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## Differences in self-reported cannabis prices across purchase source and quantity purchased among Canadians

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### ABSTRACT

**Background:** In October 2018, Canada legalized non-medical cannabis. A primary goal of legalization is to reduce illicit market transactions; however, there is little 'baseline' data on the price and purchase sources of cannabis prior to legalization in Canada. This study examined the self-reported price of dried cannabis, quantity purchased, and sources used before retail stores opened.

**Methods:** Data come from the baseline wave of the International Cannabis Policy Study (ICPS), a prospective cohort survey conducted in August–October 2018, immediately before legalization. Respondents were 1227 Canadians aged 16–65 years who reported purchasing dried cannabis in the past 12 months. Respondents were recruited using the Nielsen Consumer Insights Global Panel. A linear regression model examined price-per-gram by quantity purchased, source used, and socio-demographics.

**Results:** Overall, the mean self-reported price-per-gram among cannabis users was C\$9.56 (standard errors of the mean [SEM] = 0.2). The price-per-gram of cannabis significantly decreased as quantity purchased increased. For example, the mean price of cannabis purchased in smaller quantities (<3.5 g) (\$12.81/g, SEM = 0.5) was more than double the price of cannabis purchased in larger quantities (>28 g) (\$5.60/g, SEM = 0.2). The estimated quantity discount elasticity was  $-0.21$  (95% CI:  $-0.25$ ,  $-0.18$ ). The most common purchase sources used were family member/friends (53.0%) and illicit street dealers (51.7%). Price-per-gram varied across sources; however, variation was largely accounted for by consumers purchasing different quantities at different sources.

**Conclusions:** Variations in the price of dried cannabis were largely determined by the quantity purchased. The findings highlight the importance of accounting for purchase quantity when assessing cannabis prices, particularly in illicit markets.

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Cannabis; marijuana; price; legalization; quantity discount; illicit market

### Introduction

Cannabis is the most widely used illicit substance in the world and Canada has one of the highest prevalence rates of use among developed countries (United Nations Office on Drugs and Crime 2017; Statistics Canada 2018a). In the 2018 Canadian Cannabis Survey, 22.4% of Canadians over 16 years reported cannabis use in the past 12 months and 15.4% reported use in the past month (Government of Canada 2018). Of those who used in the past 12 months, 19% reported daily cannabis use (Government of Canada 2018). In Canada, medical cannabis has been legally available since 2001. Under the Access to Cannabis for Medical Purposes Regulations (ACMPR), those with authorization from a licensed physician could access cannabis from either a Health Canada registered licensed producer, grow a defined quantity or designate someone else to grow for them. During the same period, illicit cannabis was also widely available in Canada and could be accessed through illicit street dealers, 'dispensaries', and online retail sources (Mahamad and Hammond 2019).

On 17 October 2018, Canada became the second country after Uruguay to legalize non-medical cannabis. Reducing the illicit cannabis market is one of the primary objectives of the federal Cannabis Act (Parliament of Canada 2018). In 2017, Canadians spent on the order of \$6 billion CAD on cannabis, of which 90% was estimated to be from illicit sources (Statistics Canada 2018b). In an effort to minimize illicit sales, Canada set excise tax rates so that the price of legal cannabis products would be competitive with those in the illicit market. Cannabis is subject to a federal excise tax of \$1 per gram of cannabis or 10% of a product's price, whichever is greater (Department of Finance Canada 2018), as well as provincial sales taxes, which vary from 5% to 15%. For example, one gram of dried cannabis costing CAD \$8 pretax could cost between \$9.45 and \$10.35. The use of taxation to increase price is widely recognized as an effective public health measure for reducing tobacco and alcohol consumption (Babor, Alcohol and Public Policy Group 2010; Chaloupka et al. 2012; Wright et al. 2017). Therefore, higher cannabis prices may be desirable. However, if the legal price

exceeds that of illicit cannabis, higher prices may increase demand for and retain the illicit market. Indeed, the primary driver of illicit sales is the difference between legal and illicit prices (Clements and Zhao 2009; US National Cancer Institute and World Health Organization 2016; Maslov et al. 2016).

Price plays a central role in economic theories of consumer behavior (US National Cancer Institute and World Health Organization 2016). ‘Price elasticity of demand’ is the economic concept that explains how sensitive consumers are to changes in price. Price elasticity of demand is usually negative, as an increase in price usually reflects a decrease in quantity demanded, including for addictive substances. For example, tobacco is an inelastic good and its price elasticity of demand is estimated to be  $-0.4$  in high-income countries (US National Cancer Institute and World Health Organization 2016). This means that a 10% increase in price is expected to decrease consumption by 4%. Tobacco is inelastic because there are few substitutes, and nicotine, the main component of tobacco, is highly addictive (US National Cancer Institute and World Health Organization 2016). However, researchers argue that reliable price elasticities for cannabis do not yet exist; therefore, it is difficult to predict consumption (Pacula and Lundberg 2015). Prior studies have calculated elasticities using prevalence data, which capture infrequent consumers (Pacula and Lundberg 2015). Infrequent consumers account for the majority of cannabis users, but not the majority of cannabis consumed (Kilmer et al. 2014). As a result, different types of users may be differentially sensitive to price. Two populations with particular relevance to public health outcomes – heavy users and youth – may have greater price sensitivities and warrant special consideration (Manning et al. 1995; Pacula et al. 2001; Williams et al. 2004; Caulkins and Pacula 2006; van Ours and Williams 2007; Pacula and Lundberg 2015; Davis et al. 2016).

