Prevalence and factors associated with self-reported exposure to secondhand cannabis smoke in the United States and Canada in 2019

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A B S T R A C T

Little is known about exposure to secondhand cannabis smoke (SHCS) among residents of detached single-family homes and multiunit housing (MUH). Using data from the 2019 International Cannabis Policy Study, the prevalence of (a) self-reported exposure to SHCS at home ($n = 33,024$) and (b) self-reported SHCS incursions into MUH (defined as SHCS from another unit/the outdoors, $n = 15,634$) was estimated in (1) Canada; (2) US states where non-medical cannabis use was legal, and (3) US states where it remained illegal. Factors associated with exposures and incursions were assessed using weighted logistic regression. Overall, 16.9% of residents in Canada, 20.6% in US legal states, and 15.5% in US illegal states reported exposure to SHCS in their homes at least once in the previous month. One quarter (25.7%) of Canadian MUH residents, 26.6% from US legal states, and 20.1% from US illegal states reported at least monthly incursions. Sociodemographic factors associated with incursions suggested MUH residents reporting incursions lived in qualitatively different MUH than those not reporting incursions. Irrespective of the legality of non-medical cannabis use, smoke-free policies in MUH should protect residents from involuntary exposure to all types of secondhand smoke.

1. Introduction

In 2019, 25% of Canadians and 18% of Americans reported using cannabis in the previous year (Health Canada, 2019; Substance Abuse and Mental Health Services Administration, 2020). In both countries, smoked cannabis is the most common form used (Government of Canada, 2017; Schauer et al., 2016; Goodman et al., 2020a). Although evidence linking cannabis smoking and secondhand cannabis smoke (SHCS) to chronic disease outcomes is limited (Ghasemiesfe et al., 2018; Ravi et al., 2018; Holitzki et al., 2017), SHCS contains many of the same toxic chemicals known to cause cardiac and respiratory disease as secondhand tobacco smoke (SHTS) (Moir et al., 2008; Wang et al., 2016; Graves et al., 2020). Smoking cannabis joints indoors produces higher concentrations of fine particulate matter than other combustible methods (Ott et al., 2021). Metabolites of cannabis smoke have been

found in nonsmokers under controlled laboratory conditions and among nonsmokers exposed to SHCS in occupational settings (Cone et al., 2015; Herrmann et al., 2015; Wiegand et al., 2020). While smoke-free tobacco laws protect nonsmokers from SHTS, the liberalization of cannabis laws permitting non-medical use in several US states and Canada may increase the prevalence of involuntary exposure to SHCS.

Involuntary exposure to SHCS at home is particularly concerning. As the prevalence of regular cannabis use increases among parents living with children, potential exposure to SHCS may also increase (Goodwin et al., 2018). Children whose parents smoke cannabis inside their home have greater risk of acute adverse health outcomes (e.g., ear infections, bronchitis; Posis et al., 2019). Involuntary exposure to SHCS also occurs among residents of multiunit housing (MUH), often defined as semi-detached homes, townhouses, apartment buildings, and condominiums. In 2017, an estimated 827,000 adults from Ontario living in MUH

(7.5% of the population) noticed cannabis smoke entering their homes from neighbouring units or the outdoors at least once in the previous six months (Chu et al., 2019). In 2018, 67% of residents living in 21 subsidized high-rise buildings in New York City reported smelling cannabis smoke in their homes (from other units or the outdoors) at least once in the previous year (Anastasiou et al., 2020).

Given the chemical similarity between SHCS and SHTS (Moir et al., 2008; Graves et al., 2020; Ott et al., 2021) and the ease with which secondhand smoke transfers throughout MUH (Nguyen et al., 2016), it is important to protect residents from involuntary exposure to both SHTS and SHCS, especially as jurisdictions legalize non-medical cannabis use. Because little is currently known about personal exposures to SHCS (Ott et al., 2021), this study estimated the prevalence of self-reported exposure to SHCS in three jurisdictions: US states where non-medical cannabis use was legal in 2019 (US "legal" states: Alaska, California, Colorado, Maine, Massachusetts, Michigan, Nevada, Oregon, Vermont, Washington, and the District of Columbia); US states where non-medical use was illegal in 2019 (US "illegal" states: all remaining states); and Canada, where non-medical use was legalized in 2018. Specific objectives were to (1) compare self-reported exposures among residents who did not use cannabis or did not smoke cannabis inside their homes by dwelling type (detached single-family homes vs. MUH) within jurisdictions; (2) compare self-reported SHCS incursions into MUH across jurisdictions; and (3) examine factors associated with (a) self-reported exposures and (b) self-reported incursions into MUH.

2. Methods

2.1. Sample

Data came from Wave 2 (2019) of the International Cannabis Policy Study (ICPS), a cross-sectional, web-based, population survey of adults aged 16 to 65 living in Canada and the US (Goodman et al., 2020b). Respondents were recruited from the Nielsen Consumer Insights Global Panel. Email invitations were sent to a random sample of panelists; ineligible respondents, based on age and country, were not invited. All respondents provided consent before completing the survey and were remunerated according to their panel's usual incentives. The ICPS was reviewed by and received ethics clearance through a University of Waterloo Research Ethics Committee (ORE# 31330).

Overall, 45,735 respondents completed the Wave 2 Survey (Canada $n = 15,256$; US illegal states $n = 10,275$; US legal states $n = 20,204$). Respondents completed the survey via smartphone (49.3%), tablet (7.2%), or computer (43.6%). Post-stratification sampling weights were computed and calibrated to census estimates within jurisdictions and population subgroups using a raking algorithm. Complete details of the ICPS study are available elsewhere (Hammond et al., 2020; Goodman et al., 2020b).

2.2. Measures

2.2.1. Dwelling type

Current housing conditions were assessed by asking "Which of the following best describes where you live?" Responses were dichotomized into detached single-family homes vs. MUH (an attached house, e.g., townhouse, semi-detached house; a multiple unit building e.g., apartment building, condominium apartment, duplex; and shared accommodations e.g., rooming house, residence/dorm, retirement home). Respondents not reporting dwelling information ("don't know" or "refuse", $n = 1301$) were classified as missing and excluded from the analysis.

