

RESEARCH ARTICLE

Neighborhood level factors and use of cigarettes, cannabis and e-cigarettes: A population-based study among Canadian adults

Truman Fraser Wood¹, Trevor J.B. Dummer¹, Cheryl E. Peters^{1,2,3}, Rachel A. Murphy^{1,4*}

1 School of Population and Public Health, University of British Columbia, Vancouver, British Columbia, Canada, **2** Prevention and Health Promotion, BC Centre for Disease Control, Vancouver, British Columbia, Canada, **3** Prevention, Screening and Hereditary Cancer, BC Cancer, Vancouver, British Columbia, Canada, **4** Population Health Sciences, BC Cancer, Vancouver, British Columbia, Canada

* Rachel.murphy@ubc.ca



OPEN ACCESS

Citation: Fraser Wood T, Dummer TJB, Peters CE, Murphy RA (2025) Neighborhood level factors and use of cigarettes, cannabis and e-cigarettes: A population-based study among Canadian adults. PLoS One 20(11): e0320035. <https://doi.org/10.1371/journal.pone.0320035>

Editor: Vasileios Kallinterakis, University of Durham: Durham University, UNITED KINGDOM OF GREAT BRITAIN AND NORTHERN IRELAND

Received: February 11, 2025

Accepted: November 6, 2025

Published: November 24, 2025

Copyright: © 2025 Fraser Wood et al. This is an open access article distributed under the terms of the [Creative Commons Attribution License](#), which permits unrestricted use, distribution, and reproduction in any medium, provided the original author and source are credited.

Data availability statement: The data used in this manuscript is governed by the Canadian Partnership for Tomorrow's Health (CanPath). When participants consented to take part in CanPath, they agreed to use of their data for

Abstract

Despite public health efforts, use of legal substances such as cigarettes, cannabis and e-cigarettes are common in Canada. Most policies focus on individual level factors, which do not account for possible influences of the environments to which people belong (i.e., neighborhoods). This study aimed to identify neighborhood-level risk factors for use of cigarettes, cannabis and e-cigarettes in the Canadian Partnership for Tomorrow's Health cohort. Participants completed questionnaires on demographics and health behaviors including recent (30-day) use of cigarettes, cannabis and e-cigarettes. Geospatial neighborhood-level measures: deprivation, gentrification, household security, labor force participation, immigration and visible minority proportion were linked via postal codes. Regression models were built to understand associations between substance use and neighborhood factors. Neighborhood material deprivation, social deprivation, and household insecurity were positively associated with odds of using cigarettes, cannabis, and e-cigarettes. Odds of using these substances was higher for participants living in gentrified neighborhoods. Lower odds of cigarette, cannabis, and e-cigarette use were found for participants living in neighborhoods with a high proportion of recent immigrants and/or visible minorities. Evidence from this study suggests interventions aimed at reducing or preventing substance use should be multidimensional, encompassing strategies directed at both individuals and neighborhoods.

Introduction

Substance use including cigarette, cannabis, and electronic cigarette (e-cigarette) use is common in Canada [1,2] despite sustained public health efforts to reduce use. Cigarette smoking has been a significant public health concern in Canada for decades, although, cigarette smoking has been trending downwards in Canada since

future research. However, the consent form (and thus ethics approvals) outlined that additional use of data would be granted upon approval of data access requests. The data used in this manuscript was obtained through the data access request which required us to sign the CanPath data use agreement which only permits access of data by approved researchers (named on the data access request). Further, our ethics approval by the BC Cancer/University of British Columbia research board outlines a defined list of researchers who can access the data. Further information on the CanPath data access process can be found at: <https://canpath.ca>.

Funding: BC Cancer Foundation.

