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Who consumes most of the cannabis in Canada? Profiles of cannabis consumption by quantity

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ABSTRACT

Aim: To establish whether the population-level pattern of cannabis use by quantity is similar to the distributions previously reported for alcohol, in which a small subset of drinkers accounts for a majority of total population alcohol consumption.

Method: The current study pooled Waves 1–3 of the 2018 National Cannabis Survey (n = 18,900; 2584 past-three-month cannabis users), a set of stratified, population-based surveys designed to assess cannabis consumption and related behaviors in Canada. Each survey systematically measured self-reported cannabis consumption by quantity across seven of the major cannabis-product types. In order to enable the conversion of self-reported consumption of non-flower cannabis products into a standard joint equivalent (SJE: equal to 0.5 g of dried cannabis), we created conversion metrics for physical production equivalencies across cannabis products.

Results: Similar to the findings in the alcohol literature, study results show that cannabis consumption is highly concentrated in a small subset of users: the upper 10% of cannabis users accounted for approximately two-thirds of all cannabis consumed in the country. Males reported consuming more cannabis by volume than females (approximately 60% versus 40%), with young males (15–34 years old) being disproportionately represented in the heaviest-using subgroups.

Conclusions: Most of the cannabis used in Canada is consumed by a relatively small population of very heavy cannabis users. Future research should attempt to identify the characteristics of the heaviest-using groups, as well as how population-level cannabis consumption patterns relate to the calculus of cannabis-related harms in society.

1. Introduction

Understanding the distribution of cannabis consumption in the population is likely to be a foundational component for developing a policy framework for reducing cannabis-related harms in society. Population-level patterns of alcohol consumption and associated harms have been widely studied (Greenfield and Rogers, 1999; Kehoe et al., 2012; Rehm et al., 2009; Rossow et al., 2014; Skog, 1985, 2006a). For example, Greenfield and Rogers (1999) reported that a small subgroup of alcohol users (the top 10% of heaviest consumers) accounted for a disproportionately large portion of total alcohol consumption (~56%) in the United States. To our knowledge, such data are not available for other recreational drugs, and it is not certain whether this pattern would necessarily be similar for other drugs such as opiates, stimulants, or cannabis. At this time, there is an important opportunity to study cannabis use in Canada, as Statistics Canada has recently completed a multi-wave National Cannabis Survey (NCS) in the lead-up to the country-wide legalization of adult recreational cannabis use on October 17, 2018 (Statistics Canada, 2018a, 2018b, 2018c).

In order to estimate population-level distributions of cannabis consumption, a study must overcome a number of obstacles, including the measurement of cannabis use across a range of products (e.g., dried leaf, oils, concentrates, edibles) and assessment of cannabis-use intensity across product type (Casajuana et al., 2016; Temple et al.,

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2011). Available population-based surveys (and other relevant research) have focused almost exclusively on the assessment of cannabis-use frequency, while omitting questions eliciting information about quantity of use or consumption of various cannabis products (Asbridge et al., 2014; Casajuana Kögel et al., 2017; Hindocha et al., 2017; Walden and Earleywine, 2008). In addition, such studies need to develop an algorithm to establish a standard unit (usually expressed as a standard joint equivalent) across different kinds of cannabis products in order to construct an aggregate individual-level measure of total volume of cannabis consumption.

The current paper aims to establish whether the pattern of cannabis consumption by quantity in the Canadian population in 2018 prior to legalization (which occurred on October 17, 2018) is generally similar to that reported for alcohol consumption (Caetano et al., 2012; Greenfield and Rogers, 1999). Not only may these data help to lay the foundation for understanding how cannabis consumption is distributed in the population, but they may also support future research aiming to relate such population-level consumption patterns to cannabis-related harms.

2. Methods

2.1. Data source

NCS – Wave 1, Wave 2, and Wave 3. Developed and conducted by Statistics Canada, the NCS is an anonymous, stratified, population-based survey designed to assess cannabis use patterns and related behaviours among individuals at least 15 years of age within Canada's 10 provinces. Participants could respond via an electronic questionnaire or a computer-assisted telephone interview. Statistics Canada completed the data collection for the NCS in each of the first three quarters of 2018: Wave 1 (February 19-March 18, 2018; response rate: 51.2%); Wave 2 (May 16-June 12, 2018; response rate: 51.3%); and Wave 3 (August 16-September 12, 2018; response rate 51.6%) (Statistics Canada, 2018a, 2018b, 2018c). Statistics Canada released the survey data for Waves 1–3 to the Canadian Regional Data Centre Network in late 2018. All three waves of the NCS were completed before cannabis legalization in Canada on October 17, 2018.

2.2. Sample

Waves 1–3 of the NCS included 18,900 respondents (Wave 1: 5817; Wave 2: 7285; Wave 3: 5798), with a total of 2584 identified past-three-month cannabis users (747 from Wave 1, 1056 from Wave 2, and 781 from Wave 3).

