal and illegal states showed a similar plateau and even a decrease between 2019 and 2020, coinciding with the EVALI outbreak (U.S. Centers for Disease Control and Prevention, 2021). The current findings on the use of cannabis-derived products are highly consistent with two Canadian national monitoring surveys conducted in 2020 (Rotermann, 2021; Health Canada, 2020). We are unaware of national data from US studies for comparison.

This study is among the first to quantify patterns of consumption for a range of diverse cannabis products across different jurisdictions. Quantifying consumption for processed cannabis products is important for estimating overall market demand and for advancing our understanding of the potential risks of dependence or other health outcomes. Similar consumption frequencies were reported across jurisdictions, although amounts were somewhat higher in US illegal states than US legal states and Canada in 2020. The reasons for this are not entirely clear, but may reflect the availability and proliferation of hemp-derived products throughout the US after the 2018 Federal Farm Bill, which removed hemp and hemp-derived products from Schedule 1 of the Controlled Substances Act, effectively legalizing hemp-derived CBD products that contain negligible levels of THC (Congressional Research Services, 2019). The availability of only low THC cannabis-derived products in US illegal states may increase their consumer appeal. Unfortunately, there is little data from other studies to compare consumption

amounts for processed cannabis products. The current study found an average of 1.2 g of concentrate consumed per usage day. An experimental study of *ad libitum* use of concentrates found that consumers used an average of 0.1 g of concentrate during a single session (Cinnamon Bidwell et al., 2020), similar to a previous study in which consumers used approximately 0.9 g of concentrate per dab (Prince et al., 2018). If these estimates are combined with findings from another study, in which concentrate consumers an average of report 3.8 'hits' per day (Cutler & Spradlin, 2017), this would suggest consumers consume approximately 0.5 g of concentrate per day. In comparison, the estimate of 1.2 g per day from the current study is considerably higher. Participants may have overestimated daily intake of concentrates, despite the use of images to assist with self-reporting (Prince et al., 2018).

Consistent with previous research, notable sex differences were observed in cannabis consumption (Callaghan et al., 2019). In general, males were more likely than females to report daily/almost daily use. A notable exception was greater use of topicals among females, which may reflect the greater use of topical creams and ointments as beauty and health care products. Cannabis consumption also varied by age. Young adults aged 21-35 years reported the highest consumption of most product forms (Callaghan et al., 2019). Previous studies have also found that pre-rolled joints, vape pens, and edibles are more prevalent among younger consumers, with few age or sex differences for ingestible oils, topicals, and tinctures (Ueno et al., 2021). Vape oils were particularly popular among 16-20-year-olds. This is consistent with other findings on the popularity of vaping cannabis and nicotine among young people (Fataar & Hammond, 2019; Hammond et al., 2021; Johnston et al., 2021). One potential difference across jurisdictions emerged, in that 36-65-year-olds in US legal states were more likely to be frequent consumers of most product types than 16-20-year-olds. This was the case for only a few product types in other jurisdictions. It may reflect greater 'normalization' of cannabis use among adult consumers after legalization.

Limitations

This study is subject to limitations common to survey research. Data are repeat cross-sectional and cannot speak to individual-level changes over time, including how shifts in the types of products affects consumption amounts. Respondents were recruited using non-probability-based sampling; therefore, the findings do not necessarily provide nationally representative estimates. The data were weighted by age group, sex, region, education and smoking status (in 2019-2020) in both countries and region-by-race in the US, but the US sample had fewer respondents with low education levels and Hispanic ethnicity than the US population. Cannabis use estimates were within the range of national estimates for young adults, whereas estimates among the full ICPS sample were generally higher than national surveys in the US and Canada. This is likely due to the fact that the ICPS sampled individuals aged 16-65, whereas the national surveys included older adults, who have lower rates of cannabis use. In both countries, the ICPS sample also had poorer self-reported general health than the national population, which is a feature of many non-probability samples (Fahimi et al., 2018). The higher prevalence of use may be partly due to the use of web surveys, which provide greater perceived anonymity than the in-person and telephone-assisted interviews often used in national surveys (Fahimi et al., 2018). As noted earlier, comparisons between the current sample and nationally representative data from Canada suggest a high level of comparability for the use of different cannabis product categories (Health Canada, 2019; 2020). No similar 'benchmark' data is available for comparison with nationally-representative data in the US due to gaps in government surveillance surveys (Geissler et al., 2020).

The ability of consumers to accurately self-report their cannabis consumption also represents a potential limitation. Previous research found that frequent consumers overestimated the amount of cannabis they consumed when asked to report amounts in grams (Prince et al., 2018).

However, the ICPS surveys have several advantages over previous studies (Caulkins et al., 2020; Cuttler & Spradlin, 2017): the surveys use detailed prompts tailored to consumers' frequency of use, and used images to assist consumers when reporting consumption amounts. Images were also tailored for each processed cannabis product, such as images of liquid 'droppers' and common bottle sizes for oral oils, and images of 1 g of hash and various types of solid concentrate. Nevertheless, the measurement of cannabis consumption would benefit from additional validation work, including comparisons between self-reported estimates and sales data in legal cannabis markets. Unlike self-reported data, sales data do not reflect products sources from illegal markets, which may differ; however, preliminary analyses of legal sales data suggest similar patterns, including the increasing popularity of pre-rolled joints and processed cannabis products (Ontario Cannabis Store, 2020).

Although it would be desirable to compare the level of THC consumption among cannabis consumers in self-reported surveys (Freeman & Lorenzetti, 2020; National Institute of Drug Abuse, 2021), self-reported THC content is largely unreliable due to inconsistent product labelling and consumers' lack of familiarity with the units and concentrations in which THC content is communicated (Hammond & Goodman, 2020). There is also a need to examine how consumers report THC-containing versus non-THC containing hemp-derived products, such as CBD products.

Finally, the study compared legal US states that had legalized non-medical cannabis versus other illegal states but did not reflect differences between states that had and had not legalized medical cannabis. Future research should examine potential differences between medical and non-medical states, and the potential impact of different regulatory standards between legal markets, such as Canada's requirement that edibles can contain a maximum of 10 mg of THC.

Conclusion

Overall, the findings depict a diverse and rapidly evolving cannabis market. Although dried flower continues to dominate the market, it has begun declining with a notable shift towards increasing popularity of processed cannabis products. The impact of cannabis legalization on different forms of product use remains unclear: similar trends were observed in all jurisdictions, the use of processed products was somewhat greater in legal markets. The impact of this shift has implications for public health impact of cannabis, as well regulatory approaches to encourage less harmful modes of cannabis use: processed cannabis products offer potential advantages such as non-combusted forms of delivery, as well as potential risks, such as higher THC concentration and contaminants from poor manufacturing standards. Finally, there is a need to improve measures of cannabis consumption in the population, particularly processed cannabis products. More detailed measures of consumption are particularly important given the emergence of non-THC containing cannabis products, such as CBD products and Delta-8 THC, which have the potential to distort prevalence estimates in monitoring surveys that do not distinguish between these product categories (Goodman et al., 2020b).

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Declaration of Competing Interest

The authors have no conflicts of interest to declare.

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Supplementary materials

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