Competing interests: RAM is a consultant for Pharmavite. All other authors declare no conflict of interest.

the 1980s [3]. In 2021, there were 1.5 million less cigarette smokers in Canada compared to 2015 [4] and 10.2% of Canadian adults (age 15 and older) reported currently smoking cigarettes [2]. Cigarette smoking remains higher among individuals with low household income, less education, and those who are single [5]. Legal cannabis sales began in 2019 following federal legislation that permitted its sale at licensed retailers in Canada [6]. In 2020, 27% of Canadian adults (age 16 and older) reported using cannabis in the past 12 months [7]. Prevalence of past-year cannabis use was highest among young adults, about 50%, compared to 44% in 16–19-year-olds, and 23% in adults 25 years and older [7]. E-cigarettes, also referred to as vapes and electronic nicotine delivery systems, entered the Canadian market in 2004 and are therefore a relatively novel form of substance use. In 2021, 17% of Canadian adults reported ever use of e-cigarette products [2]. E-cigarette use is becoming increasingly prevalent in Canada [2]. Among young adults aged 20–24, the rate of past 30-day use has increased from 13% to 17% from 2019 to 2021 [2]. This could be due to more people transitioning from using cigarettes to e-cigarettes.

Among many other health conditions, cigarette smoking is associated with the development of cancers, heart disease, and death from common illnesses (such as pneumonia) [8,9]. An estimated 72% of lung cancers are attributable to cigarette smoking [10]. In 2017, it was estimated that 48,000 deaths were attributable to tobacco use in Canada [8]. Our understanding of the health impacts of using cannabis and e-cigarettes is limited by the more recent legalization and introduction of these substances in Canada. Studies on cannabis and health have been limited by its illicit status in most countries, which hinders research efforts as there is hesitancy for people to report use [11]. Smoking cannabis may be linked to carbon monoxide intoxication and some studies have found associations with adverse cardiac outcomes [11]. Changing laws and social norms around cannabis use may allow clarification around these associations in the future. Understanding factors that are associated with the use of these substances in Canada has important implications for the primary prevention of numerous chronic diseases. However, research on risk factors for substance use has historically focused on individual-level factors, such as sex or income. More recently, there has been a shift in our understanding of what can influence health and behaviors to include components of the environment where a person lives, works, and/or engages in recreation.

The social ecological model (SEM) is a framework for prevention that conceptualizes four levels; individual, interpersonal relationships, communities, and societal (i.e., policies) [12]. The framework posits that factors belonging to one level can influence factors at all other levels of the framework [12]. The SEM can be applied to better understand substance use. Using this systems approach, individuals can influence and be influenced by their interactions with others, their community, and available resources or institutions [12]. The community level of the SEM framework includes the settings where health behaviors (i.e., substance use) may occur and characteristics of one's environment that may influence health behaviors. Application of this framework may help to expand our understanding of risk factors for substance use and how multiple factors at the individual and built environment level may disadvantage certain people.

In reference to the SEM framework, there are several theories detailing mechanisms through which an individual's behavior can be influenced by their neighborhood environment. The social interactive theory proposes that an individual's social network is affected by the neighborhood they live in, ultimately impacting behaviors by influencing one's attitudes and beliefs (including those about social norms) as well as their access to supports, information, and resources [12]. Having higher social or community cohesion is also thought to promote healthier behaviors by improving access to health information and services [13]. The structural hypothesis suggests that living in a particular neighborhood determines residents' accessibility to certain structural environments (sidewalks, parks, etc.), institutions and businesses (community centers, grocery stores, liquor re-tailers, etc.), and employment opportunities [14]. Living in a neighborhood with variable access to the aforementioned structures may affect residents use of resources and any directly or indirectly related behaviors [14]. There is also evidence that the neighborhood one lives in can impact their exposure to stressors, potentially related to their neighborhood social environment and their access to specific resources [15]. Stress can have strong impacts on behavior, especially when stress originates from an unavoidable source such as the area where one lives [15].

Research has increasing recognized the potential role of social and structural factors on substance use, providing support that the forementioned theories (and other frameworks) can be applied provide insight into substance use. For example, there is evidence that social motives and social norms influence substance use behaviors [16,17]. Additionally, there is evidence that substance use is associated with structural aspects of one's environment [18,19]. The sociodemographic make-up of residents in a neighborhood, which likely influences the social environment and resource distribution of neighborhoods, has also been associated with substance use behaviors [20,21]. Structural determinants of health, including the physical environment (in addition to institutional practices, social norms, government policies, and economic systems) have established associations with substance use. A recent narrative review of structural determinants and substance use [22] highlighted several studies that reported geographical/neighborhood factors [23,24] that were associated with various measures of substance use or substance use related outcomes such as emergency visits due to substance use [25]. The review also emphasized the need for ongoing studies to bring awareness to the importance of structural determinants and substance use within and across different countries [22].