2.2.2. Primary outcome measures

Exposure to SHCS was assessed by asking "In the past 30 days, how often were you exposed to secondhand marijuana smoke in your home?" Respondents could answer "not at all", "less than once a week", "more

than once a week", "every day", or "several times a day". Responses were classified to create three binary indicators of exposure: (1) any exposure in the previous month (less than once a week, more than once a week, every day, or several times a day) vs. none (not at all); (2) at least weekly exposure (more than once a week, every day, or several times a day) vs. less frequent exposure (not at all, less than once a week); and (3) daily exposure (every day or several times a day) vs. less frequent exposure (not at all, less than once a week, more than once a week). Analysis was restricted to respondents who did not use cannabis, or those who used cannabis but did not smoke it inside their homes in the previous year ($n = 33,024$).

Cannabis smoke incursions into the home were assessed by asking "In the past 6 months, have you noticed any marijuana smoke entering your home from a neighbouring unit or from outside your building?" Respondents could answer "never", "at least once in the past 6 months", "at least once in the past 3 months", "at least once a month", "at least once a week", or "every day". Responses were also classified into three binary indicators of exposure: (1) any exposure in the previous month (at least once a month or more often vs. less frequently); (2) weekly exposure (at least once a week vs. less frequently); and (3) daily exposure (daily vs. less frequently). Analysis was restricted to respondents living in MUH who provided valid data for self-reported cannabis smoke incursions, irrespective of whether they smoked cannabis inside their homes in the previous year ($n = 15,634$).

2.2.3. Covariates

Sociodemographic measures were sex at birth (male vs. female), age group (16–25, 26–35, 36–45, 46–55 vs. 56–65), ethnicity (other/mixed race/not reported vs. white), education (high school/equivalent, some/completed post-secondary, Bachelor's degree or higher vs. less than high school), and income adequacy ("Thinking about your family's income, how difficult or easy is it to make ends meet?"). Income adequacy was defined as difficult ("difficult/very difficult"), neither, not stated vs. easy ("easy/very easy"). Respondents were also asked whether they currently lived with children younger than 18 (yes vs. no). Women who reported being pregnant were classified as currently living with children ($n = 310$).

Cannabis use was defined as never used, used more than 12 months ago, used in the past 12 months, current monthly use, current weekly use, and current daily/almost daily use. *Current cigarette smoking* was defined as current daily/occasional smoker vs. non-smoker. *Current e-cigarette use* was defined as current daily/occasional user vs. non-user. Finally, respondents were asked whether they smoked cannabis inside their home in the past 12 months (yes, no, non-cannabis user).

General self-rated health was classified as excellent/very good/good vs. fair/poor. *Self-rated mental health* was classified as experiencing at least one of the following mental health issues in the previous 12 months (vs. none): anxiety, depression, post-traumatic stress disorder, bipolar disorder/mania/borderline personality disorder, psychosis or dissociative identity disorder, schizophrenia, alcohol or other drug use, eating disorder, attention deficit disorder/attention deficit hyperactivity disorder, or Autism spectrum disorder.

Societal norms about cannabis use were assessed by asking "In the past 12 months, how often have you noticed someone using marijuana near you in a public place?" (don't know, less than monthly, at least weekly vs. not in the past 12 months). *Perceived harmfulness of cannabis smoke* was assessed by asking "Based on what you know or believe, can marijuana smoke be harmful?" (yes vs. no/maybe/don't know).

2.3. Statistical analysis

Sample characteristics were described using weighted descriptive statistics. Weighted multivariable logistic regression estimated the adjusted prevalence of self-reported exposure to SHCS in the home among the subset of respondents who did not use cannabis or who did but did not smoke cannabis inside their homes in the previous year ($n =$

33,024). Among MUH residents (*n* = 15,634), weighted logistic regression estimated the adjusted prevalence of self-reported SHCS incursions in MUH. For all outcomes (any, at least weekly, and daily exposures/incursions), the adjusted prevalence was estimated using average marginal effects from the logistic models that account for differences in covariate distributions across jurisdictions and are the regression-based equivalent of epidemiological standardization methods (Graubard and Korn, 1999; Muller and MacLehose, 2014). Adjusted percentages controlled for survey device, sex at birth, age group, ethnicity, education, income adequacy, living with children, cannabis use (or smoking cannabis inside the home for SHCS incursions), and dwelling type.

The overall prevalence of self-reported exposure was estimated within jurisdictions. A second logistic model estimated jurisdiction-specific prevalence by dwelling type using a two-way jurisdiction-by-dwelling type interaction. Differences in prevalence across jurisdictions and by dwelling type within jurisdictions were tested. For self-reported SHCS incursions in MUH, jurisdiction-specific prevalence was estimated and differences in prevalence between jurisdictions were tested. All comparisons within models accounted for multiple testing using the false discovery rate (FDR) adjustment (Benjamini and Hochberg, 1995).

Adjusted odds ratios (aOR) were estimated using weighted multivariable logistic regression to assess correlates of self-reported SHCS

exposure and self-reported SHCS incursions in MUH. Sociodemographic covariates were survey device type, sex at birth, age group, ethnicity, education, income adequacy, and living with children. Cannabis use (or smoked cannabis use inside the home for SHCS incursions), cigarette smoking status, and e-cigarette use were included, as were general health, mental health, noticing cannabis use in public, and perceived harmfulness of cannabis smoke. Statistical analyses were conducted using SAS-callable SUDAAN (Version 11.0.3) to account for the sampling design and sampling weights.