2.3. Data access and release of study results

Study team members (RCC, MS) gained approval from Statistics Canada to access the required restricted-use NCS Waves 1–3 data files at secure Regional Data Centre (RDC) locations (University of Toronto, University of Victoria), and they agreed to abide by the Statistics Canada RDC security and confidentiality requirements. The research ethics board at the lead author's (RCC) home institution (UNBC) does not require its own review and approval of projects conducted under the aegis of the Statistics Canada RDC system.

Statistics Canada approved release of study results, including sample sizes for cannabis users and non-cannabis users across NCS Waves 1–3. More detailed unweighted cell sizes included in stratified analyses were not approved for release.

2.4. Assessment of cannabis use

Respondents were identified as cannabis users if they reported any frequency of use of cannabis in the past three months (NCS question: "During the past three months, how often did you use cannabis?" Responses available were: "Not in the past three months"; "Once or twice"; "Monthly"; "Weekly"; "Daily or almost daily"). Individuals were asked about their use of a range of cannabis products, including: (1) dried flower or leaf; (2) hashish or kief; (3) liquid concentrate (e.g., oils); (4) cannabis oil cartridges or disposable vape pens; (5) solid concentrates (e.g., "shatter," "budder"); (6) cannabis edibles; (7) cannabis-infused drinks; and (8) "other" types of cannabis product (e.g., topical ointments, fresh flower or leaf for juicing). For each type of cannabis product consumed, respondents were asked to estimate the amount of consumption within the last three months of the specific product in relevant measurement units (e.g., joints, grams, drops).

2.5. Physical production equivalencies of cannabis products

In order to enable the conversion of self-reported consumption of non-flower cannabis products into a common flower-based unit, we calculated physical production equivalencies of cannabis product types, where infused edibles or concentrates were linked back to their corresponding weight of dried flower or trim inputs. This conversion process allowed for the calculation of total aggregate cannabis consumption (within the past three months) in cannabis standard joint equivalents (SJEs). Table 1 provides a detailed description of the physical production equivalencies across cannabis-product types for all cannabis products specifically assessed in the NCS, using the benchmark of a "standard joint" defined below. The last column of Table 1, titled "Rationale/Comments," provides a justification of our method for each cannabis product type assessed in the NCS.

There are two noteworthy issues in the physical production equivalency table used in our paper. In the first three waves of the NCS, respondents could report the quantity of cannabis edibles they used in the past three months as a function of the following four response units: "milligrams"; "grams"; "packages"; or "servings." For the physical production equivalencies for edibles, we assumed that when survey participants reported in "milligrams" or "grams" regarding the quantity of cannabis edibles they used in the past three months, these individuals were reporting the weight of tetrahydrocannabinol (THC) in the edibles – not the total weight of the edibles themselves. This approach may have introduced bias into the estimates of cannabis edible consumption in the current paper. It is important to note that Statistics Canada addressed this potential assessment bias in the fourth and subsequent waves of the NCS by removing the response categories "milligrams" and "grams" from the cannabis-edible response categories, leaving only the response categories of "servings" and "packages." Also, in the assessment of "other" cannabis products, the NCS elicited information about the measurement units of "other" products (e.g., milligrams, grams, milliliters), as well as the number of units of "other" products consumed in the prior three months – but the survey did not capture the cannabis-product type. In other words, the survey elicited information about the use of "other" cannabis products and assessed the number of units consumed, but the survey did not provide information about the explicit type of cannabis product used. So, in order to capture the volume of consumption of "other" products, we transformed the reported unit and number of units consumed using the most frequent equivalency associated with reported unit of cannabis-product type. For example, if a respondent reported consumption of "other" cannabis products and reported using 10 ml of this "other" cannabis product, we used the physical production equivalency unit for cannabis oils (quantities of which are frequently expressed in the cannabis measurement unit of "milliliters").

2.6. Standard joint size

In the current study, we assumed a standard joint equivalent (SJE) to contain 0.5 g of dried cannabis, based on two lines of evidence. First, prior Canadian research has shown the usefulness of defining a "standard" joint as containing 0.5 g of cannabis in relation to the prediction

Table 1
Physical production equivalencies across major cannabis-product types in the National Cannabis Survey, Waves 1–3.