This study aimed to understand how neighborhood-level factors were associated with the use of cigarettes, cannabis, and e-cigarettes in over 100,000 adults across Canada as part of the Canadian Partnership for Tomorrow's Health (CanPath) cohort.

Materials and methods

Study population

The data used in this study were collected as part of the CanPath cohort [26]. CanPath is Canada's largest longitudinal cohort, of over 330,000 Canadians across British Columbia, Alberta, Ontario, Quebec, and the Atlantic Provinces. Participants are being recruited in Saskatchewan and Manitoba but data was not available at the time of this analysis. To be included in CanPath, participants had to be aged 30–74 at study baseline (between 2009 and 2015), reside in one of the participating Canadian provinces, and be able to complete questionnaires in English or French [26]. Participants were asked to complete sociodemographic and health questionnaires and also consented to be contacted for future research and follow-up. An online, self-administered follow-up questionnaire was administered between 2016 and 2018. In total, 134,404 CanPath participants completed the follow-up questionnaire, making it the most recent and comprehensive self-reported data on participants' use of cigarettes, cannabis, and e-cigarettes, and thus the focus of this cross-sectional analysis. Access to the CanPath de-identified participant data was granted July 4, 2023. The study was conducted in accordance with the Declaration of Helsinki, and approved by the Joint Institutional Review Board BC Cancer/University of British Columbia (REB #H23-01508).

Written, informed consent was obtained from all participants in the CanPath study at in person assessment centres, via mail or online study systems. Consent included agreement to de-identified participant data being accessed by researchers upon approval from CanPath.

Covariates used in regression models were drawn from the follow-up CanPath questionnaire when possible to provide contemporaneous measures. Demographic and health related variables included age, sex, household income, marital status, perceived health status, and participants' self-reported history of chronic diseases (cancer, diabetes, cardiovascular disease, and mental health conditions). Variables not queried in the follow-up questionnaire were obtained from the baseline questionnaire (2009–2015), including participant's ethnicity, education, physical activity levels, body mass index (BMI), and fruit and vegetable consumption.

Neighborhood measures. Data on neighborhood measures were generated through the Canadian Urban Environmental Health Research Consortium (CANUE) [27]. The six-digit postal code of CanPath participants who completed the follow-up questionnaire were linked to CANUE data to provide measures of the neighborhood where each participant resided: material deprivation, social deprivation, gentrification, and the Canadian Marginalization (CAN-Marg) indices. Neighborhood measures are at the level of dissemination area (DA). DAs cover all of Canada and are the smallest geographic area that standard census data is collected for, with the average population of DAs ranging from 400 to 700 [28]. The neighborhood measures available through CANUE were generated using data from the Statistics Canada census, primarily the census completed in 2016. Every five years Statistics Canada asks all Canadian households to respond to either a long form questionnaire (about 25% of households) or short form questionnaire. Questions in the census cover a range of primarily sociodemographic topics, such as education, income, religion, and housing. The census questionnaire can be completed online, through mail, or over the phone. The 2016 census had a response rate above 95% [29].

Material deprivation scores were generated for each DA in Canada based on the proportion of residents without a high school diploma, the employment to population ratio in the area, and the average personal income [30]. Using principal component analysis, a factor score was generated from the aforementioned information and allowed the creation of population-weighted quintile values (1–5, least deprived to most deprived) for each DA. Social deprivation scores were generated for each DA in Canada based on the proportion of residents living alone, the proportion of residents that were separated, divorced, or widowed, and the proportion of single-parent families [30]. Quintile scores were generated in the same manner as for material deprivation. Material and social deprivation quintile scores scaled to the corresponding Canadian province of a neighborhood were used in the current study.