A reduction in price post-legalization could affect cannabis use rates among current users, as shown by evidence from other substances (Wagenaar et al. 2009; Hall and Lynskey 2016). There is concern that this may increase the risk of cannabis-related problems and addiction (Caulkins 2001). Indeed, longitudinal research has shown that around 1 in 11 cannabis users will become dependent (Lopez-Quintero et al. 2011; Hall 2015) and that this probability increases with daily use (1 in 2 users) and with initiation in adolescence (1 in 6 users) (van der Pol et al. 2013; Hall 2015).

There is limited data on the price of illicit cannabis in Canada prior to legalization. Available estimates are drawn from three sources: ‘crowdsourced’ data collected online (Ouellet et al. 2017; Statistics Canada 2018c), self-reported data in population surveys (Government of Canada 2018), and objective price data collected directly from illicit retail sources (Mahamad and Hammond 2019). The reliability of crowdsourced data remain highly uncertain and is particularly susceptible to self-selection bias and potential manipulation. Only one study to date has collected objective prices in Canada’s illicit market. In a study investigating the price of cannabis in illicit retail and online dispensaries in the most populous city of each province and territory, the

average price-per-gram of the most popular strain of cannabis was \$10.02/g (Mahamad and Hammond 2019), somewhat higher than estimates from crowdsourced and self-reported data (\$7.14/g–\$8.62/g).

Accurate price estimates of illicit cannabis are essential for assessing the potential impact of legalization. Knowing what Canadian cannabis users pay for their illicit cannabis is important as this helps to shape legal cannabis prices and tax rates and whether legal prices are sufficient to encourage transition from illicit to legal sources as the market stabilizes post-legalization. Creating a legal market is predicted to reduce the cost of production, as certain costs associated with the illicit market are no longer required, such as paying workers a higher wage to compensate for illicit activity (Hunt and Pacula 2017). Legalization also has the potential to reduce monetary costs due to increased efficiency through innovation, expansion, and technology (Kilmer et al. 2010; Hall and Lynskey 2016). The price of legal cannabis is also expected to change over time as legal retail markets and supply chains become established. In Canada, Statistics Canada reported crowdsourced price data between December 2018 and June 2019 that showed a 9% increase in the average price of dried cannabis from legal sources (\$9.82/g–\$10.65/g) and an 8% decrease in the price from illicit sources (\$6.51/g–\$5.93/g) (Statistics Canada 2019). In a review of Colorado’s cannabis market – one of the first legal non-medical retail markets – the price of cannabis declined 62% from 2014 to 2017 (Orens et al. 2018). In Oregon, the price of cannabis declined 50% from 2016 to 2018 due to increased supply (Oregon Liquor Control Commission 2019). Unfortunately, aside from legal non-medical cannabis prices post-legalization, US states that have legalized lack ‘baseline’ data and often have limited data on illicit sources following legalization (Hunt and Pacula 2017). The transition to a legal market in legal states has occurred incrementally over many years; thus, data are just beginning to emerge from the first US states to legalize, such as Colorado and Washington (Pacula and Sevigny 2014; Subritzky et al. 2016; Hunt and Pacula 2017; Ouellet et al. 2017).

Few studies have examined self-reported price of dried cannabis in Canada before legalization (Government of Canada 2018). This study is timely given the importance of analyzing baseline or ‘pre-implementation’ measures before cannabis legalization in Canada to compare with post-legalization data. This study examined Canadian results from the International Cannabis Policy Study (ICPS), immediately prior to legalization of non-medical cannabis in Canada. The aims of this study were to: (1) examine the self-reported price-per-gram of dried cannabis across Canada; (2) examine the effect of purchase source on price-per-gram; and (3) explore the associations between self-reported price-per-gram of dried cannabis, purchase source, and quantity purchased.

## Methods

Data were from the baseline wave of the ICPS, a prospective cohort survey conducted annually with participants aged

16–65 years living in Canada ( $n = 10,057$ ) and the USA ( $n = 17,112$ ). The survey will be repeated annually at 12-, 24-, and 36-months follow-up to monitor changes over time, as well as key mediators and moderators of use, in each of three jurisdictions: Canada (all provinces); US states that have legalized non-medical cannabis (US ‘legal’ states) and those that have not (US ‘illicit’ states). This study reports data from the Canadian sample of Wave 1 of the ICPS Survey, conducted between 27 August 2018 and 7 October 2018. Respondents completed an online survey in English or French with a median survey time of 19.9 min.

