

# Prevalence and modes of cannabis use among youth in Canada, England, and the US, 2017 to 2019

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## ABSTRACT

**Objective:** Cannabis markets are evolving in terms of greater diversity and potency of products. The current study examined changes in cannabis use and modes of consumption among 16- to 19-year-olds in three markets with different regulatory frameworks: England, Canada, and the United States (US).

**Methods:** Repeat cross-sectional online surveys were conducted in 2017, 2018, and 2019, with samples of 16- to 19-year-olds recruited from commercial panels in Canada (n = 11,779), England (n = 11,117), and the US (n = 11,869). Regression models examined changes in the prevalence of any cannabis use and use of seven modes of consumption, across the countries.

**Results:** Cannabis use among youth was more prevalent among respondents in Canada and the US than in England in all years and increased to a greater extent between 2017 and 2019 (p < .001 for all contrasts). Among past 30-day cannabis consumers, the prevalence of vaping oils/liquids and the use of cannabis extracts (oil, wax and shatter) increased in all countries, and was significantly higher in Canada and US. For example, the prevalence of vaping oils/liquids increased from 24.2 % in 2017 to 52.1 % in 2019 among past 30-day cannabis consumers in the US (AOR = 3.46, 95 %CI = 2.57–4.66).

**Conclusion:** Prevalence is increasing for the most potent categories of cannabis products, particularly among youth in Canada and the US. Future research should examine the potential risks of these products and whether shifts in modes of cannabis reflect recent permissive changes to cannabis policy.

## 1. Introduction

Cannabis is the most widely used “illicit” substance in the world (United Nations Office of Drugs and Crime, 2019). There is a growing trend towards more permissive cannabis policies, particularly in North America. In the United States (US), 33 states have legalized medical cannabis, while 11 states and the District of Columbia (DC) have legalized recreational cannabis for adults aged 21 years and older (Smart and Pacula, 2019). In Canada, medical cannabis has been legally available since 2001, and recreational cannabis was legalized in October 2018 for adults over 18 years. An increasing number of countries outside North America have also legalized medical cannabis, although access remains tightly controlled in many cases. For example, the United Kingdom (UK) rescheduled previously unlicensed cannabis-based products to be prescribed legally in November 2018; however, prescriptions to date have been minimal given that national guidelines on cannabis-based products were only released in November 2019

(Freeman et al., 2019).

To date, there is relatively little evidence regarding the impact of cannabis legalization on youth (Smart and Pacula, 2019). Research on medical cannabis laws in the US indicates that cannabis use is more prevalent in states where medical cannabis is legal; however, these differences reflect pre-existing trends, with similar trends between states that have and have not legalized medical cannabis (Melchior et al., 2019; Smart and Pacula, 2019). Evidence on the impact of recreational cannabis legalization is mixed, in part due to the recency of implementation of recreational cannabis laws and the time required to establish legal retail markets (Dilley et al., 2019; Smart and Pacula, 2019). Analyses of cannabis policies in European countries have also found no consistent association between prevalence and policy liberalization (Stevens, 2019).

Cannabis policies also have the potential to influence the types of cannabis products used by youth. Smoking dried flower remains the most common mode of consumption across many countries: for

*Abbreviations:* AOR, adjusted odds ratio; CI, confidence interval; US, United States; UK, United Kingdom; THC, delta-9-tetrahydrocannabinol.

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example, more than 78 % of cannabis consumers in Canada and the US report smoking dried flower (Goodman et al., 2020; Government of Canada, 2017; Knapp et al., 2019). However, the manner in which cannabis is smoked differs across markets. In England and most other European countries, consumers typically smoke cannabis mixed with tobacco, whereas cannabis is more likely to be smoked without tobacco in North America (Hindocha et al., 2016). In addition, use of cannabis extracts and concentrates is increasing in jurisdictions with legalized medical and recreational cannabis (Borodovsky et al., 2017; Caulkins et al., 2018; Goodman et al., 2020; Government of Canada, 2017). THC vape oils and solid concentrates are particularly popular among youth and young adults (Fataar and Hammond, 2019; Jones et al., 2016). The THC concentration of these products can exceed 90 %—three to four times that of the most potent dried flower—and they have been associated with problematic use (Caulkins et al., 2018; Fischer et al., 2017; Wang et al., 2016). THC oils have emerged as a particular concern in the North American market due to the recent emergence of acute health risks responsible for more than 60 deaths and 2700 cases of serious pulmonary disease in the US (Centers for Disease Control and Prevention, 2020). The majority of these cases are believed to be related to contaminants in THC oils, such as vitamin E acetate (Centers for Disease Control and Prevention, 2020); however, concerns remain about the potential effects of inhaling constituents in the aerosols produced from manufactured THC vape oils.