The Gentrification, Urban Interventions and Equity (GENUINE) tool was used to produce area-level measures of gentrification within Canada [31]. The tool uses multiple measures in the domains of income, housing, occupation, education, and age to produce measures of gentrification [31]. Information from the Statistics Canada Census in 2006 and 2016 was used to identify if gentrification occurred in census tracts between 2006 and 2016. A neighborhood was considered to be gentrifying if there was an increase in the proportion of residents with a university-level education, an increase in housing value, or an increase in rental costs, between 2006 and 2016, that was greater than that observed in the respective region to which a neighborhood belonged [31]. For the purpose of analysis, neighborhoods identified as non-gentrifiable (in 2006, the median neighborhood income was greater than the median income in the respective region) and stable (did not experience gentrification) were combined into one category that was compared against gentrifying neighborhoods.

CAN-Marg consists of four measures developed based on previous research on neighborhood deprivation and marginalization: household security (i.e., household and dwellings, residential instability), material resources (i.e., material deprivation), labor force participation (i.e., dependency), and immigration and visible minority (IVM) proportion (i.e., ethnic concentration) [32]. The measure of household security is developed using indicators of family structures, population demographics, home ownership, household density, and migration into the neighborhood [32]. The measure of material resources is similar to the aforementioned material deprivation score [32]. The measure of labor force participation

captures the proportion of residents in a neighborhood who are over the age of 65 and the proportion of residents over the age of 15 who are unemployed [32]. The measure of IVM captures the proportion of residents in a neighborhood who are recent immigrants to Canada and/or who self-identify as visible minorities [32]. Factor scores, for each Canadian DA with census information, were computed from factor loadings and scores were used to divide DAs into quintiles for each measure. For this study, the CAN-Marg measures of household security, labor force participation, and IVM were studied since material resources is captured in the aforementioned material deprivation score.

Study variables

Participants self-reported their cigarette use as either daily (at least one cigarette every day for the past 30 days), occasional (at least one cigarette in the past 30 days, but not every day), or none (did not smoke at all in the past 30 days). Those who reported never smoking cigarettes in their lifetime had their past 30-day cigarette use recorded as “none”. Participants who responded yes to ever using cannabis and yes to ever using cannabis once a month for over a year were asked about their cannabis use in the past 30 days. If participants skipped or reported no to ever using cannabis once a month for over a year, they were not asked to report their current cannabis use, which thus resulted in a large number of participants (~50,500) with missing cannabis use data. Cannabis use was categorized as none, infrequent use (1–5 days a month), occasional use (6–20 days a month), and frequent use (21–30 days a month). This categorization is similar to that of the American National Survey on Drug Use and Health [33,34]. Participants self-reported whether they had ever used an e-cigarette or “vaping” device. Those who responded yes were then asked if they had used an e-cigarette in the past 30 days. E-cigarette use was dichotomized as yes/no, as the number of days of use was not queried.

Covariates. Covariates related to substance use and neighborhood measures based on evidence in existing literature were considered for inclusion in models. Categorization of covariates was based upon established thresholds or prior studies in CanPath [35,36]. Covariates included age, sex, region of residence, income, education, marital status, ethnicity, health perception, physical activity, fruit and vegetable consumption, BMI, and history of chronic conditions (cancer, diabetes, cardiovascular disease, and mental health conditions). Age was considered as a continuous variable. Sex was dichotomized as male/female. Study region reflected CanPath cohorts, with each participant belonging to either British Columbia, Alberta, Ontario, Quebec, or the Atlantic Provinces (Nova Scotia, New Brunswick, Prince Edward Island, and Newfoundland and Labrador). Annual household income was categorized <\$25,000, \$25,000 - \$50,000, \$50,000 - \$75,000, \$75,000 - \$100,000, \$100,000 - \$150,000, and >\$150,000. Education was categorized as high school or below, college level, or bachelor's degree or higher. Marital status was dichotomized as single (including widowed) or partnered. Ethnicity was dichotomized as white or non-white, as 93.2% of the sample was white. Health perception was categorized as excellent to very good, good, and fair to poor. Physical activity was categorized as low, moderate, or high, based on participants' responses to the International, Physical Activity Questionnaire [37]. Fruit and vegetable consumption was the number of servings of fruit and vegetables consumed on a typical day. BMI was calculated from measured (if available) or self-reported height and weight and categorized as <25 kg/m², 25.0–29.9 kg/m², and >30 kg/m².