Individuals were eligible to participate if they resided in a Canadian province, were 16–65 years of age at the time of recruitment and had access to the internet. Respondents were recruited using the Nielsen Consumer Insights Global Panel (<http://www.nielsen.com/ca/en/about-us.html>). The Nielsen panels use both probability and nonprobability sampling methods. For the current project, Nielsen drew stratified random samples from the online panels, based on known proportions in each age group. To account for differential response rates, Nielsen modified these sampling proportions to place greater weight on sub-groups with lower response rates. All the data provided by respondents were anonymous and kept strictly confidential. Respondents provided consent prior to completing the survey. Respondents received remuneration in accordance with their panel’s usual incentive structure (e.g. points-based or monetary rewards, chances to win prizes). A full technical report for the study is available from <http://cannabisproject.ca/methods/>.

### Measures

Survey measures were drawn or adapted from national surveys or selected based on previous research. In all cases, participants had the option of selecting ‘Don’t Know’ or ‘Refuse’.

### Socio-demographic measures

Socio-demographic measures included sex at birth, age in years, ethnicity, education, and province of residence. Cannabis use status was assessed through questions, ‘How often do you use cannabis?’ and ‘When was the last time you used cannabis?’ Responses were recoded into: (‘Less than monthly user’, ‘At least monthly user’, ‘At least weekly user’, ‘Daily or almost daily user’).

### Self-reported price-per-gram of dried cannabis

Participant’s price-per-gram was calculated from two questions. First, participants were asked, ‘The last time you purchased dried cannabis, how much did you buy...?’ (‘Less than 1/8 gram’, ‘1/8 gram’, ‘1/4 gram’, ‘1/2 gram’, ‘3/4 gram’, ‘1 gram’, ‘2 grams’, ‘3 grams’, ‘1/8 ounce’, ‘1/4 ounce’, ‘More than 1/4 ounce’, ‘1/2 ounce’, ‘1 ounce’, ‘More than 1 ounce’). Respondents had a choice of units in which to report. Units were standardized into grams (g) and responses were continuous. Second, participants were asked, ‘The last time you purchased dried cannabis, how much did

you pay for the quantity you bought?’ (continuous variable). Participants who had a price-per-gram outside of the range \$2.20–\$30 were excluded ( $n = 336$ ). This range was based on the minimum and maximum price-per-gram identified in a retail scan of the illicit cannabis market in a separate study (Mahamad and Hammond 2019).

### Purchase source

Participants were asked: ‘In the past 12 months, how did you get the dried cannabis you used?’ (‘I grew my own’, ‘From a family member or friend’, ‘From a dealer (in person)’, ‘Health Canada medical marijuana licensed producer, by mail order’, ‘Other internet delivery service’, ‘From a store, co-operative or dispensary (in person)’, ‘Other’). ‘Other’ was recoded according to responses provided. Participants could select all that applied; however, only participants who purchased from only one source in the past 12 months were recoded to the respective source. It was assumed that those who purchased from only one source in the past 12 months would have used that source at their last purchase. Participants who purchased from more than one source in the past 12 months were recoded to ‘Not reported’. For the current price analysis, ‘I grew my own’ was excluded because price paid for seeds/plants might differ from price of dried cannabis ( $n = 2$ ). All purchase sources were illicit before legalization in Canada, except purchases from a Health Canada licensed producer.

### Data analysis

In Wave 1, 1,428,857 respondents were sent an email invitation to the survey, where 44,364 respondents accessed the survey link, of which 28,471 (2%) completed the entire survey. A total of 10,646 Canadian respondents completed the survey. Due to data integrity questions or ineligible location, 589 respondents were excluded. The final analytic sample included 10,057 respondents. For the current analysis, 8824 participants were excluded for not having used and purchased dried cannabis in the past 12 months. An additional six were excluded for data quality because their postal code did not align with the province indicated. The final analytic sample for this study was 1227 participants. A total of 336 respondents were excluded from analyses on a case-wise basis for measures with missing data in the price-per-gram calculation. Of those that were excluded, 184 respondents either refused or did not know the price and quantity of cannabis they purchased and 152 respondents reported a quantity or price that was outside the valid range of \$2.20–\$30.00. The proportion of respondents who had a price-per-gram within the valid range differed by sociodemographic characteristics: more females were within range than males ( $\chi^2 = 7.5, p = .006$ ); more respondents with bachelor’s degrees or higher were within range than respondents with a high school diploma or some college degree ( $\chi^2 = 14.1, p = .003$ ); more white respondents were within range than other respondents ( $\chi^2 = 11.6, p < .001$ ); and more daily/almost daily users were within range than less frequent users ( $\chi^2 = 27.0, p < .001$ ).



Post-stratification sample weights were constructed based on the Canadian Census estimates. Respondents from Canada were classified into age-by-sex-by-province and education groups. Correspondingly grouped population count and proportion estimates were obtained from Statistics Canada (Statistics Canada 2016, 2017). A raking algorithm was applied to the full analytic sample ( $n = 10,057$ ) to compute weights that were calibrated to these groupings. Weights were rescaled to the sample size for Canada. Estimates are weighted unless otherwise specified. First, the mean price-per-gram of dried cannabis with standard errors of the mean (SEM) were examined by quantity purchased, purchase source, and province. Second, a multiple linear regression model was fitted to examine the relationship between the natural log of quantity purchased and purchase source and province of residence. Third, a multiple linear regression model was fitted to examine the relationship between the natural log of price-per-gram and quantity purchased (log-transformed), purchase source, and province of residence. The model estimates are reported with 95% confidence intervals (95% CIs) and adjusted for age, sex, ethnicity, education, and cannabis use status. Analyses were conducted using PROC SURVEY commands in SAS version 9.4 (SAS Inc., Cary, NC).