The regulatory frameworks in Canada, the US, and England provide an opportunity to examine trends across jurisdictions with substantially different cannabis policies. Historically, cannabis use has been much less prevalent in England than either Canada or the US. In 2017, past 12-month cannabis use was estimated at 15 % among 16- to 19-year-olds in England and Wales, 28 % among 15- to 19-year-olds in Canada, and 34 % among 16- to 20-year-olds in the US (Government of Canada, 2017; Home Office, 2019; Substance Abuse and Mental Health Services Administration, 2018). However, direct comparison of these estimates is limited by different methodologies, including different sampling and age ranges and different measures used to assess cannabis use.

The current study examined changes in cannabis use and modes of consumption among 16- to 19-year-olds in three markets with different regulatory frameworks using the same methodology. The current study had two primary objectives: 1) to compare changes in cannabis use among 16- to 19-year-olds between 2017 and 2019 in Canada, England, and the US; and, 2) to examine changes in the modes of consumption for cannabis across the three countries.

## 2. Methods

### 2.1. Data source

Data are from cross-sectional Waves 1–3 of the International Tobacco Control Policy Evaluation Project (ITC) Youth Tobacco and Vaping Survey, conducted in Canada, England, and the US. Online surveys were conducted in July/August 2017 (Wave 1), August/September 2018 (Wave 2), and August/September 2019 (Wave 3). ‘New’ samples of respondents were recruited at each survey wave from the Nielsen Consumer Insights Global Panel, as well as their partners’ panels. Eligible respondents included youth aged 16 through 19 at the time of recruitment. Respondents were recruited either directly or through their parents. Email invitations (with a unique link) were sent to panelists after targeting for age criteria. Panelists known to be parents were also contacted; those who confirmed they had one or more children aged 16–19 living in their household were asked for permission for their child to complete the survey (if more than one child, specifically the one whose birthday was coming up next). After eligibility screening, all potential respondents were provided with information about the study and were asked to provide consent before participating. Respondents received remuneration in accordance with their panel’s usual incentive structure, which could include points-based or monetary rewards and/or chances

to win monthly prizes. In Waves 1 and 2, a restriction on small screen size was applied, but all devices were permitted in Wave 3.

The response rates across the surveys were 3.7 % in Wave 1 (2017), 2.3 % in Wave 2 (2018), and 1.6 % in Wave 3 (2019). The current analyses are based on the cross-sectional samples, after exclusions based on data integrity checks and those missing or incomplete data on variables required for calculating weights or determining smoking and/or vaping status:  $n = 12,128$  recruited in 2017,  $n = 11,753$  recruited in 2018, and  $n = 11,609$  recruited in 2019. A full description of the study methods and surveys are available (see <http://davidhammond.ca/projects/e-cigarettes/itc-youth-tobacco-ecig/>).

This study was reviewed and received ethics clearance through a University of Waterloo Research Ethics Committee (ORE#21847) and the King’s College London Psychiatry, Nursing and Midwifery Research Ethics Subcommittee.

### 2.2. Measures

#### 2.2.1. Cannabis prevalence

All respondents were asked, “When was the last time you used marijuana/cannabis?”, with the following response options: “I have never used marijuana/cannabis”; “Earlier today”; “Not today but sometime in the past 7 days”; “Not in the past 7 days but sometime in the past 30 days”; “Not in the past 30 days but sometime in the past 6 months”; “Not in the past 6 months but sometime in the past 12 months”; “1 to 4 years ago”; “5 or more years ago”; “Don’t know”; and, “Refused”. Responses were recoded into variables for use “ever”, in the past 12 months, and in the past 30 days. Those who responded with “Don’t Know” ( $n = 383$ ) or “Refused” ( $n = 355$ ) were excluded from the analytic sample.