Cannabis Unit	Is equivalent to:	Rationale/Comments
Standard Joint		
1 standard joint	0.5 g dried cannabis	In the current study, we assumed a standard joint to contain 0.5 g of dried cannabis, based on two lines of evidence. First, prior Canadian research has shown the usefulness of defining a "standard" joint as containing 0.5 g of cannabis (Asbridge et al., 2014; Zeisser et al., 2012). Secondly, the smallest retail joint size available through provincial/territorial government cannabis stores in Canada contains 0.5 g of dried cannabis (Alberta Gaming and Liquor Commission (AGLC), 2018; Alcool New Brunswick Liquor (ANBL), 2018; B.C. Cannabis Stores, 2018; Cannabis Yukon, 2018; Northwest Territories Liquor and Cannabis Commission, 2018; Nova Scotia Liquor Corporation, 2018; Ontario Cannabis Store, 2018; Prince Edward Island Cannabis Management Corporation, 2018; Société québécoise du cannabis, 2018).
Dried Cannabis: Ounce		
1 standard joint	0.0177 oz dried cannabis Using the same calculations, ¼ oz dried cannabis is equivalent to 2.82 joints, or 6.54 g.	1 oz of dried cannabis is equivalent to 28.3 g of dried cannabis.
Hashish or kief		
1 standard joint	0.125 g of hashish or kief	For this conversion from dried cannabis to concentrates (i.e., hashish or kief), we used Schedule 3 ("Equivalent Amounts") in the *Cannabis Act* (Statutes of Canada, 2018).
Hash oil, butane honey oil		
1 standard joint	0.096 g of hash oil, butane honey oil	This conversion comes from Table III-4 from Orens et al. (2015) (pg. 21). See row "Butane Concentrate," with a ratio of dried cannabis to butane honey oil of 5.2 g dried cannabis to 1 g butane honey oil (Orens et al., 2015).
Oil cartridges		
1 standard joint	3.295 ml of cannabis oil	This estimate of 1 g (dried cannabis) is equivalent to 6.59 ml (cannabis oil) comes from Sen and Wyonch (2018), based on the average of physical production equivalency listings for the relation between dried cannabis to cannabis oils from Health Canada-licensed cannabis producers' websites (see Table A-4, pg. 22). Cannabis oil cartridges in non-disposable and disposable vape pens usually range from 500-1000 mg. In Sen and Wyonch (2018), 1 mL of cannabis oil weighs 920 mg. So, if we assume that the average cartridge contains 750 mg of oil, this would be equivalent to 0.81 mL of oil in each cartridge. So, 0.81 mL of oil in a "standard" cannabis oil cartridge or disposable pen is physically equivalent to 0.12 g of dried cannabis.
Cannabis oil (drops)		
1 standard joint	65.8 drops of cannabis oil	This result is based on the following: 1 g of dried cannabis is physically equivalent to 6.59 ml of oil (see Table A-4, pg. 22, Sen and Wyonch, 2018); 1 mL of oil yields 20 drops; and 6.59 mL of oil is equivalent to 131.6 drops of cannabis oil. So, 1 g of dried cannabis is physically equivalent to 131.6 drops of cannabis oil.
Cannabis concentrates ("shatter," "budder")		
1 standard joint	0.096 g of "shatter" or "budder" cannabis concentrate	We use the same conversion from Table III-4 from Orens et al. (2015) (pg. 21). That is, 5.2 g of dried cannabis is physically equivalent to 1 g of "shatter" or "budder." In the Orens et al. (2015) document, butane hash oil is also called "shatter" or "budder."
Edibles		
1 standard joint	7 single serving edibles of 10 mg of THC per edible 1 serving is equivalent to 10 mg of THC per edible. We assume that "packages" contain 3 servings of edibles, each containing 10 mg of THC per edible.	We use Table ES-1 in Orens et al. (2015) as a basis for this conversion. We assume the solvent butane is used to distill cannabis oil in the preparation of cannabis edibles in the calculation. Currently, the sale of cannabis edible products is illegal in Canada. It is possible that the cannabis edibles sold illegally in Canada during the study period would be similar in terms of packaging as those edibles sold legally in the United States. The maximum amount of THC in a single edible product is: in Colorado, California, and Washington – 10 mg of THC; in Alaska and Oregon – 5 mg of THC (American Public Health Association, 2017; California Department of Public Health, 2019). The maximum amount of THC in a single multi-serving "package" of cannabis edibles is: 100 mg of THC in Colorado, Washington, and California (American Public Health Association, 2017; California Department of Public Health, 2019); and 50 mg of THC in Alaska and Oregon (American Public Health Association, 2017). At this time, the average number of single-serving items in multi-serving packages sold in Canada is unclear and, as a result, we estimated a likely conservative average number of 3 single servings per each multi-serving "package" of cannabis edibles consumed in the country. If this number is closer to the maximum of 5 or 10 10-milligram THC single servings per multi-serving package sold (as in Alaska, Colorado, Oregon, Washington, and California), our approach would lead to an underestimate of edible consumption in the Canadian population.
Cannabis-infused drinks		
1 standard joint	7 servings of 10 mg of THC per edible product that is drinkable (e.g., a cannabis-infused drink)	See Table III-4 from Orens et al. (2015) (pg. 21) for justification of the 1:14 ratio of 1 g dried cannabis to 14 servings of 10 mg of THC strength per edible products. In the United States, a standard 355 ml cannabis-infused drink (e.g., cola, tea) cannot contain more than 10 mg of THC in each single product. So, we will consider 355 ml to be a single serving containing 10 mg of THC per serving. So, 1 cannabis infused drink of 355 ml containing 10 mg of THC would have a physical production equivalency equal to approximately 0.07 g of dried cannabis. We will also assume that a cup of cannabis-infused tea or cola equals 237 ml and contains 6.7 mg of THC per cup. 1 cup (237 mL) of cannabis-infused drink has a physical production equivalency equal to 0.048 g of dried cannabis. 1 L of cannabis-infused drink equals 4.23 cups of cannabis-infused drink; so, 1 L of cannabis-infused drink has a physical production equivalency equal to 0.202 g of dried cannabis.
Cannabis tincture		
1 standard joint	65.8 drops of cannabis tincture	Cannabis tinctures use ethanol (alcohol) as the solvent and medium, and this carrier liquid is lighter than oil [alcohol (ethanol) weighs 0.789 g/ml]. At this time, we are not aware of any available physical production equivalency calculations equating grams of dried cannabis to cannabis-tincture units. At this time, cannabis tinctures are not legal in Canada. So, we used the physical production equivalency calculations for "1 drop cannabis oil" for "one drop of cannabis tincture" as an approximation in relation to dried cannabis products.