### Ethics

The project was reviewed by and received ethics clearance through a University of Waterloo Research Ethics Committee (ORE#22392).

### Results

Table 1 displays the weighted and unweighted sample characteristics among Canadians who had used and purchased dried cannabis in the past 12 months.

#### Cannabis quantity purchased and price paid

Table 2 displays the quantity of cannabis and the price paid at last purchase by frequency of cannabis use. Across all cannabis users, the mean total price paid for cannabis at last purchase was \$81.30 (SEM = 5.4). The price paid at last purchase differed by frequency of use ( $\chi^2 = 219.1$ ,  $p < .001$ ). In general, price paid at last purchase increased as frequency of use increased: daily/almost-daily users had the largest mean price paid at their last purchase, compared to at least monthly users with the smallest mean price, as shown in Table 2.

Across all cannabis users, the mean quantity of cannabis purchased at last purchase was 12.6 g (SEM = 1.3). The quantity of dried cannabis purchased at last purchase differed by frequency of use ( $\chi^2 = 267.5$ ,  $p < .001$ ). In general, the quantity bought at last purchase increased as frequency of use increased: daily/almost-daily users bought the largest quantity of dried cannabis at their last purchase, compared to at least monthly users with the smallest mean quantity (Table 2).

**Table 1.** Sample characteristics ( $n = 1227$ ).

	Unweighted % (n)	Weighted % (n)
Age group		
16–25	18.4 (226)	18.9 (232)
26–35	22.6 (277)	31.4 (385)
36–45	17.1 (210)	21.0 (258)
46–55	19.1 (234)	16.1 (198)
56–65	22.8 (280)	12.6 (155)
Sex		
Female	48.8 (599)	39.8 (488)
Male	51.2 (628)	60.3 (739)
Race/ethnicity		
White	80.9 (993)	79.4 (974)
Other	19.1 (234)	20.6 (253)
Education		
Less than high school	12.7 (156)	19.4 (237)
High school diploma	17.4 (213)	29.5 (362)
Some college or technical vocation	46.1 (566)	34.5 (424)
Bachelor's degree or higher	23.6 (290)	16.4 (201)
Province		
British Columbia	11.9 (146)	15.9 (195)
Alberta	9.4 (115)	12.8 (156)
Saskatchewan	6.0 (74)	2.8 (34)
Manitoba	8.0 (98)	3.5 (43)
Ontario	28.2 (346)	39.0 (479)
Quebec	9.2 (113)	19.1 (234)
New Brunswick	8.8 (108)	2.1 (26)
Nova Scotia	10.2 (125)	2.9 (36)
Prince Edward Island	2.3 (28)	0.5 (6)
Newfoundland & Labrador	6.0 (74)	1.4 (17)
Cannabis use status		
Less than monthly user	14.4 (177)	13.1 (161)
At least monthly user	17.4 (213)	18.9 (232)
At least weekly user	21.6 (265)	21.9 (268)
Daily/almost daily user	46.6 (572)	46.1 (566)

#### Self-reported price-per-gram

Supplemental Table 1 displays the self-reported price-per-gram of dried cannabis at last purchase across the Canadian provinces. Across all quantities purchased, the average price-per-gram was the largest in Newfoundland and Labrador (\$10.48/g, SEM = 0.9) and smallest in Prince Edward Island (\$7.67/g, SEM = 0.6).

Table 3 displays the self-reported price-per-gram paid for three different purchase quantities. The mean price-per-gram of dried cannabis across consumers at all quantities purchased was \$9.56/g (SEM = 0.2). The mean price-per-gram for all consumers purchasing in quantities under 3.5 g was \$12.81/g (SEM = 0.5) and decreased with increasing purchase quantity. Table 3 also shows self-reported prices among consumers who purchased cannabis from a single source *versus* multiple sources over the past 12 months. Across all quantities purchased, consumers that purchased from multiple sources over the past 12 months had a lower mean price-per-gram than those that only purchased from one source. In addition, consumers that purchased from multiple sources had a larger mean purchase quantity (16.4 g, SEM = 2.9) compared to those that only purchased from one source (9.8 g, SEM = 0.9).