3. Results

3.1. Sample characteristics

After weighting to the population of each jurisdiction, the sex, gender, ethnic, and income adequacy distributions of respondents were similar across jurisdictions (Supplementary Table 1). A smaller percentage of respondents living in Canada than the US had more than a high school education or lived with children; 43.8% of respondents in Canada lived in MUH compared with 31.1% in US illegal states and 37.0% in US legal states.
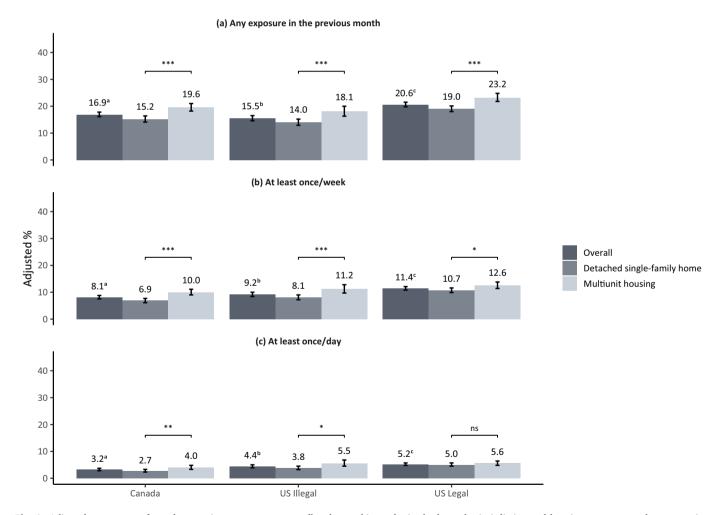

Fig. 1. Adjusted percentage of people reporting exposure to secondhand cannabis smoke in the home by jurisdiction and housing type among those not using cannabis in the previous year or not smoking cannabis inside their home in the previous year (n = 33,024; International Cannabis Policy Study, 2019). Estimates are adjusted for survey device type, sex at birth, age group, ethnicity, education, income adequacy, living with children under 18, cannabis use, and dwelling type. Jurisdictions having different letters are statistically different (adjusted p < 0.05). Within jurisdictions, differences between detached single-family homes and MUH were tested. All *p*-values were adjusted for multiple comparisons using the false discovery rate adjustment. * p < 0.05; ** p < 0.01; *** p < 0.001; ns = not significant.

3.2. Prevalence of exposure to secondhand cannabis smoke

3.2.1. Self-reported exposure to SHCS at home

Among respondents who did not use cannabis in the previous year or did not smoke cannabis inside their homes in the previous year, 16.9% from Canada and 15.5% from US illegal states reported any past-month exposure to SHCS after adjusting for dwelling type and sociodemographic covariates (Fig. 1). Prevalence in Canada and US illegal states was significantly lower than in US legal states, where 20.6% of residents reported any exposure (both p < 0.001). In all jurisdictions, a significantly greater percentage of MUH residents reported any exposure to SHCS than residents of detached single-family homes (all p < 0.001).

More frequent exposures to SHCS were less common. Fewer Canadian residents (8.1%) reported at least weekly exposure than residents from US illegal states (9.2%, p = 0.04) or legal states (11.4%, p < 0.001). The difference in at least weekly exposure was also significantly lower in US illegal states than in US legal states (p < 0.001). Only 3.2% of Canadian residents, 4.4% of residents from US illegal states, and 5.2% of residents from US legal states reported daily exposure to SHCS. The prevalence of daily exposure differed by dwelling type within Canada (p = 0.009) and US illegal states (p = 0.012), but not within US legal states (p = 0.28).

3.2.2. Self-reported SHCS incursions in multiunit housing

Self-reported SHCS incursions into the homes of MUH residents differed significantly by jurisdiction (Fig. 2). Overall, the adjusted prevalence of at least monthly incursions was significantly higher in Canada (25.7%) and US legal states (26.6%) than in US illegal states (20.1%, both p < 0.001), with no difference in Canada versus US legal states (p = 0.43). A similar trend was observed for at least weekly incursions. There were no significant differences across jurisdictions in the self-reported prevalence of daily incursions.

3.3. Correlates of exposure to secondhand cannabis smoke

3.3.1. Self-reported exposure among people not using cannabis or not smoking cannabis at home

Jurisdiction-specific multivariable logistic models were estimated to qualitatively compare factors associated with any exposure to SHCS in the previous month (Table 1). Across jurisdictions, males (vs. females), people aged 45 or younger (vs. those aged 56–65), and those of other/mixed/unstated ethnicity (vs. white) had significantly greater odds of reporting exposure to SHCS in the previous month. Cannabis use was consistently associated with self-reported exposure. In all jurisdictions, people who used cannabis weekly and daily/almost daily had the greatest odds of reporting exposure to SHCS compared with never users. Although living with children was not associated with self-reported exposure, living in MUH (vs. detached single-family homes) was significantly associated in Canada (aOR = 1.23, 95% CI: 1.07, 1.41) and US legal states (aOR = 1.23, 95% CI: 1.09, 1.40).

Self-rated health was not associated with self-reported exposure. However, people who reported experiencing at least one mental health
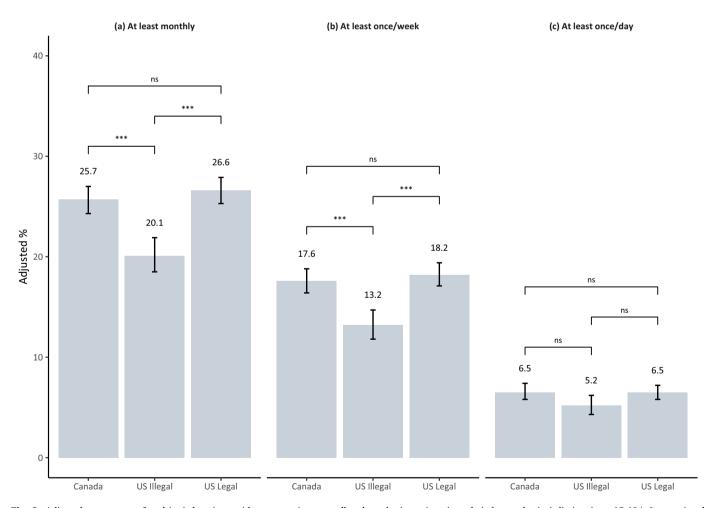

Fig. 2. Adjusted percentage of multiunit housing residents reporting secondhand smoke incursions into their homes by jurisdiction (n = 15,634; International Cannabis Policy Study, 2019). Estimates are adjusted for survey device type, sex at birth, age group, ethnicity, education, income adequacy, living with children under 18, and use of smoked cannabis inside the home in the previous year. Differences between jurisdictions were tested. All *p*-values were adjusted for multiple comparisons using the false discovery rate adjustment. *** p < 0.001; ns = not significant.