of cannabis-related harms (Asbridge et al., 2014; Zeisser et al., 2012). Secondly, the smallest retail joint size available through provincial/territorial government cannabis stores in Canada contains 0.5 g of dried cannabis (Alberta Gaming and Liquor Commission (AGLC), 2018; Alcool New Brunswick Liquor (ANBL), 2018; B.C. Cannabis Stores, 2018; Cannabis Yukon, 2018; Northwest Territories Liquor and Cannabis Commission, 2018; Nova Scotia Liquor Corporation, 2018; Ontario Cannabis Store, 2018; Prince Edward Island Cannabis Management Corporation, 2018; Société québécoise du cannabis, 2018). In the current paper, we express total consumption in terms of SJEs.

2.7. Analytic plan

First, we aggregated all data from Waves 1–3. We created for each cannabis user a total past-three-month cannabis consumption variable in SJE units, based on the physical production equivalency conversion values listed in Table 1. Then, we ranked individuals according to past-three-month cannabis consumption, from highest to lowest, and we assigned individuals to ranked-order groups based on total consumption over the past three months. For example, the "2.5%" group represented the upper 2.5% of cannabis users, the "5%" category indicated the top 5% of users, and so on. The cumulative consumption within each of these ranked cannabis-using groups was calculated as follows, from heaviest to lowest groups: the average amount of cannabis consumed in the past three months (in SJE units) within each subgroup was multiplied by the subgroup's survey-weighted sample size, and then divided by the total weighted amount of cannabis consumed (in joint equivalents) in the past three months of all cannabis users (indicating cannabis use in the past three months).

3. Results

Table 2 presents the demographic profile and key cannabis-related behavioral characteristics of the pooled sample (n = 18,900) from Waves 1–3. Approximately 14% (n = 2584) of the respondents in the pooled sample reported past-three-month cannabis use. Survey respondents were approximately equally split between males and females, and the youngest (15–34 years) and oldest (65+ years) age groups comprised the largest subgroups of participants.

Table 3 shows the means and cumulative proportions of cannabis consumption in SJEs for volume-based percentile subgroups of cannabis users. The bottom three rows of Table 2 provide key findings related to the concentration of the cannabis-use distribution in Canada: the

Table 2
Characteristics of survey participants (n = 18,900), National Cannabis Survey Waves 1–3.

		Cannabis Use, Past 3 Months		
Characteristic	Value	No	Yes	Total
Gender[a]	Male	47.6(0.25)[b]	57.6(1.4)	49.1(0.05)
	Female	52.2(0.24)	41.7(1.38)	50.7(0.02)
Age	15–34 years	26.8(0.3)	55.6(1.38)	31.1(0)[c]
	35–44 years	15.8(0.17)	16.9(0.98)	16.0(0)
	45–54 years	16.9(0.14)	11.0(0.79)	16.0(0)
	55–64 years	17.7(0.13)	11.0(0.71)	16.7(0)
	65+ years	22.7(0.12)	5.5(0.48)	20.2(0)
Marital Status	Married	53.9(0.51)	30.5(1.28)	50.4(0.46)
	Living common-law	10.3(0.34)	18.3(1.26)	11.5(0.34)
	Widowed	5.6(0.2)	1.8(0.39)	5.1(0.17)
	Separated	2.0(0.16)	2.5(0.45)	2.1(0.15)
	Divorced	5.5(0.22)	3.6(0.42)	5.2(0.2)
	Single	22.3(0.46)	43.2(1.59)	25.4(0.41)
Education level	Less than high school diploma or its equivalent	10.9(0.4)	11.7(1.26)	11(0.39)
	High school diploma	22.5(0.52)	25.2(1.39)	22.9(0.49)
	Trade certificate or diploma	8.1(0.3)	10.6(0.83)	8.4(0.28)
	College, CEGEP or other non-university certificate or diploma (other than trades certificates or diplomas)	20.2(0.46)	20.4(1.23)	20.2(0.43)
	University certificate or diploma below the Bachelor's level	5.1(0.25)	4.3(0.53)	5.0(0.22)
	Bachelor's degree (e.g. B.A., B.Sc., LL.B.)	20.8(0.52)	20.1(1.3)	20.7(0.48)
	University certificate, diploma, degree above the Bachelor's level	11.6(0.35)	7.7(0.78)	11(0.32)
Main Activity Last Week	Working at a paid job/ Vacation (From paid work)	56.3(0.53)	65.9(1.59)	57.7(0.51)
	Looking for paid work	1.7(0.16)	3.3(0.66)	1.9(0.17)
	Going to school	6.2(0.36)	9(1.18)	6.6(0.34)
	Caring for children, Household work, Parental leave	7.6(0.32)	6.4(0.76)	7.4(0.29)
	Retired	22.3(0.28)	6.5(0.53)	19.9(0.24)
	Long-term illness/Volunteer/ Caregiver other than for child/Other	5.7(0.28)	8.9(0.95)	6.2(0.28)