Respondents who reported using cannabis in the past 30 days were asked, “In the last 30 days, how often did you use marijuana/cannabis?” with options: “Once or twice”; “Once or twice a week”; “3 or 4 times a week”; “5 to 6 times a week”; “Every day”; “Don’t know”; and, “Refused”. Daily smoking prevalence was recoded as youth who responded “Every day”, or those who used less often. “Don’t Know” ( $n = 76$ ) and “Refused” ( $n = 26$ ) responses were treated as missing.

#### 2.2.2. Cannabis modes

Youth who reported using cannabis in the past 30 days were asked: “In the last 30 days, did you...”: “Smoke marijuana/cannabis WITHOUT tobacco”; “Smoke marijuana/cannabis WITH tobacco in a joint or blunt”; “Use a waterpipe/bong to smoke marijuana/cannabis”; “Use a vapourizer to heat dried marijuana/cannabis leaves or herb”; “Use an e-cigarette to vape marijuana/cannabis oil or liquid”; “Eat or drink marijuana/cannabis in a food or beverage”; “Use marijuana/cannabis extracts, including oil, wax or shatter”; and, “Use another form of marijuana/cannabis”. Responses to each item were “Yes”, “No”, “Don’t know” and “Refused”.

#### 2.2.3. Socio-demographic measures

Socio-demographic measures included country of residence, age, sex at birth (male/female), and race/ethnicity (recoded into ‘White’ vs. other). Education level was not included, given the collinearity with age. In each year, US states were coded for whether recreational cannabis was legalized or not at the time that the survey was conducted.

### 2.3. Analysis

Post-stratification sample weights were constructed for each country, based on age, sex, race/ethnicity (in the US only), and geographic region, and rescaled to the sample size. In addition, Waves 2 and 3 were calibrated back to Wave 1 for student status (student vs. not) and grades (<70 %, “Don’t know”, or “Refused”; 70–79 %; 80–89 %; 90–100 %), and used the National Youth Tobacco Survey in the US and the Canadian Student Tobacco, Alcohol and Drugs Survey in Canada to calibrate to the

trend over time for past 30-day smoking. A full description of the weighting procedures is available in the Technical Reports at <http://davidhammond.ca/projects/e-cigarettes/itc-youth-tobacco-ecig/>.

Separate logistic regression models were estimated to examine prevalence and modes of cannabis use. All regression models were adjusted for age group (16–17 vs. 18–19), sex, and race/ethnicity ('White' vs. other), and included a two-way interaction between country and wave. Simple effects were used to describe changes between waves for each country, and differences between countries were examined by testing the two-way interactions between country and wave. The logistic regression models that examined specific modes of cannabis use were estimated among past 30-day consumers of cannabis. Using US data only, a set of parallel logistic regression models were estimated to examine prevalence and modes of cannabis use between states that had and had not legalized recreational cannabis.

Adjusted odds ratios (AORs), 95 % confidence intervals (95 % CIs), and weighted estimates are reported, unless otherwise noted. Respondents who indicated "Don't know" or "Refused" for when they last used cannabis ( $n_{2017} = 240$ ;  $n_{2018} = 208$ ;  $n_{2019} = 290$ ) were excluded from all analyses, providing an analytic sample of  $n = 11,888$  in 2017,  $n = 11,545$  in 2018, and  $n = 11,319$  in 2019. Respondents with missing data on outcome measures or covariates were also excluded from models on a case-wise basis, as follows: those who indicated "Don't know" or "Refused" to past 30-day frequency of cannabis use ( $n_{2017} = 28$ ;  $n_{2018} = 30$ ;  $n_{2019} = 44$ ) were excluded from daily cannabis use prevalence models; those who did not provide a state of residence ( $n_{2017} = 6$ ) were excluded from US-only prevalence models; and, those responding "Refused" to modes of cannabis use were excluded from models for the respective modes. Analyses were conducted using SAS 9.4.

### 3. Results

#### 3.1. Sample

Characteristics of the sample in each country and at each wave are shown in Table 1.