#### Cannabis purchase source

Figure 1 displays the sources used to purchase dried cannabis over the past 12 months. Across all consumers who had

**Table 2.** Cannabis quantity purchased and price paid (CAD \$) by frequency of use ( $n = 891$ ).

	All users $n = 891$	Less than monthly user $n = 102$	At least monthly user $n = 159$	At least weekly user $n = 180$	Daily/almost daily user $n = 450$
... How much did you pay for the quantity you bought?					
Mean \$ (SEM)	\$81.30 (5.4)	\$37.44 (5.7)	\$37.83 (4.3)	\$61.36 (5.2)	\$114.49 (9.8)
Amount paid (% , $n$ )					
Less than \$25	28.1% (250)	58.8% (60)	54.4% (86)	24.6% (44)	13.2% (60)
\$25–50	20.8% (185)	10.9% (11)	22.2% (35)	24.0% (43)	21.3% (96)
\$50–100	22.2% (197)	24.6% (25)	9.1% (14)	34.9% (63)	21.1% (95)
Over \$100	29.0% (258)	5.7% (6)	14.3% (23)	16.4% (30)	44.4% (200)
... How much did you buy?					
Mean grams (SEM)	12.6 g (1.3)	4.2 g (1.0)	4.3 g (.7)	7.7 g (.8)	19.4 g (2.5)
Quantity purchased (% , $n$ )					
<1 g	4.5% (40)	17.3% (18)	10.6% (17)	2.4% (4)	0.2% (1)
1 g–3.5 g	29.4% (262)	44.5% (45)	57.9% (92)	36.7% (66)	13.1% (59)
3.5 g–28 g	48.7% (434)	36.7% (37)	26.3% (42)	53.0% (95)	57.6% (259)
>28 g	17.4% (155)	1.5% (2)	5.2% (8)	7.9% (14)	29.1% (131)

**Table 3.** Self-reported price-per-gram at different quantities among consumers who had purchased dried cannabis from one source vs. multiple sources in the past 12 months ( $n = 891$ ).

	All quantities purchased \$/g (SEM) $n = 891$	<3.5 g \$/g (SEM) $n = 302$	3.5 g–28 g \$/g (SEM) $n = 434$	>28 g \$/g (SEM) $n = 155$
All consumers	\$9.56 (0.2)	\$12.81 (0.5)	\$8.71 (0.3)	\$5.60 (0.2)
Multiple purchase sources	\$8.47 (0.3)	\$11.47 (0.7)	\$8.23 (0.3)	\$5.28 (0.2)
One purchase source	\$10.42 (0.4)	\$13.57 (0.6)	\$9.14 (0.4)	\$5.98 (0.3)

bought dried cannabis over the past 12 months ( $n = 891$ ), 53.0% purchased from a family member or friend, 51.7% purchased from an illicit dealer, 12.7% purchased from a Health Canada registered Licensed Producer, 15.5% purchased *via* another online source/mail order, and 21.9% purchased from a store, cooperative, or dispensary. Of consumers who had purchased from multiple sources, the majority had purchased from a family member or friend (74.6%) or an illicit dealer (74.4%). Fewer participants had purchased from Health Canada Licensed Producers, online, or stores and dispensaries.

Figure 2(A) displays the average self-reported quantity of dried cannabis purchased by consumers who purchased from only one purchase source over the past 12 months. Those who purchased online or via mail order purchased in larger quantities compared to those who purchased from stores, cooperatives or dispensaries.

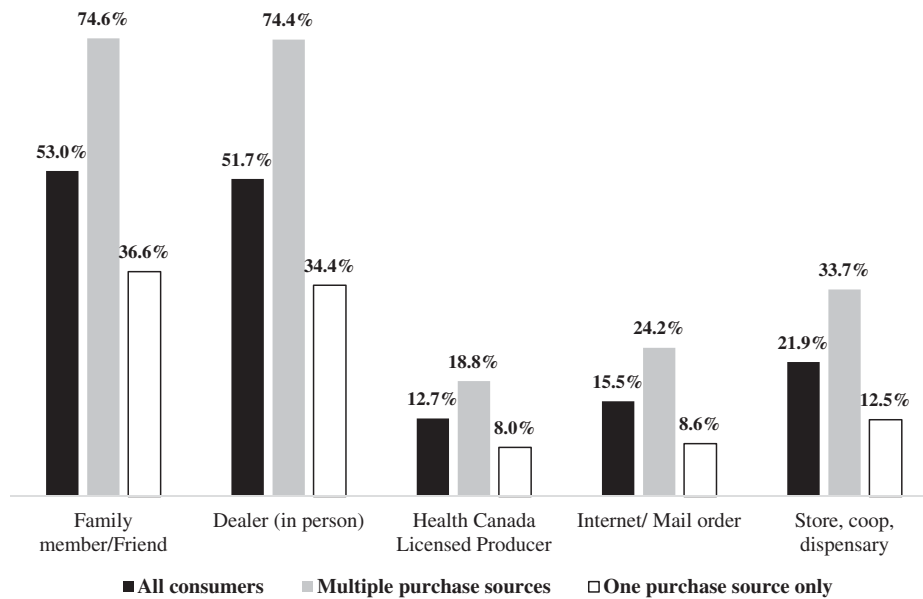
A linear regression model was fitted to examine correlates of the log-transformed quantity purchased of dried cannabis at last purchase (Table 4). Purchase source was a significant predictor of quantity at last purchase. Purchasing online or *via* mail order was associated with a 6.5% increase in the average quantity purchased compared to those purchasing from family or friends. Cannabis use status was also a significant predictor of the quantity purchased at last purchase. Less than monthly, at least monthly, and at least weekly users were associated with a 12.7%, 12.0%, and 6.6% reduction, respectively, in the average quantity purchased compared to daily/almost-daily users. Province of residence, age, sex, ethnicity, and education were not significantly associated with purchase quantity.