Table 1

Weighted multivariable logistic regression of factors associated with any self-reported exposure to secondhand cannabis smoke in the previous month among respondents who did not use cannabis or did not smoke cannabis inside their homes in the previous year, by jurisdiction (International Cannabis Policy Study, 2019).

Covariate (reference group)	Canada ($n = 11,510$)				US illegal ($n = 7419$)				US legal ($n = 13,550$)			
	aOR	(95% CI)	χ^2	p	aOR	(95% CI)	χ^2	p	aOR	(95% CI)	χ^2	p
Sex (female)												
Male	1.45	(1.27, 1.67)	28.92	< 0.001	1.69	(1.41, 2.03)	31.30	< 0.001	1.56	(1.38, 1.76)	53.16	< 0.001
Age group (56–65)												
16–25	1.86	(1.44, 2.40)	40.08	< 0.001	3.04	(2.14, 4.31)	61.22	< 0.001	2.87	(2.32, 3.56)	122.37	< 0.001
26–35	2.01	(1.59, 2.55)			2.78	(2.01, 3.83)			2.40	(1.98, 2.90)		
36–45	1.50	(1.19, 1.89)			2.13	(1.53, 2.95)			1.97	(1.62, 2.39)		
46–55	1.33	(1.07, 1.65)			1.33	(0.95, 1.87)			1.40	(1.15, 1.70)		
Ethnicity (white)												
Other/mixed/not reported	1.87	(1.61, 2.18)	63.95	< 0.001	1.61	(1.30, 1.99)	19.44	< 0.001	1.38	(1.20, 1.58)	21.36	< 0.001
Education (< high school)												
High school/equivalent	0.84	(0.64, 1.10)	1.67	0.644	2.19	(1.50, 3.21)	17.91	< 0.001	0.96	(0.69, 1.34)	15.05	0.002
Some/completed post-secondary	0.87	(0.68, 1.11)			1.82	(1.25, 2.65)			0.76	(0.55, 1.04)		
Bachelor's degree/higher	0.87	(0.67, 1.13)			2.04	(1.41, 2.97)			0.96	(0.70, 1.32)		
Income adequacy (easy/very easy)												
Not stated	0.61	(0.35, 1.06)	25.79	< 0.001	0.46	(0.15, 1.45)	4.92	0.178	0.49	(0.28, 0.85)	10.06	0.018
Neither	0.93	(0.79, 1.10)			0.80	(0.64, 1.01)			0.87	(0.75, 1.01)		
Difficult/very difficult	1.37	(1.15, 1.63)			0.91	(0.73, 1.14)			0.99	(0.85, 1.16)		
Interview device (smartphone)												
Tablet	0.78	(0.61, 1.01)	3.59	0.166	0.68	(0.41, 1.12)	2.88	0.237	1.11	(0.87, 1.43)	0.92	0.631
Computer	0.95	(0.82, 1.10)			1.05	(0.86, 1.27)			0.98	(0.86, 1.12)		
Cannabis user (never used)												
More than 12 months ago	1.42	(1.20, 1.67)	36.97	< 0.001	1.38	(1.11, 1.71)	44.39	< 0.001	1.27	(1.10, 1.46)	64.24	< 0.001
Past 12-months	1.22	(0.95, 1.56)			1.09	(0.74, 1.62)			1.38	(1.09, 1.75)		
Monthly	1.47	(1.07, 2.02)			1.92	(1.10, 3.35)			1.94	(1.39, 2.70)		
Weekly	2.49	(1.69, 3.68)			3.69	(2.29, 5.94)			2.10	(1.45, 3.04)		
Daily/almost daily	1.91	(1.37, 2.67)			3.20	(1.85, 5.53)			2.89	(2.13, 3.94)		
Lives with children < 18 (does not)												
Lives with children	0.93	(0.78, 1.10)	0.75	0.385	0.97	(0.79, 1.18)	0.12	0.734	1.01	(0.88, 1.16)	0.03	0.872
Housing type (detached single-family home)												
Multiunit housing	1.23	(1.07, 1.41)	8.47	0.004	1.02	(0.83, 1.24)	0.03	0.865	1.23	(1.09, 1.40)	10.58	0.001
Current cigarette smoker (does not smoke)												
Current daily/occasional smoker	1.20	(0.98, 1.45)	3.26	0.071	1.16	(0.91, 1.49)	1.41	0.235	1.53	(1.30, 1.81)	24.83	< 0.001
Current e-cigarette user (does not use)												
Current daily/occasional e-cigarette user	1.42	(1.09, 1.84)	6.97	0.008	2.57	(1.94, 3.41)	43.49	< 0.001	1.97	(1.59, 2.44)	38.50	< 0.001
Self-rated health (fair/poor)												
Good/very good/excellent	1.14	(0.94, 1.39)	1.81	0.178	0.94	(0.73, 1.21)	0.21	0.645	1.03	(0.88, 1.21)	0.12	0.728
Mental health (no issues in past year)												
At least 1 mental health issue	1.29	(1.11, 1.50)	10.91	< 0.001	1.25	(1.03, 1.51)	5.23	0.022	1.41	(1.24, 1.61)	27.86	< 0.001
Noticed cannabis use in public (not in past year)												
Don't know	2.23	(1.51, 3.29)	181.94	< 0.001	3.17	(2.10, 4.80)	451.13	< 0.001	1.91	(1.40, 2.61)	358.49	< 0.001
Less than monthly	2.92	(2.24, 3.81)			4.21	(3.24, 5.46)			3.20	(2.62, 3.91)		
At least once/week	5.17	(3.98, 6.71)			15.07	(11.65, 19.48)			5.95	(4.90, 7.23)		

Table 1 (*continued*)

Covariate (reference group)	Canada (*n* = 11,510)				US illegal (*n* = 7419)				US legal (*n* = 13,550)			
	aOR	(95% CI)	χ^2	p	aOR	(95% CI)	χ^2	p	aOR	(95% CI)	χ^2	p
Cannabis smoke can be harmful (no/maybe/don't know)												
Yes	0.69	(0.60, 0.79)	27.97	< 0.001	0.72	(0.60, 0.87)	12.02	< 0.001	0.66	(0.59, 0.75)	45.34	< 0.001