#### 3.2. Prevalence of cannabis use

Fig. 1 illustrates past 12-month, past 30-day, and daily prevalence of cannabis use in each of the countries, from 2017 to 2019. Prevalence of cannabis use was significantly lower in England than Canada and the US in all years ( $p < 0.001$  for all contrasts). Across years, cannabis use was more prevalent in Canada and the US than England for use in the past 12 months (Canada: AOR 1.53, 95 % CI 1.43–1.65,  $p < 0.0001$ ; US: AOR 1.47, 95 % CI 1.37–1.59,  $p < 0.0001$ ). Prevalence was also higher in Canada and the US compared to England for use in the past 30 days (Canada: AOR 1.75, 95 % CI 1.60–1.92,  $p < 0.0001$ ; US: AOR 1.70, 95 % CI 1.55–1.87,  $p < 0.0001$ ), and daily use (Canada: AOR 3.39, 95 % CI

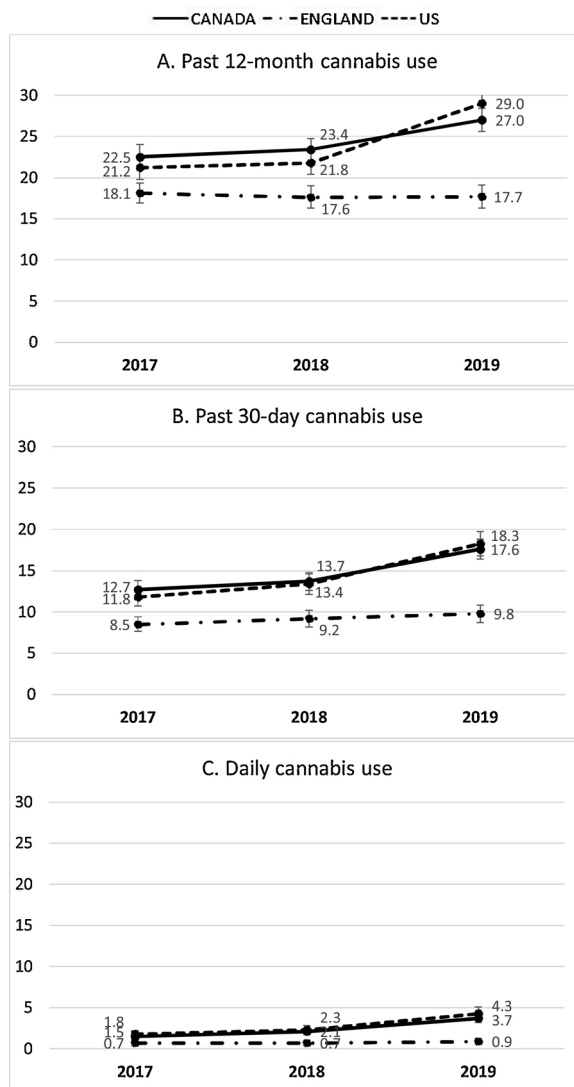


Fig. 1. Prevalence of cannabis use (weighted), by country and survey wave. Missing values for daily use ( $n_{2017} = 28$ ,  $n_{2018} = 30$ ,  $n_{2019} = 44$ ) are excluded (removed from the denominator).

2.61–4.41,  $p < 0.0001$ ; US: AOR 3.78, 95 % CI 2.89–4.93,  $p < 0.0001$ ).

Prevalence did not change significantly in England between 2017 and 2019 for past 12-month use (AOR 0.98, 95 % CI 0.86–1.11;  $p = 0.72$ ), past 30-day use (AOR 1.18, 95 % CI 0.99–1.39;  $p = 0.063$ ) or daily use (AOR 1.35, 95 % CI 0.77–2.36;  $p = 0.29$ ). In contrast, prevalence

Table 1  
Sample characteristics (weighted), by country and survey wave.