Figure 2(B) displays the average self-reported price-per-gram of dried cannabis among participants who purchased from only one source over the past 12 months. Across all quantities purchased, those who purchased from a store, coop, or dispensary had the largest mean price-per-gram and those who purchased from another online source/mail order had the smallest mean price-per-gram.

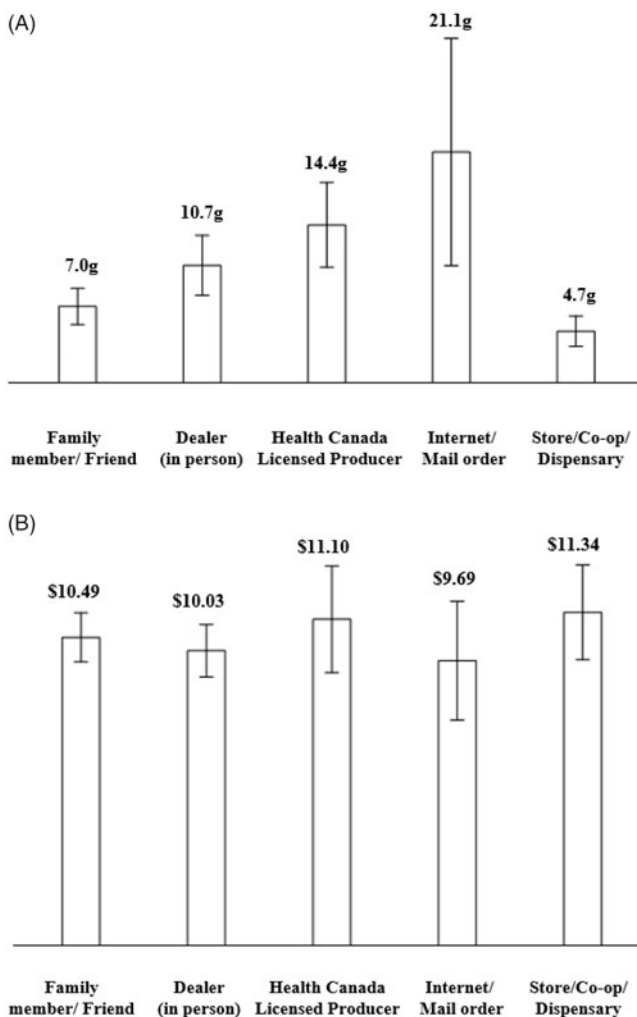
A linear regression model was fitted to examine correlates of the log-transformed price-per-gram paid for dried cannabis at last purchase (Table 4). Purchase quantity was a significant predictor of price-per-gram. A 10% increase in the quantity purchased was associated with a 2.0% reduction in the average price-per-gram of dried cannabis. Purchase source was a significant predictor of price-per-gram. Purchasing from an illicit dealer, licensed producer, and online/mail order was associated with a 16.1%, 33.5%, and 23.7% increase, respectively, in the average price-per-gram of dried cannabis compared to purchasing from a family member or friend. Cannabis use status was also a significant predictor of price-per-gram at last purchase. At least monthly and weekly users were associated with a 14.9% and 14.6% increase, respectively, in the average price-per-gram of dried cannabis, compared to daily/almost-daily users. Province, age, sex, ethnicity, and education were not significantly associated with the price-per-gram of dried cannabis.

## Discussion

This study presents self-reported cannabis prices of dried cannabis across Canada and sources used. Overall, the mean self-reported price-per-gram among cannabis users was \$9.56/g and those who purchased from multiple sources had a lower average price-per-gram than those purchasing from only one source. The average price-per-gram of \$9.56/g across all users was higher than previous pre-legalization estimates that used crowdsourced data and self-reported data in population surveys (Ouellet et al. 2017; Government of Canada 2018; Statistics Canada 2018c). The lower prices found in the crowdsourced data – ranging from \$7.14/g to \$7.69/g – may be attributed to the self-selected sample, where respondents submitting their data to crowdsourced websites may not be representative of all cannabis users,



**Figure 1.** Cannabis sources used by those who have purchased dried cannabis in the past 12-months from multiple sources and from one source only ( $n = 891$ ).



**Figure 2.** (A) Mean self-reported quantity of dried cannabis purchased by source, among those who purchased from only one source over the past 12 months ( $n = 501$ )\*. \*Whisker bars represent confidence intervals of the mean self-reported quantity of dried cannabis. (B) Mean self-reported price-per-gram of dried cannabis purchased by source, among those who purchased from only one source over the past 12 months ( $n = 501$ )\*. \*Whisker bars represent confidence intervals of the mean self-reported price-per-gram of dried cannabis.