Notes: aOR = adjusted odds ratio; 95% CI = 95% confidence interval.

condition in the previous year had significantly higher odds of exposure than those not reporting any mental health issues (Canada aOR = 1.29, 95% CI: 1.11, 1.50; US illegal aOR = 1.25, 95% CI: 1.03, 1.51; US legal aOR = 1.41, 95% CI: 1.24, 1.61). Cigarette smoking status was only associated with SHCS exposure in US legal states (p < 0.001). Current use of e-cigarettes was associated with exposure in all jurisdictions (all *p*-values < 0.01). Noticing cannabis use in public was strongly associated with exposure: people who noticed cannabis being used in public at least once a week had 5.17 (Canada, 95% CI: 3.98, 6.71), 15.07 (US illegal, 95% CI: 11.65, 19.48), and 5.95 (US legal, 95% CI: 4.90, 7.23) times the odds of reporting SHCS exposure at home compared with people not noticing public cannabis consumption. Finally, people who believed cannabis smoke can be harmful had significantly lower odds of reporting exposure to SHCS at home in the previous month than people who did not (Canada aOR = 0.69, 95% CI: 0.60, 0.79; US illegal states aOR = 0.72, 95% CI: 0.60, 0.87; US legal aOR = 0.66, 95% CI: 0.59, 0.75).

3.3.2. Self-reported, at least monthly SHCS incursions in MUH

Few sociodemographic factors were associated with self-reported monthly SHCS incursions into MUH (Table 2). In US legal states, males living in MUH had significantly lower odds of reporting incursions than females (aOR = 0.78, 95% CI: 0.67, 0.90). Education was also associated with reporting incursions in US legal states. MUH residents who completed a Bachelor's degree had significantly lower odds of reporting incursions than MUH residents with less than a high school education (aOR = 0.58; 95% CI: 0.39, 0.86). Income adequacy was only associated with monthly incursions in Canada. Canadian MUH residents stating it was difficult to make ends meet had greater odds of reporting monthly incursions than residents who said it was easy (aOR = 1.64; 95% CI: 1.33, 2.03).

In US legal states, MUH residents who smoked cannabis inside their homes in the previous year had significantly lower odds of reporting at least monthly SHCS incursions compared with residents not using cannabis in the previous year (aOR = 0.76, 95% CI: 0.64, 0.90). Cigarette smoking was not associated with reported incursions. However, MUH residents who noticed cannabis use in public in the previous year had significantly greater odds of reporting incursions in all jurisdictions. MUH residents who reported noticing public cannabis consumption at least once a week had 5.74 (Canada, 95% CI: 4.23, 7.78) to 7.72 (US illegal, 95% CI: 5.41, 11.00) times the odds of reporting incursions into their homes than MUH residents not noticing public cannabis consumption in the previous year.

Self-reported mental health and living with children were inconsistently associated with self-reported incursions (Table 2). Only residents from US legal states experiencing at least one mental health issue (vs. none) had significantly higher odds of reporting SHCS incursions (aOR = 1.25; 95% CI: 1.07, 1.46; *p* = 0.005). Likewise, only Canadian MUH residents living with children (vs. not) had significantly higher odds of reporting incursions (aOR = 1.35, 95% CI: 1.11, 1.65). Beliefs about the harmfulness of cannabis smoke were not associated with self-reported incursions among MUH residents.

4. Discussion

In 2019, 17% of Canadian residents who did not use cannabis in the previous year or who did not smoke cannabis inside their homes

reported being exposed to SHCS inside their homes at least once in the previous month. Self-reported exposure was similar in US states where non-medical cannabis was illegal (16%) and slightly higher in US states where non-medical cannabis was legal (21%). More frequent exposures were less common: only 3% of Canadian residents and 5% of US residents (both illegal and legal states) reported at least daily exposure. Almost all levels of exposure (previous month, at least weekly, at least daily) were significantly more common among MUH residents across jurisdictions compared with residents of detached single-family homes. In Canada and US legal states, 26% and 27% of MUH residents, respectively, reported that SHCS entered their home from another unit or the outdoors at least once a month while 20% of MUH residents from US illegal states reported such incursions. Although more frequent incursions were less common, these findings demonstrate that exposure to SHCS in MUH occurs irrespective of the legality of non-medical cannabis use.

Similar factors were associated with self-reported home exposures across jurisdictions, including sex, age, self-reported mental health, use of e-cigarettes, noticing cannabis use in public, and perceived harmfulness of cannabis smoke. These factors include personal characteristics that are, in part, associated with cannabis use, as well as situational factors reflecting social surroundings that might increase the likelihood of exposure. For example, both males and younger people had significantly greater odds of reporting previous month exposure to SHCS across jurisdictions. People who noticed cannabis use in public at least occasionally also had significantly greater odds of reporting exposure in the previous month than people who did not notice use in public.

Beyond these factors, people who believed that cannabis smoke can be harmful had significantly lower odds of reporting SHCS exposure than people who did not. It is possible that people having greater risk perceptions are less likely to smoke cannabis themselves (Salloum et al., 2018; Goodman and Hammond, 2022) and less likely to live in areas where cannabis use is common. Taken together, these associations suggest it is important to raise awareness of the potential harms of SHCS. As Wang et al. point out, policymakers and the general public need to understand that exposure to SHCS is not harmless (Wang et al., 2016), especially given recent evidence suggesting smoking cannabis joints indoors produces significantly higher concentrations of fine particulate matter compared with other combustible methods (Ott et al., 2021).

Similar to Chu et al. (2019), few sociodemographic factors were associated with self-reported SHCS incursions into the homes of MUH residents. Residents from US legal states who completed a Bachelor's degree had significantly lower odds of reporting monthly SHCS incursions than those having less than a high school education. It could be that more highly educated people live in qualitatively different multi-unit buildings than less educated MUH residents which might reduce their likelihood of involuntary exposure. In Canada, MUH residents who reported that it was difficult to make ends meet had significantly higher odds of reporting SHCS incursions compared with those who said otherwise. It is possible that the types of multiunit buildings people live in are constrained by their financial situation which, in turn, is correlated with SHCS incursions. This is supported by a limited study of subsidized MUH in New York City, which found that SHCS was pervasive (Anastasiou et al., 2020).