[a] The total percentages do not sum to 100% because some participants reported their gender as other than "male" or "female." Statistics Canada privacy policy precluded release of information related to the "other" category because of small cell sizes and privacy concerns.
[b] Values in parentheses represent standard errors of the estimate.
[c] The age variable was used in the construction of the Statistics Canada bootstrap weights and, as a result, the application of bootstrap weights to the age-group prevalence estimates resulted in exact estimates (i.e., standard errors equal to zero).

Table 3
Means and cumulative proportions of cannabis consumption in standard joint equivalents (SJEs) for volume-based percentile subgroups of cannabis users.

Number of SJEs consumed in last 3 months	Cumulative % of Users	Pop (in 1000s)[a]	Mean number SJEs/3 mths	Cumulative % Consumed	95% Confidence Interval	% Subjects
≤ 0.7	100.0%	410	0.2	99.9%	–	9.8%
> 0.7–1.5	90.1%	423	1.0	99.9%	99.97%–99.99%	10.1%
> 1.5– 3	79.9%	425	2.2	99.8%	99.84%–99.9%	10.2%
> 3–7	69.7%	402	4.8	99.6%	99.57%–99.73%	9.6%
> 7–14.2	60.0%	430	10.2	99.1%	99.01%–99.39%	10.3%
> 14.2–30	49.7%	398	23.5	98.1%	97.91%–98.71%	9.5%
> 30–60	40.1%	428	47.5	95.9%	95.1%–96.88%	10.3%
> 60–105	29.8%	198	82.4	91.2%	89.42%–93.09%	4.7%
> 105–122	25.0%	200	114.3	87.4%	84.91%–90.02%	4.8%
> 122–169.8	20.2%	217	153.3	82.1%	78.41%–85.86%	5.2%
> 169.8–224	14.9%	205	185.9	74.3%	69.43%–79.34%	4.9%
> 224–400	10.0%	201	301.6	65.5%	59.12%–71.93%	4.8%
> 400–675	5.2%	109	520.3	51.3%	42.85%–59.91%	2.6%
> 675	2.5%	105	1561.9	38.1%	28.11%–48.28%	2.5%

[a] Estimated population numbers of cannabis-user subgroups in the Canadian population in 2018, given the pooled population weights across Waves 1–3 of the National Cannabis Survey.

heaviest 2.5% of cannabis users consumed 38.1% of the total volume of cannabis consumed in the country; the heaviest 5.2% of users consumed 51.3% of the total volume; and the upper 10% of users accounted for 65.5% of all cannabis products consumed. Table 3 also presents the mean number of SJEs consumed across the 14 volume-based consumption groups. Estimates of the mean consumption (in joint equivalent units) increased exponentially from the lightest- to heaviest-using groups: the lightest-using group consumed on average 0.7 SJEs in the past three months, while the heaviest-using group (the top 2.5% in terms of consumption) had a mean consumption of 1561.3 SJEs in the past three months. Fig. 1 presents mean cannabis consumption levels across volume-based groups, with the solid circles representing the estimates within each use group. It is also important to note that individuals who reported daily or near daily cannabis use accounted for 85% (95% CI, 81%–89%) of all cannabis consumed in the past-three-month period.

Stratified by gender, Fig. 2 illustrates the cumulative percentage of cannabis consumption (in joint equivalents) plotted on the y-axis as a function of the volume-based percentile groups (from heaviest to lightest cannabis users) on the x-axis. This figure visually depicts the cumulative-consumption results shown in Table 3: the heaviest-using groups (represented in the far left of the figure) consumed the majority of cannabis in the country. Fig. 2 also shows that males consumed a greater volume of cannabis (in joint equivalents) in each of the volume-based consumption groups, with males accounting for approximately 60% of all self-reported cannabis consumed in the combined Waves 1–3 of the NCS.