and/or may represent more frequent users. Indeed, in this study daily/almost-daily users had a significantly lower price-per-gram of dried cannabis than less frequent users. However, \$9.56/g was more similar to the price-per-gram (incl. tax) of legal cannabis that was predicted by the Canadian Government post-legalization (Department of Finance Canada 2018) and the post-legalization crowd-sourced price from StatsCannabis, \$9.82/g (Statistics Canada 2019). The price of legal cannabis is expected to decrease post-legalization, albeit not immediately. While the benefit of prices being lower in the legal than the illicit market includes the incentive to transition, a reduction in price could also lead to increased consumption and adverse health outcomes, as seen with other substances (Caulkins 2001; Stockwell et al. 2011; Wagenaar et al. 2009; Wagenaar et al. 2010; Pacula and Lundberg 2015; Hall 2017). Legal cannabis prices should aim to compete with illicit prices, yet not increase consumption or harms. The ‘ideal’ price of legal cannabis is difficult to quantify and is likely to change over time as legal markets evolve. Initially, cannabis prices may need to more aggressively compete with well-established illegal markets; however, evidence from tobacco control and other domains indicate that price and taxes can increase considerably with relatively modest impact on illicit purchasing depending on other factors (US Department of Health and Human Services 2014). Other factors are likely to moderate the influence of cannabis price on legal vs. illegal purchases, including access/proximity to legal retail outlets, as well as perceptions of product quality and safety. In addition, tax revenue from cannabis sales should feed into cannabis prevention, education, and treatment services.

The most important determinant of price was the quantity of cannabis purchased. The price-per-gram of cannabis significantly decreased as quantity purchased increased. For example, consumers purchasing in smaller quantities paid an average of \$12.81/g, compared to \$5.60 when purchasing in larger quantities – a discount of 56.3%. The quantity

**Table 4.** Weighted linear regression analysis for outcome variables by ln (quantity purchased) and ln (price-per-gram) ( $n = 891$ ).

	ln (Quantity purchased)		ln (price-per-gram)	
	$\beta$ (95% CI)	Sig. ( $p$ Value)	$\beta$ (95% CI)	Sig. ( $p$ Value)
ln (Quantity purchased)	–	–	–0.21 (–0.25, –0.18)	<.001
Source used last ( <i>vs. family member/friend</i> )				
Dealer	0.18 (–0.09, 0.45)	.188	0.15 (0.02, 0.28)	.028
Health Canada Licensed Producer	0.25 (–0.23, 0.72)	.305	0.29 (0.13, 0.45)	<.001
Internet/Mail order	0.66 (0.25, 1.07)	.002	0.21 (0.02, 0.40)	.028
Store, coop, or dispensary	–0.29 (–0.59, 0.01)	.059	0.10 (–0.09, 0.28)	.202
Not specified	0.23 (–0.02, 0.48)	.067	0.02 (–0.09, 0.13)	.764
Cannabis use status ( <i>vs. daily/almost daily user</i> )				
Less than monthly	–1.43 (–1.72, –1.13)	<.001	0.05 (–0.08, 0.18)	.451
At least monthly	–1.35 (–1.64, –1.05)	<.001	0.14 (0.01, 0.27)	.044
At least weekly	–0.72 (–0.96, –0.48)	<.001	0.14 (0.03, 0.24)	.010
Province ( <i>vs. Newfoundland and Labrador</i> )				
British Columbia	–0.12 (–0.54, 0.31)	.596	–0.15 (–0.30, 0.01)	.054
Alberta	0.23 (–0.19, 0.65)	.280	0.12 (–0.01, 0.26)	.072
Saskatchewan	0.01 (–0.60, 0.58)	.981	0.09 (–0.06, 0.26)	.229
Manitoba	–0.08 (–0.54, 0.39)	.743	0.03 (–0.12, 0.18)	.732
Ontario	0.07 (–0.30, 0.43)	.727	0.01 (–0.11, 0.13)	.868
Quebec	–0.20 (–0.61, 0.22)	.347	–0.10 (–0.25, 0.06)	.232
New Brunswick	–0.20 (–0.62, 0.22)	.352	–0.10 (–0.27, 0.07)	.258
Nova Scotia	–0.17 (–0.68, 0.34)	.513	–0.08 (–0.22, 0.06)	.271
Prince Edward Island	0.43 (–0.37, 1.24)	.294	–0.03 (–0.20, 0.14)	.745

discount observed in this study is similar to objective prices found by a retail scan of Canadian illicit dispensaries (Mahamad and Hammond 2019). Quantity discounts are also common in legal cannabis stores after legalization, such as the online Ontario Cannabis Store, albeit at a more modest discounted rate of 7.5–14.6% (Ontario Cannabis Store 2019). Quantity discounts are frequent in illicit drug markets (Caulkins and Padman 1993; Clements 2006; Caulkins et al. 2009). This study found a quantity discount elasticity of  $-0.21$ , which is within the range of what was found in previous studies in illicit cannabis markets (Caulkins and Padman 1993; Clements 2006; Caulkins and Pacula 2006), but higher than what found in a legal cannabis market (Smart et al. 2017). As Smart et al. (2017) argued, their smaller estimate found within Washington State's legal market could be explained by the inclusion of potency within the models, which the previous studies on illicit cannabis markets did not include.

To note, the current analysis did not include potency or THC content; therefore, the potential for potency differences to have contributed to the price-per-gram differences is unknown. Potency is important when discussing the price of cannabis, as prior studies have shown an association between price and perceived potency (Cole et al 2008; Lakhdar et al. 2016; Smart et al 2017). However, collecting and interpreting potency pre-legalization is difficult due to a lack of information in the illicit market and unreliable labeling on illicit products (Caulkins and Pacula 2006; Ouellet et al. 2017). Overall, the findings suggest that reporting cannabis prices as a single mean based on 'price-per-gram' may obscure important differences in purchase price across different purchase quantities, and the potential importance of potency.