Across jurisdictions, MUH residents living with children had similar odds of reporting at least monthly SHCS incursions into their homes.

Table 2

Weighted multivariable logistic regression of self-reported, at least monthly secondhand cannabis smoke incursions into the homes of residents living in multiunit housing by jurisdiction (International Cannabis Policy Study, 2019).

Covariate (reference group)	Canada (n = 5804)				US illegal (n = 2823)				US legal (n = 6658)			
	aOR	(95% CI)	χ^2	p	aOR	(95% CI)	χ^2	p	aOR	(95% CI)	χ^2	p
Sex (female)												
Male	0.91	(0.77, 1.07)	1.33	0.248	0.90	(0.70, 1.15)	0.71	0.399	0.78	(0.67, 0.90)	10.75	0.001
Age group (56–65)												
16–25	1.00	(0.74, 1.36)	2.68	0.612	1.18	(0.78, 1.79)	4.02	0.404	0.90	(0.70, 1.15)	6.66	0.155
26–35	0.88	(0.68, 1.14)			1.04	(0.70, 1.56)			0.94	(0.75, 1.18)		
36–45	0.95	(0.73, 1.22)			0.97	(0.64, 1.45)			0.99	(0.78, 1.25)		
46–55	1.06	(0.83, 1.37)			1.38	(0.92, 2.06)			1.21	(0.96, 1.53)		
Ethnicity (white)												
Other/mixed/not reported	1.05	(0.88, 1.27)	0.32	0.569	1.24	(0.96, 1.60)	2.68	0.102	1.10	(0.93, 1.29)	1.24	0.265
Education (< high school)												
High school/equivalent	0.99	(0.72, 1.35)	4.25	0.236	1.33	(0.79, 2.26)	3.14	0.371	0.75	(0.50, 1.11)	13.60	0.003
Some/completed post-secondary	0.94	(0.70, 1.24)			1.44	(0.87, 2.39)			0.76	(0.52, 1.11)		
Bachelor's degree/higher	0.80	(0.60, 1.09)			1.59	(0.94, 2.70)			0.58	(0.39, 0.86)		
Income adequacy (easy/very easy)												
Not stated	0.63	(0.33, 1.22)	32.41	< 0.001	0.62	(0.11, 3.43)	1.68	0.640	0.84	(0.46, 1.54)	1.74	0.628
Neither	1.07	(0.87, 1.31)			1.00	(0.72, 1.38)			1.00	(0.82, 1.22)		
Difficult/very difficult	1.64	(1.33, 2.03)			1.15	(0.84, 1.58)			1.09	(0.90, 1.32)		
Survey device (smartphone)												
Tablet	1.17	(0.86, 1.60)	1.09	0.579	1.24	(0.65, 2.36)	2.88	0.237	1.15	(0.85, 1.56)	1.00	0.607
Computer	1.05	(0.89, 1.25)			1.25	(0.96, 1.63)			1.05	(0.90, 1.23)		
Smoked cannabis inside home in past year (non-users)												
Did not smoke cannabis inside	0.92	(0.73, 1.16)	0.61	0.739	1.05	(0.70, 1.57)	4.53	0.104	0.81	(0.64, 1.03)	11.39	0.003
Smoked cannabis inside	1.01	(0.82, 1.24)			1.38	(1.02, 1.87)			0.76	(0.64, 0.89)		
Living with children < 18 (does not)												
Lives with children	1.35	(1.11, 1.65)	8.99	0.003	1.31	(0.99, 1.72)	3.58	0.058	1.18	(0.99, 1.41)	3.46	0.063
Current cigarette smoker (does not smoke)												
Current daily/occasional smoker	0.93	(0.76, 1.15)	0.40	0.526	0.98	(0.73, 1.33)	0.01	0.919	1.02	(0.84, 1.23)	0.03	0.861
Current e-cigarette user (does not use)												
Current e-cigarette user	0.99	(0.75, 1.30)	0.01	0.917	1.59	(1.12, 2.26)	6.81	0.009	1.47	(1.16, 1.86)	10.11	0.001
Self-rated health (fair/poor)												
Good/very good/excellent	0.79	(0.65, 0.96)	5.37	0.020	0.93	(0.70, 1.23)	0.25	0.618	1.05	(0.88, 1.24)	0.26	0.613
Mental health (no issues in past year)												
At least 1 mental health issue	1.17	(0.98, 1.38)	3.09	0.079	1.12	(0.87, 1.44)	0.75	0.385	1.25	(1.07, 1.46)	7.86	0.005
Noticed cannabis use in public (not in past year)												
Don't know	1.32	(0.81, 2.13)	271.74	< 0.001	1.76	(0.97, 3.18)	159.70	< 0.001	1.82	(1.23, 2.68)	364.86	< 0.001
Less than monthly	1.68	(1.21, 2.33)			2.23	(1.53, 3.25)			2.20	(1.69, 2.87)		
At least once/week	5.74	(4.23, 7.78)			7.72	(5.41, 11.00)			6.80	(5.33, 8.68)		
Cannabis smoke can be harmful (no/maybe/don't know)												
Yes	1.10	(0.94, 1.30)	1.38	0.240	1.03	(0.80, 1.33)	0.07	0.792	0.96	(0.83, 1.11)	0.30	0.586

Notes: aOR = adjusted odds ratio; 95% CI = 95% confidence interval.

While it was not possible to quantify the number of youth exposed using these data, 5.2% (US illegal) to 6.5% (Canada and US legal) of MUH residents reported daily SHCS incursions and 13% (US illegal states) to 18% (US legal states) of MUH residents reported weekly SHCS incursions. Although less is known about the health hazards of SHCS than SHTS, it is important to note that SHCS incursions are involuntary for children, highlighting the importance of smoke-free building policies that reduce exposure to SHCS (Chu et al., 2019). There is therefore a need to increase awareness of the harms of SHCS among MUH residents and building operators to increase support for comprehensive bans on tobacco and cannabis smoking in MUH. Although the US Department of Housing and Urban Development banned smoking in public housing in 2018 (Department of Housing and Urban Development, 2016), additional work is needed to eliminate involuntary exposure to all types of secondhand smoke in MUH.