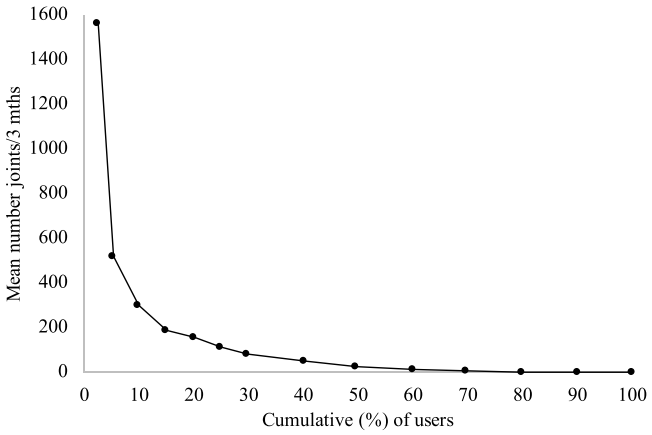

Fig. 1. Mean number of standard joint equivalents (SJEs) consumed in last three months across cannabis-use groups (denoted by filled circles), from heaviest-using group (far left) to lightest-using group (far right).

Fig. 3 presents the cumulative percentage of cannabis consumption, stratified by age group, across volume-based groups (from heaviest to lightest). Fig. 3 shows that the 15-34-year-old age group accounted for the largest volume of cannabis consumption, especially in the heaviest-using groups, followed by the 35-44-year-old and 45-54-year-old age groups. Fig. 4 depicts the market share of major types of cannabis products across volume-based groups (from heaviest to lightest): dried cannabis leaf/flower represented the bulk of the cannabis consumed, followed by cannabis concentrates, and edibles. In total, dried cannabis leaf/flower accounted for approximately 60% of the total market share; cannabis concentrates, 23%; cannabis edibles, 14%; and "other" cannabis products, 3%.

4. Discussion

The current study provides key baseline information about patterns of cannabis consumption in Canada, just prior to the legalization of adult recreational cannabis use on October 17, 2018. Similar to the findings in the alcohol literature (Caetano et al., 2012; Greenfield and Rogers, 1999), study results show that cannabis consumption is highly concentrated in a small subset of the heaviest users: the upper 10% of cannabis users accounted for approximately two-thirds of all cannabis consumed in the country, with the heaviest-using group reporting an exponentially higher mean number of consumed SJEs than other cannabis-using groups (c.f., Greenfield and Rogers, 1999). In addition, males reported consuming more cannabis by volume than females (approximately 60% versus 40%), with young males (15–34 years old) being disproportionately represented in the heaviest-using subgroups. Dried cannabis flower/leaf represented the cannabis product with the greatest market share across volume-based user groups, followed by cannabis concentrates (e.g., oils, hash, "shatter," "budder"), and cannabis edibles.

Researchers aiming to estimate quantity of cannabis consumption must address the central challenge of developing an equivalency table for various kinds of cannabis products. In order to enable the conversion of self-reported consumption of non-flower cannabis products into a common flower-based unit, we calculated physical production equivalencies of cannabis product types, where infused edibles or concentrates were equated to their corresponding weight of dried flower or trim inputs. This conversion process allowed for the calculation of total aggregate cannabis consumption (within the past three months) in SJEs, with a standard joint being equivalent to 0.5 g of dried cannabis. In the alcohol field, the definition of a "standard drink"

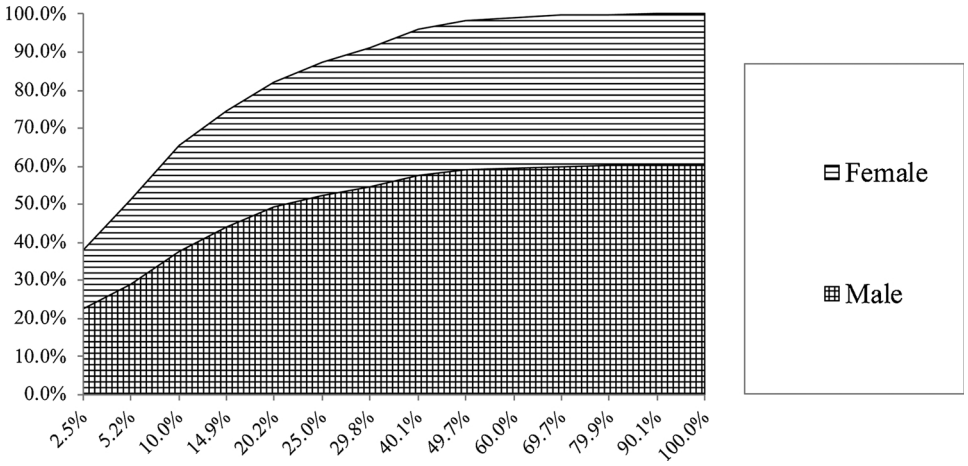

Fig. 2. Percentage of total self-reported cannabis consumption in both males and females.

functions not only as a central component in the assessment of alcohol consumption, but also in the communication of levels of consumption vis-à-vis low-risk drinking guidelines and in the application of some recent alcohol-taxation strategies (e.g., minimum-unit pricing) (Boniface et al., 2017; Kerr and Stockwell, 2012; Stockwell et al., 2012). A consensus definition of a "standard joint" may serve a similar role in the cannabis research and policy domains in the future.