Survey wave (unweighted n)	ENGLAND			CANADA			US		
	2017 n =	2018 n =	2019 n =	2017 n =	2018 n =	2019 n =	2017 n =	2018 n =	2019 n =
	3914	3812	3392	3967	3762	4056	4007	3971	3871
Age	17.5 (1.02)	17.6 (1.03)	17.5 (0.95)	17.6 (1.05)	17.5 (1.08)	17.5 (1.09)	17.5 (1.08)	17.5 (1.06)	17.5 (1.08)
Male	51.1 (1999)	51.0 (1944)	51.0 (1732)	51.0 (2021)	51.2 (1928)	50.9 (2063)	51.1 (2049)	51.0 (2024)	50.9 (1977)
White (only) race/ethnicity <sup>a</sup>	79.7 (3115)	77.3 (2944)	76.3 (2589)	58.6 (2320)	47.4 (1785)	54.5 (2207)	73.5 (2947)	73.7 (2926)	74.1 (2878)
Current student	91.8 (3588)	91.7 (3496)	91.8 (3116)	93.1 (3689)	93.2 (3510)	93.0 (3768)	91.2 (3660)	91.1 (3619)	91.3 (3548)
Past 12-month alcohol use (any) <sup>b</sup>	76.2 (2923)	74.9 (2794)	72.9 (2420)	61.7 (2378)	58.2 (2134)	55.2 (2165)	41.4 (1629)	38.5 (1499)	39.4 (1495)

Data are % (n) or mean (SD). Missing values for alcohol use (England:  $n_{2017} = 75$ ,  $n_{2018} = 66$ ,  $n_{2019} = 86$ ; Canada:  $n_{2017} = 154$ ,  $n_{2018} = 101$ ,  $n_{2019} = 134$ ; US:  $n_{2017} = 84$ ,  $n_{2018} = 84$ ,  $n_{2019} = 122$ ) are excluded (removed from the denominator).

<sup>a</sup> Wording of the Canadian source question changed slightly, from response option "White" in 2017 to "European" in 2018, to "White or European" in 2019.

<sup>b</sup> Assessed using the question, "In the last 12 months, how often did you have a drink of alcohol that was more than just a sip?"

increased between 2017 and 2019 in Canada (past 12-month use AOR 1.28, 95 % CI 1.15–1.43;  $p < 0.0001$ ; past 30-day use AOR 1.48, 95 % CI 1.29–1.69;  $p < 0.0001$ ; daily use AOR 2.49, 95 % CI 1.81–3.41;  $p < 0.0001$ ). Prevalence was also higher in the US in 2017 versus 2018 for all frequencies assessed (past 12-month use AOR 1.52, 95 % CI 1.35–1.71;  $p < 0.0001$ ; past 30-day use AOR 1.67, 95 % CI 1.44–1.93;  $p < 0.0001$ ; daily use AOR 2.48, 95 % CI 1.79–3.43;  $p < 0.0001$ ).

A supplementary analysis between US states that had and had not legalized recreational cannabis found no differences in 2019 for prevalence of cannabis use in the past 12 months (29.1 % vs. 28.9 %; AOR 1.00, 95 % CI 0.81–1.25;  $p = 0.97$ ) or past 30 days (20.1 % vs. 17.7 %; AOR 1.17, 95 % CI 0.92–1.48;  $p = 0.21$ ). Prevalence of daily use was lower in US states that had legalized non-medical cannabis use (2.9 % vs. 4.7 %; AOR 0.59, 95 % CI 0.38–0.92;  $p = 0.020$ ). Between 2017 and 2019, in states that had legalized non-medical cannabis, there were no significant changes in prevalence of past 12-month or daily cannabis use, although past 30-day prevalence increased (from 14.4%–20.1%; AOR 1.50, 95 % CI 1.10–2.04;  $p = 0.011$ ). In states that had not legalized, prevalence increased between 2017 and 2019 for past 12-month (20.1%–28.9%; AOR 1.57, 95 % CI 1.38–1.79;  $p < 0.0001$ ), past 30-day (11.1%–17.7%; AOR 1.74, 95 % CI 1.47–2.04;  $p < 0.0001$ ), and daily cannabis use (1.6%–4.7%; AOR 3.06, 95 % CI 2.11–4.44;  $p < 0.0001$ ).

### 3.3. Modes of cannabis use

Table 2 shows the prevalence of each mode of cannabis consumption among those who used cannabis in the past 30 days.