4.1. Limitations

This study is subject to limitations common to survey research. First, ICPS respondents were recruited from a commercial consumer panel that used non-probability-based sampling. Although data were weighted, results are not nationally representative of the Canadian and US populations. Thus, the prevalence of self-reported exposures to SHCS in the home and self-reported SHCS incursions into MUH may not represent the true prevalence in these jurisdictions.

Second, respondents older than 65 were not sampled for the ICPS survey. Therefore, the extent of exposure to SHCS in this older population remains unknown. However, few adults older than 65 use cannabis (Rotermann, 2019). Thus, the prevalence of self-reported exposures and incursions is likely lower in areas where a larger proportion of the population is older than 65. Third, this study reports cross-sectional data collected at the individual level. As a result, relationships between personal and situational factors and self-reported exposures are correlational and only suggest the types of people potentially exposed to SHCS at home or in MUH. It was also not possible to compare residents of different building types (e.g., high income, market-rate buildings vs. low-income, subsidized housing).

Fourth, estimates of self-reported exposures in the home were restricted to the subset of respondents who did not use cannabis in the previous year or who did but did not smoke cannabis inside their homes. Including people who smoked cannabis in the home would have complicated interpretation of results, because it is unclear whether this group of users is reporting exposure to their own cannabis smoke or the smoke of others with whom they live. Fifth, some people may be unable to distinguish cannabis smoke from tobacco smoke (Chu et al., 2019) or may be unfamiliar with the smell of cannabis smoke. To address this limitation, sensitivity analyses estimated the prevalence of self-reported exposures at home (Supplementary Table 2) and self-reported incursions in MUH (Supplementary Table 3) among respondents who never used cannabis or had used but not in the previous year. In all cases, self-reported exposures and incursions were slightly lower among those who never used cannabis than among those not using in the previous year. Thus, estimates presented in Figs. 1 and 2 may only slightly underestimate the magnitude of self-reported exposures. Finally, exposure to SHCS was based on subjective reports rather than quantitative atmospheric monitoring. Additional work should assess the relationship between quantitative measures of SHCS and self-reported exposures.

5. Conclusion

Both Canadian and American residents reported exposure to SHCS in 2019, irrespective of whether they lived in detached single-family homes or MUH. Across jurisdictions, 20% to 25% of MUH residents reported SHCS incursions in their homes from other units or the outdoors at least once in the previous month. This was true irrespective of the legality of non-medical cannabis use. As research on the adverse health effects of SHCS accumulates (Wang et al., 2016), efforts are needed to increase awareness of the risks of exposure, especially among people who smoke cannabis inside their homes. Smoke-free policies in MUH must consider both SHTS and SHCS to protect residents from involuntary incursions.

CRediT authorship contribution statement

Pete Driezen: Conceptualization, Methodology, Formal analysis, Validation, Visualization, Writing – original draft, Writing – review & editing. **Pamela Kaufman:** Methodology, Writing – review & editing. **Michael Chaiton:** Methodology, Writing – review & editing. **Samantha Goodman:** Project administration, Writing – review & editing. **David Hammond:** Funding acquisition, Resources, Writing – review & editing, Supervision.

Declaration of Competing Interest

None of the authors have any conflicts of interest to declare.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ypmed.2022.107006.

References

Anastasiou, E., Chennareddy, S., Wyka, K., Shelley, D., Thorpe, L.E., 2020. Self-reported secondhand marijuana smoke (SHMS) exposure in two new York City (NYC) subsidized housing settings, 2018: NYC housing authority and lower-income private sector buildings. J. Community Health 45, 635–639. https://doi.org/10.1007/s10900-019-00783-x.

Benjamini, Y., Hochberg, Y., 1995. Controlling the false discovery rate: a practical and powerful approach to multiple testing. J. R. Stat. Soc. Ser. B Methodol. 51, 289–300. URL. https://www.jstor.org/stable/2346101.

Chu, A.K., Kaufman, P., Chaiton, M., 2019. Prevalence of involuntary environmental cannabis and tobacco smoke exposure in multi-unit housing. Int. J. Environ. Res. Public Health 16. https://doi.org/10.3390/ijerph16183332.

Cone, E.J., Bigelow, G.E., Herrmann, E.S., Mitchell, J.M., LoDico, C., Flegel, R., Vandrey., 2015. Non-smoker exposure to secondhand cannabis smoke. I. Urine screening and confirmation results. J. Anal. Toxicol. 39, 1–12. https://doi.org/10.1093/jat/bku116.

Department of Housing and Urban Development, 2016. Instituting Smoke-Free Public Housing; Final Rule. Federal Register 81 (233), 87430–87444. https://www.federalregister.gov/d/2016-28986.

Ghasemiesfe, M., Ravi, D., Vali, M., Korenstein, D., Arjomandi, M., Frank, J., Austin, P.C., Keyhani, S., 2018. Marijuana use, respiratory symptoms, and pulmonary function: a systematic review and meta-analysis. Ann. Intern. Med. 169, 106–115. https://doi.org/10.7326/M18-0522.

Goodman, S., Hammond, D., 2022. Perceptions of the health risks of cannabis: estimates from national surveys in Canada and the United States, 2018–2019. Health Educ. Res. https://doi.org/10.1093/her/cyac006. In press.

Goodman, S., Wadsworth, E., Leos-Toro, C., Hammond, D., 2020a. Prevalence and forms of cannabis use in legal vs. illegal recreational cannabis markets. Int. J. Drug Policy 76. https://doi.org/10.1016/j.drugpo.2019.102658.

Goodman, S., Burkhalter, R., Hammond, D., 2020b. International Cannabis Policy Study Technical Report – Wave 2 (2019). University of Waterloo, Waterloo, ON, Canada. URL: http://cannabisproject.ca/wp-content/uploads/2014/05/INTERNATIONAL-CANNABIS-POLICY-STUDY-TECHNICAL-REPORT-W2-2019-April-30-2020.pdf.