Approximately 40% of the total volume of cannabis consumed in our study took the form of non-dried leaf products, such as cannabis concentrates and edibles. This use of a wide range of cannabis products in Canada appears similar to the current trends in the United States. Recent US-based research has shown that even though smoking dried flower/leaf was the most prevalent form of cannabis use in 2017, slightly more than half of cannabis users reported past-year use of dried flower/leaf and at least one additional cannabis product type, such as edibles or concentrates (Steigerwald et al., 2018). Also, Orens and colleagues (2018) found that non-flower/trim products (e.g., edibles, concentrates) accounted for approximately 33% of the market share (measured as a function of physical production equivalents) based on Colorado cannabis sales data from 2017. While a number of recent studies have attempted to define characteristics of a standard joint (Casajuana Kögel et al., 2017; Hindocha et al., 2017) – a much needed measurement touchstone for the scientific field – the current results show that future research will also need to assess cannabis exposure across a much broader spectrum of cannabis-product consumption.

Lower Risk Cannabis Use Guidelines (LRCUG) – a set of 10 population-oriented recommendations designed to mitigate both individual- and societal-level harms of cannabis use (Fischer et al., 2017) – have recently been proposed. The current LRCUG do not advocate lower risk guidelines for actual standard amounts of cannabis use in regards to daily, weekly or single-sitting limits, as do country-specific low risk drinking guidelines, for example (Kalinowski and Humphreys, 2016). As a result, it is not possible at this time to identify those cannabis users in our study exceeding any established quantity-based lower-risk consumption limits. For the field to be able to develop general-population cannabis-use guidelines regarding quantity of cannabis use, it will be necessary to assess both quantity of cannabis consumed and route of administration, as well as how such use is associated with potential individual-level increased risks (Volkow et al., 2016). At the population level, it is unclear whether the "prevention paradox" might hold vis-à-vis cannabis use in the population (Andreasson, 2011; Kreitman, 1986; Skog, 2006b; Stockwell, 2006; Stockwell et al., 1996) – that is, whether the majority of cannabis-related harms might be situated in the small subgroup of heaviest users (usually defined by high consumption levels over an extended period of time), the much more numerous set of moderate-to-low-consuming individuals (as the prevention paradox would predict), or some other population subset (for a debate about the validity and applicability of the "prevention paradox" in the alcohol field, see, for example: Skog, 2006b; Stockwell, 2006). Research will need to assess this issue, which is often used as a justification for broad-based policy and public health initiatives.

In our understanding, our paper is among the first articles attempting to describe the distribution of cannabis consumption by quantity in a population of cannabis users (c.f., Burns et al., 2013; Hall and Swift, 2000). Reflecting on where this type of work has led in the alcohol field, this article opens avenues for future research. First, cannabis distributions should be studied and defined in more countries and contexts, building on this work. As the cannabis literature continues to

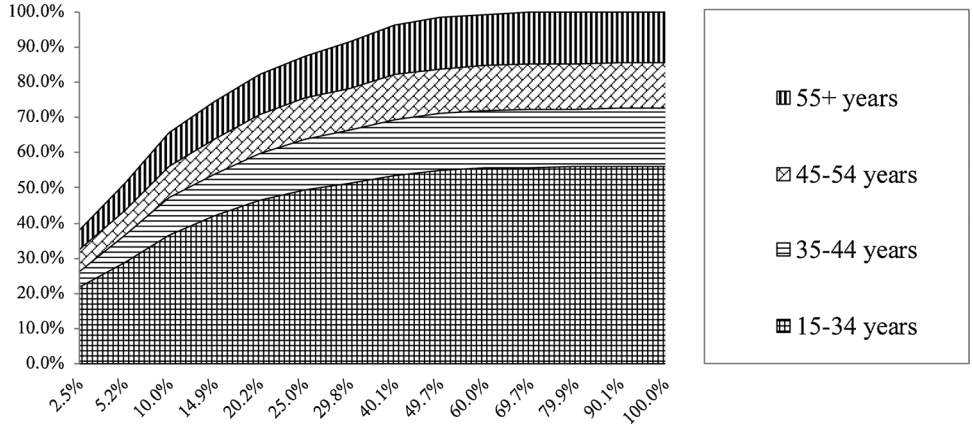

Fig. 3. Percentage of total self-reported cannabis use by age group.