In 2019, the prevalence of every mode of cannabis use except smoking with tobacco was greater among past 30-day consumers in Canada and the US compared to England ( $p < .01$  for all contrasts). Past 30-day cannabis consumers in England were more likely to smoke cannabis with tobacco (64.4 % in 2019) compared to Canada (34.8 % in 2019; AOR 3.45, 95 % CI 2.56–4.76;  $p < 0.0001$ ) and the US (33.3 % in

2019; AOR 3.57, 95 % CI 2.63–5.00;  $p < 0.0001$ ).

As Table 2 indicates, considering specific forms of cannabis, prevalence of using e-cigarettes to vape oil/liquid, and using extracts (oil, wax, shatter) increased between 2017 and 2019 among past 30-day cannabis consumers in all three countries. In addition, between 2017 and 2019, smoking with tobacco decreased in England (AOR 0.57, 95 % CI 0.39–0.82,  $p = 0.003$ ), and smoking dried herb decreased in the US.

In US states where recreational cannabis was NOT legal, prevalence of using e-cigarettes to vape oil/liquid and using extracts increased among past 30-day consumers between 2017 and 2019—see Supplementary Table 1. In states where recreational cannabis was legal, using e-cigarettes to vape oil/liquid increased among past 30-day consumers between 2017 and 2019, and both smoking without tobacco and using a waterpipe/bong decreased during this time.

## 4. Discussion

National surveys from all three countries suggest that past 12-month cannabis use declined or remained stable among youth over the past two decades. However, the current findings suggest that this trend may be changing in Canada and the US. Both countries had very similar levels of prevalence in 2019 and similar increases in use since 2017. The extent to which the increases observed among youth in Canada are the result of non-medical cannabis legalization is unclear, given that similar increases were observed in the year prior to legalization (from 2017 to 2018), as the year following legalization (from 2018 to 2019), consistent with other studies that also observed increased use in the lead-up to legalization. (Government of Canada, 2019; Rotermann, 2019; Statistics Canada, 2019; Zuckermann et al., 2019). Data on cannabis use among Canadian youth since legalization are scarce and somewhat mixed, with one national monitoring survey showing very modest increases (Nicksic et al., 2020) and another survey showing increases similar in magnitude to the current study (Government of Canada, 2019; Health Canada, 2020). In the US, monitoring surveys indicate very modest increases in

Table 2

Past 30-day prevalence of specific modes of cannabis use among past 30-day cannabis consumers aged 16-19 years (weighted), and change between 2017 and 2019, by country and survey wave.

Modes	ENGLAND				CANADA				US			
	2017(n = 331)	2018(n = 350)	2019(n = 331)	Change from 2017 to 2019 <sup>a</sup> AOR (95% CI)	2017(n = 502)	2018(n = 516)	2019(n = 711)	Change from 2017 to 2019 <sup>a</sup> AOR (95% CI)	2017(n = 474)	2018(n = 531)	2019(n = 710)	Change from 2017 to 2019 <sup>a</sup> AOR (95% CI)
Smoke without tobacco	53.5 (177)	54.1 (188)	48.5 (159)	0.83(0.60, 1.15) $p = 0.27$	81.6 (404)	80.3 (413)	80.4 (568)	0.97 (0.70, 1.33) $p < 0.83$	88.6 (421)	85.4 (452)	80.9 (574)	<b>0.55 (0.39, 0.79) <math>p &lt; 0.0011</math></b>
Smoke with tobacco	76.1 (252)	73.7 (256)	64.4 (210)	<b>0.57 (0.39, 0.82) <math>p = 0.0025</math></b>	37.4 (186)	32.6 (168)	34.8 (246)	0.89. (0.69, 1.15) $p = 0.38$	32.1 (152)	34.2 (180)	33.3 (236)	1.07 (0.81, 1.41) $p = 0.64$
Waterpipe/bong	27.3 (90)	23.4 (81)	28.6 (93)	1.08 (0.75, 1.56) $p = 0.66$	55.1 (273)	51.5 (264)	49.2 (349)	0.81 (0.63, 1.04) $p = 0.10$	55.6 (264)	48.0 (253)	50.6 (359)	0.83 (0.63, 1.08) $p = 0.16$
Vapourizer to heat dried leaves or herb	8.1 (27)	12.5 (43)	11.1 (36)	1.45 (0.83, 2.51) $p = 0.19$	15.9 (79)	19.3 (99)	19.1 (134)	1.27 (0.92, 1.78) $p = 0.15$	20.6 (97)	21.5 (114)	23.0 (163)	1.20 (0.87, 1.65) $p = 0.28$
E-cigarettes to vape oil or liquid	9.0 (30)	14.6 (50)	19.0 (62)	<b>2.39 (1.47, 3.89) <math>p = 0.0004</math></b>	12.9 (64)	18.8 (96)	25.9 (182)	<b>2.39 (1.70, 3.36) <math>p &lt; 0.0001</math></b>	24.2 (115)	31.0 (164)	52.1 (369)	<b>3.46 (2.57, 4.66) <math>p &lt; 0.0001</math></b>
Eat or drink in a food or beverage	20.4 (67)	19.9 (69)	17.9 (58)	0.85 (0.57, 1.28) $p = 0.44$	25.8 (128)	27.9 (143)	31.5 (222)	1.30 (0.99, 1.71) $p = 0.061$	29.5 (140)	29.5 (155)	33.0 (234)	1.20 (0.99, 1.71) $p = 0.21$
Extracts (oil, wax, shatter)	7.7 (25)	11.9 (41)	12.5 (41)	<b>1.75 (1.03, 2.97) <math>p = 0.039</math></b>	21.3 (106)	22.6 (115)	29.7 (211)	<b>1.61 (1.20, 2.15) <math>p = 0.0014</math></b>	26.7 (126)	30.3 (159)	41.0 (291)	<b>1.97 (1.47, 2.64) <math>p &lt; 0.0001</math></b>