The most common source from which to purchase cannabis was a family member/friend or an illicit dealer, consistent with previous studies (Reinarman 2009; Government of Canada 2018; Hathaway et al. 2018). Purchase source was

a significant predictor of price-per-gram at last purchase. Consumers purchasing from an illicit dealer, a licensed producer, and online all had a significant higher price-per-gram than those purchasing through family or friends. However, the variation across the sources was largely accounted for by the fact that consumers tended to purchase different quantities of cannabis from different sources, as purchase source was also a significant predictor of quantity purchased. For example, consumers purchasing from stores, cooperatives or dispensaries purchased in smaller quantities than those purchasing online, suggesting that consumers may be purchasing from stores in smaller quantities, perhaps due to the convenience or through purchasing 'premium' products in smaller quantities, such as 'pre-rolled' joints (Clements 2006). In contrast, consumers may be purchasing greater quantities from online sources to minimize shipping costs; indeed, some online suppliers provided free shipping for orders over a certain quantity (Mahamad and Hammond 2019). In this study, purchasing through family and friends on average reflected lower prices and smaller quantities purchased than other sources. However, family and friends may present a unique case, which do not reflect actual retail prices. For example, family and friends may discount such small quantities due to their relationship with the consumer or the product may have been 'homegrown', reducing its initial cost. Future research should explore differences in cannabis purchasing across sources, with an emphasis on changes following legalization of non-medical cannabis and the transition from illicit to legal sources (Kilmer et al. 2010; Hall and Lynskey 2016; Hunt and Pacula 2017).

In the current analysis, province of residence was not a significant predictor of the price of dried cannabis. The differences in price and quantity purchased across the provinces could be instead accounted for by the purchase source used. For example, in a retail scan conducted across the Canadian provinces in 2018, the availability of retail and online stores was found to vary across cities, ranging from



100 retail outlets in Vancouver, British Columbia, to zero in Calgary, Alberta (Mahamad and Hammond 2019).

This study has several limitations. Respondents were asked to recall cannabis purchases over a 12-month time period, which may have introduced recall bias. Data collected for 'last purchase' may be less prone to memory errors. In addition, self-report data are subject to social desirability bias. At the time of study, non-medical cannabis use in Canada remained illicit; therefore, patterns of cannabis use may have been underreported or purchase sources misrepresented. However, the survey included a data integrity question wherein those who reported not answering all questions honestly were excluded<sup>1</sup>. In addition, this survey was self-administered online, which compared to interviewer assisted surveys, can reduce social desirability bias by providing greater anonymity for sensitive topics (Krumpal 2013). As previously discussed, this study did not include the potency of dried cannabis. Thus, a potency-adjusted price may be higher or lower than the prices reported in this study (Kilmer et al. 2014; Freeman et al. 2019). Another limitation is that respondents were not asked to identify the source they had used at last purchase; thus, information on last purchase source was only available for respondents with one cannabis source in the past 12 months. In addition, when reporting price paid from online sources or mail order, participants were not asked whether the price included shipping. Similarly, prices collected from licensed producers did not specify whether the final cost included tax. Thus, the aggregate prices reported for online sources and licensed producers may be higher or lower than prices reported in this study. Finally, respondents were recruited from commercial sample, rather than using probability-based methods only. However, Nielsen drew stratified random samples based on known proportions in each age group to account for differential response rates and modified these sampling proportions to place greater weight on lower responding sub-groups. In addition, post-stratification survey weights were used to adjust for sociodemographic differences. The prevalence of cannabis use in this study was close to national benchmark surveys (Statistics Canada 2018d).

## Conclusion

To our knowledge, this study provides among the most comprehensive assessments of cannabis purchasing in illicit markets. The findings underscore the importance of purchase quantity when assessing cannabis pricing and purchasing patterns. Although price variations were observed across different purchase sources, these often masked differences in the quantity of cannabis that was purchased. Legalization of non-medical cannabis in Canada provides the opportunity to examine the transition from illicit to legal sources and the implications for prices and consumption. Accurate price estimates of cannabis in Canada post-legalization are

important as the price of legal and illicit cannabis has direct implications for tax policies. In the US, all states that have legalized non-medical cannabis have adjusted their tax rates to minimize the price gap between illicit and legal cannabis (Canadian Centre on Substance Use and Addiction 2015; State of Nevada 2017; Colorado Department of Revenue 2018; Washington State Liquor and Cannabis Board 2018). After legalization, Colorado and Washington State have legal prices that are competitive to if not lower than illicit prices (Hall and Lynskey 2016; Orens et al. 2018). Future research is needed on price, potency, and purchasing patterns for other types of cannabis products, including cannabis edibles and concentrates, which account for greater market share in legal markets.

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<sup>1</sup>Participants were asked: "Were you able to provide 'honest' answers about your marijuana use during the survey?" with response options: "No", "For some questions, but not all", "Yes, for all questions".

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