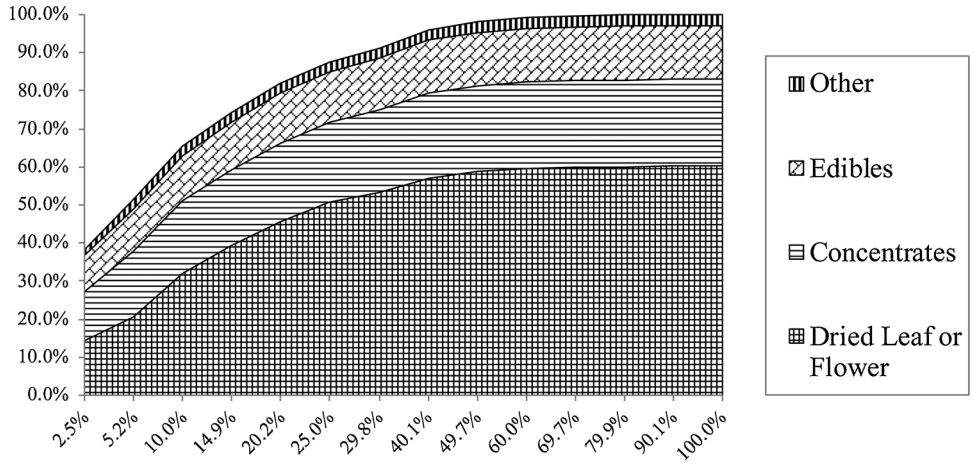

Fig. 4. Percentage of total self-reported cannabis use by type of cannabis consumed.

emerge and evolve, consideration may be given to developing models which predict the distribution of cannabis consumption in a population given certain inputs (e.g., *per capita* cannabis consumption). Models such as this exist for alcohol use and have improved the accuracy of alcohol-related health harms estimation (Kehoe et al., 2012).

The current study has a number of limitations. Given the illegality of cannabis consumption during the data collection phases for the first three waves of the NCS, it is possible that respondents may have underreported or denied their actual cannabis consumption. Also, the current study proposed that the standard joint was equivalent to 0.5 g of dried cannabis. For individuals reporting the number of joints consumed, total aggregate cannabis consumption was a function of this metric. It is possible that an individual's usual joint size may not have matched our SJE size of 0.5 g of dried cannabis. In this regard, it is important to note that researchers have proposed varying estimates for what might constitute a "standard" joint. Based on US Arrestee Drug Monitoring Data from 2000 to 2010, Ridgeway and Kilmer (2016) estimated the average amount of dried cannabis in a joint to be 0.32 g, while a Spanish study estimated that the standard joint was equivalent to 0.25 g of dried cannabis (Casajuana Kögel et al., 2017). Also, in the first three waves of the NCS, the assessment of cannabis edibles elicited ambiguous information about the amount of THC consumed in edible products in "grams" or "milligrams." We assumed that individuals reporting levels of edible consumption in "grams" or "milligrams" were reporting the weight of the key active ingredient THC in the edibles consumed over the prior three months, rather than the weight of the edibles *per se*. This may have led to an overestimation of cannabis-edible consumption in the current study. Also, the restricted-use survey data from the NCS did not provide information regarding the cannabis products used in the assessment of "other" cannabis-product types. Given that the survey data only provided information regarding the unit type (e.g., milligrams, milliliters, drops) and number of "other" cannabis units consumed, we assumed the SJE associated with the most frequently reported unit type/cannabis product combination. For example, if a respondent reported the unit type as "milliliters," then the SJE for cannabis oils was used to estimate aggregate cannabis consumption.

Despite these limitations, the current study makes a number of important contributions to the cannabis-research field. First, the study draws strength from a national, population-based survey which elicited information about consumption quantity across seven of the major cannabis product types. Secondly, the project created conversion metrics based on the physical production equivalencies across cannabis-product types, as a function of a SJE (equal to 0.5 g of dried cannabis). This approach allowed for the construction of aggregate individual-level and population-level consumption volume estimates. In addition, the results demonstrated that the cannabis cumulative distribution profiles closely resemble those found for alcohol consumption across populations, and it may be helpful for future cannabis-related research to draw upon the approaches in the alcohol research field to investigate the relations between population-level patterns of cannabis consumption and associated harms in society.

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Contributors

RC conceived of the research approach, completed the first draft of the paper, organized the statistical analyses, and supervised the integration of the co-authors' contributions to the final manuscript. MS conducted the statistical analyses and provided key interpretations of the results for the manuscript. CB contributed to the research design and manuscript. AS and TS provided substantial contributions to the text and final manuscript. SK provided critically important revisions to drafts of the manuscript.

Declaration of Competing Interest

No conflict declared.

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