Data are % (n) or adjusted odds ratios (AOR) with 95 % confidence intervals (95 % CI) and associated p values. Missing values for specific modes (Smoke without tobacco:  $n_{2017} = 4, n_{2018} = 7, n_{2019} = 7$ ; Smoke with tobacco:  $n_{2017} = 3, n_{2018} = 9, n_{2019} = 9$ ; Waterpipe/bong:  $n_{2017} = 5, n_{2018} = 13, n_{2019} = 7$ ; Vapourizer to heat dried leaves or herb:  $n_{2017} = 7, n_{2018} = 16, n_{2019} = 18$ ; E-cigarettes to vape oil or liquid:  $n_{2017} = 4, n_{2018} = 13, n_{2019} = 11$ ; Eat or drink in a food or beverage:  $n_{2017} = 6, n_{2018} = 17, n_{2019} = 16$ ; Extracts (oil, wax, shatter):  $n_{2017} = 4, n_{2018} = 17, n_{2019} = 9$ ) are excluded (removed from the denominator).

<sup>a</sup> Simple effect of year (within country) from separate logistic regression models for each mode, which included the following variables: age group, sex, race/ethnicity, country, survey wave, and a two-way interaction between country and wave.

rates for past year and past month cannabis use, but increases in daily use among high school students (Johnston et al., 2020). Both Canada and the US had substantially higher prevalence than youth in England, where cannabis use prevalence appears to be stable, similar to other studies that suggest only modest increases in England over the same period (Johnson et al., 2015; Statistics Canada, 2019).

Similar patterns of cannabis use were observed between US states that had and had not legalized recreational cannabis: although prevalence of use was somewhat higher in ‘legal’ states in 2017, by 2019 youth reported similar levels of cannabis use regardless of legal status, although somewhat greater daily use in ‘illegal’ states. The current findings are largely consistent with other studies on youth prevalence which have found similar trends in cannabis use among youth across ‘legal’ and ‘illegal’ jurisdictions in the US (Smart and Pacula, 2019).

Beyond changes in overall prevalence, the findings indicate a shift in the modes of cannabis use due to marked increases in vaping THC/cannabis oils and concentrates, particularly in North America. Prevalence of vaping such products was highest in the US: more than half of past 30-day cannabis consumers reported vaping cannabis in the past month, consistent with other studies in which cannabis vaping more than doubled between 2017 and 2019 among US high school students (Miech et al., 2019; Nicksic et al., 2020). The increase in cannabis vape oils mirrors trends in the prevalence of vaping nicotine products, which have increased in all three countries, but to a greater extent in the US (Hammond et al., 2020). The findings add to the evidence that the appeal of vaping cuts across both nicotine and cannabis products (Centers for Disease Control and Prevention, 2020), likely due to a combination of factors including the convenience, appealing flavours, more positive social norms, and aesthetic qualities of vaping compared to smoking (Romijnders et al., 2018).