Goodwin, R.D., Cheslack-Postava, K., Santoscoy, S., Bakoyiannis, N., Hasin, D.S., Collins, B.N., Lepore, S.J., Wall, M.M., 2018. Trends in cannabis and cigarette use among parents with children at home: 2002 to 2015. Pediatrics 141, e20173506. https://doi.org/10.1542/peds.2017-3506.

Government of Canada, 2017. Canadian Cannabis Survey 2017—Summary. URL: https://www.canada.ca/en/health-canada/services/publications/drugs-health-products/canadian-cannabis-survey-2017-summary.html.

Graubard, B.I., Korn, E.L., 1999. Predictive margins with survey data. Biometrics 55, 652–659. https://doi.org/10.1111/j.0006-341X.1999.00652.x.

Graves, B.M., Johnson, T.J., Nishida, R.T., Dias, R.P., Savareear, B., Harynuk, J.J., Kazemimanesh, M., Olfert, J.S., Boies, A.M., 2020. Comprehensive characterization of mainstream marijuana and tobacco smoke. Sci. Rep. 10, 7160. https://doi.org/10.1038/s41598-020-63120-6.

Hammond, D., Goodman, S., Wadsworth, E., Rynard, V., Boudreau, C., Hall, W., 2020. Evaluating the impacts of cannabis legislation: the International Cannabis policy study. Int. J. Drug Policy 77, 102698. https://doi.org/10.1016/j.drugpo.2020.102698.

Health Canada, 2019. Canadian Cannabis Survey 2019–Summary. URL. https://www.canada.ca/en/health-canada/services/publications/drugs-health-products/canadian-cannabis-survey-2019-summary.html.

Herrmann, E.S., Cone, E.J., Mitchell, J.M., Bigelow, G.E., LoDico, C., Flegel, R., Vandrev, R., 2015. Non-smoker exposure to secondhand cannabis smoke II: effect of room ventilation on the physiological, subjective, and behavioral/cognitive effects. Drug Alcohol Depend. 151, 194–202. https://doi.org/10.1016/j.drugalcdep.2015.03.019.

Holitzki, H., Dowsett, L.E., Spackman, E., Noseworthy, T., Clement, F., 2017. Health effects of exposure to second- and third-hand marijuana smoke: a systematic review. CMAJ Open 5 (4), E814–E822. https://doi.org/10.9778/cmajo.20170112.

Moir, D., Rickert, W.S., Levasseur, G., Larose, Y., Maertens, R., White, P., Desjardins, S., 2008. A comparison of mainstream and sidestream marijuana and tobacco cigarette smoke produced under two smoking machine conditions. Chem. Res. Toxicol. 21, 494–502. https://doi.org/10.1021/tx700275p.

Muller, C.J., MacLehose, R.F., 2014. Estimating predicted probabilities from logistic regression: different methods correspond to different target populations. Int. J. Epidemiol. 43, 962–970. https://doi.org/10.1093/ije/dyu029.

Nguyen, K.H., Gomez, Y., Homa, D.M., King, B.A., 2016. Tobacco use, secondhand smoke, and smoke-free home rules in multiunit housing. Am. J. Prev. Med. 51, 682–692. https://doi.org/10.1016/j.amepre.2016.05.009.

Ott, W.R., Zhao, T., Cheng, K.C., Wallace, L.A., Hildemann, L.M., 2021. Measuring indoor fine particle concentrations, emission rates, and decay rates from cannabis use in a residence. Atmospheric Environment: X 10, 100106. https://doi.org/10.1016/j.aeaoa.2021.100106.

Posis, A., Bellettiere, J., Liles, S., Alcaraz, J., Nguyen, B., Berardi, V., Klepeis, N.E., Hughes, S.C., Wu, T., Hovell, M.F., 2019. Indoor cannabis smoke and children's health. Prev. Med. Rep. 14 https://doi.org/10.1016/j.pmedr.2019.100853.

Ravi, D., Ghasemiesfe, M., Korenstein, M., Cascino, T., Keyhani, S., 2018. Associations between marijuana use and cardiovascular risk factors and outcomes: a systematic review. Ann. Intern. Med. 168, 187–194. https://doi.org/10.7326/M17-1548.

Rotermann, M., 2019. Analysis of trends in the prevalence of cannabis use and related metrics in Canada. Health Rep. 30, 3–13. https://doi.org/10.25318/82-003-x201900600001-eng.

Salloum, N.C., Krauss, M.J., Agrawal, A., Bierut, L.J., Grucza, R.A., 2018. A reciprocal effects analysis of cannabis use and perceptions of risk. Addiction 113, 1077–1085. https://doi.org/10.1111/add.14174.

Schauer, G.L., King, B.A., Bunnell, R.E., Promoff, G., McAfee, T.A., 2016. Toking, vaping, and eating for health or fun: Marijuana use patterns in adults, U.S., 2014. Am. J. Prev. Med. 50, 1–8. https://doi.org/10.1016/j.amepre.2015.05.027.

Substance Abuse and Mental Health Services Administration, 2020. Key substance use and mental health indicators in the United States: results from the 2019 National Survey on drug use and health. HHS publication no. PEP20-07-01-001 NSDUH series H-55. Center for Behavioral Health Statistics and Quality, Substance Abuse and Mental Health Services Administration, Rockville, MD. URL: https://www.samhsa.gov/data/report/2019-nsduh-annual-national-report.

Wang, X., Derakhshandeh, R., Liu, J., Narayan, S., Nabavizadeh, P., Le, S., Danforth, O. M., Pinnamaneni, K., Rodriguez, H.J., Luu, E., Sievers, R.E., Schick, S.F., Glantz, S.A., Springer, M.L., 2016. One minute of marijuana secondhand smoke exposure substantially impairs vascular endothelial function. J. Am. Heart Assoc. 5, e003858 https://doi.org/10.1161/JAHA.116.003858.

Wiegand, D.M., Methner, M.M., Grimes, G.R., Couch, J.R., Wang, L., Zhang, L., Blount, B. C., 2020. Occupational exposure to secondhand cannabis smoke among law enforcement officers providing security at outdoor concert events. Annals of Work Exposures and Health 64, 705–714. https://doi.org/10.1093/annweh/wxaa025.