Previous research suggests that more heavily “processed” cannabis products, such as oils and extracts, are more prevalent in legal jurisdictions; however, in the current study, similar trends were observed in states that had and had not legalized recreational cannabis (Fataar and Hammond, 2019). Interestingly, vape oils and solid concentrates were not legalized in Canada until December 2019, after the current data were collected, in the second ‘phase’ of cannabis legalization. Future studies should examine whether the trend towards vape oils and solid concentrates in Canada accelerates following legalization in subsequent years, and sociodemographic correlates of use to better understand the types of youth consumers who select these products. Future research should also consider potential sociodemographic differences in modes of cannabis consumption among young people. Sex differences in product use have previously been observed: dried flower and concentrates are more common among males, whereas cannabis edibles are more common among females (Greaves and Hemsing, 2020).

The health implications of the shifting modes of cannabis consumption remain unclear. Although vaping may decrease excess risk from smoke inhalation, manufactured vape oils are largely responsible for more than 60 deaths and 2700 cases of serious lung disease in the US, primarily from contaminants (Centers for Disease Control and Prevention, 2020). The findings underscore the need to accelerate research on the contents and aerosol from vape oils, including from commonly-used additives, such as flavours and terpenes. More generally, the increasing use of the most potent cannabis products among young people raises questions of how these products should be regulated in legal markets. Novel regulatory practices are beginning to emerge in some legal jurisdictions; for example, the Canadian province of Quebec’s government has prohibited edible products that appeal to youth—including the most popular products such as cookies, brownies, and confectionary products—as well as a limit of 30 % THC concentration on all cannabis concentrates. Future research should examine the impact of these and other policy measures on patterns of cannabis use among people, including potential adverse outcomes.

#### 4.1. Limitations

The study sample was not recruited using probability-based sampling and the findings may not be nationally representative. For example, the increases observed in the current study are somewhat greater than those of national benchmark surveys, possibly due to a slightly older age range, the inclusion of youth who are not in school, and typically lower socioeconomic status profile of online survey respondents in commercial panels. In addition, the survey did not ask about all forms of cannabis use, such as topicals (although these forms remain relatively rare among young people (Goodman et al., 2020)), nor did the study assess authorization for medical cannabis use. Although there are no age limits in any of the three countries for medical cannabis authorization, extremely few persons under 18 have received approval for medical cannabis. Finally, the results presented in this study are not generalizable to countries outside of the study.

#### 5. Conclusions

Although smoking dried flower remains the most common mode of cannabis use among youth, the prevalence of vape oils and solid concentrates is increasing. Shifts towards these modes of use were greatest in Canada and the US, where cannabis policies are generally more liberal than England; however, the trends were apparent across all three countries, and to a similar extent in US states that had and had not legalized recreational cannabis. While much attention has focused on the increasing potency of dried flower, the shift towards the most potent forms of cannabis use among young people warrants closer scrutiny, particularly with respect to potential adverse health outcomes.

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#### Contributors

DH conceptualized and designed the study, assisted with analyses, drafted sections of the initial manuscript, and reviewed and revised the manuscript. EW assisted with analyses, drafted sections of the initial manuscript, and reviewed and revised the manuscript. JLR helped design the data collection instruments, coordinated and supervised data collection, assisted with analyses, drafted sections of the initial manuscript, and reviewed and revised the manuscript. RB led the data analysis, drafted sections of the initial manuscript, and reviewed and revised the manuscript. All authors approved the final manuscript as submitted and agree to be accountable for all aspects of the work.

#### Declaration of Competing Interest

The authors report no declarations of interest.

#### Appendix A. Supplementary data

Supplementary material related to this article can be found, in the online version, at doi:<https://doi.org/10.1016/j.drugalcdep.2020.108505>.

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