Analytical sample. The analytical sample varied for the analysis of neighborhood measures and substance use depending on the variables under study. Participants were excluded from analysis if they had missing information on the substance use variable or the primary independent variable (neighborhood measure) for a particular model. Of the total 134,404 participants that completed the follow-up questionnaire, the number of participants eligible for final analysis varied from 128,240–51,639 depending on the missingness of the independent and dependent variable. Missing data for a particular substance use variable resulted in 6,390 participants excluded from analyses focused on cigarette use, 58,558 participants excluded from analyses focused on cannabis use, and 5,972 participants excluded from all analyses focused on e-cigarette use. Additional details on the study populations for a given exposure/outcome are provided in [S1](#), [S2](#) and [S3 Figs](#) in the Supporting Information. The Multivariate Imputations by Chained Equation (MICE) package in R was used to perform multiple imputation for covariates with missing values. Age, sex, region, and health perception were

correlated with missing values and were used as auxiliary variables in the multiple imputation to prevent/reduce bias in the generated datasets. Predictive mean matching within the MICE package was used to impute the missing values. As the percent of missing information for the imputed variables typically ranged between 30% and 40%, 30 imputed datasets were generated, with 20 iterations required to achieve convergence.

Statistical analysis: Means and standard deviations were reported for numeric variables and percentages were reported for categorical variables. Separate regression models were built to study how cigarette, cannabis, and e-cigarette use were associated with each neighborhood measure. Multinomial models were built to study how cannabis use and cigarette use were associated with the neighborhood measures being explored in this study as estimated via odds ratios (ORs). For e-cigarette use, logistic regression models were built to study associations with neighborhood measures via ORs. Model assumptions were examined through residual plots.

Model 1 was unadjusted. Model 2 adjusted for sex, age, and regional cohort. Forward stepwise regression was then performed for all other covariates. Variables that changed the estimate by ~10% and were statistically significant (p -value <0.05) remained in the adjusted model. Interactions between the neighborhood measures and sex were examined for each model. For all models, the interaction between the neighborhood measure and region was also examined. Interactions with other covariates were explored in some models based on subject area knowledge. For example, interactions between gentrification and household income were tested in models examining associations between substance use and gentrification, although no interactions at the neighborhood level were subsequently found to be significant.

All analyses and data cleaning were conducted in R Studio (R version 4.2.3) [38]. The nnet package was used to analyze multinomial models [38]. A confidence level of 95% was used as a threshold for statistical significance.

Results

Population descriptives

The demographic, lifestyle, and health characteristics of all CanPath participants who completed the follow up survey are presented in [Table 1](#). The mean age of participants was 60y, and 65.1% of participants were female. The majority of participants had a household income $>\$50,000$ and 83.1% of participants were university or college educated. When asked to rate their health, 82.9% of participants rated their health as good to excellent. Demographic, lifestyle, and health characteristics are also reported within categories of cigarette, cannabis, and e-cigarette use in the [S1](#), [S2](#) and [S3 Tables](#) in the Supporting Information.

The prevalence of cigarette, cannabis, and e-cigarette use for CanPath participants who completed the follow-up questionnaire is presented in [Table 2](#). Only 4.2% of participants smoked cigarettes daily, and only 2.3% used cannabis frequently. In the past 30-days, only 1% of participants reported cannabis use.

Descriptives of neighborhood measures by categories of substance use for all participants who completed the follow-up questionnaire are presented in [S4–S6 Tables](#). [Subxref9] More participants lived in neighbourhoods in the lowest two quintiles of material deprivation (least deprived) than in the highest two quintiles of material deprivation (most deprived), 57.5% vs. 23.6%, respectively. Similarly, for the CAN-Marg index of material resources, with 59.8% and 21.9% of participants living in neighbourhoods in bottom two and top two quintiles, respectively. Between 17.9% and 1.6% of participants lived in neighbourhoods that had experienced gentrification between 2006 and 2016 depending on the measure of gentrification used.

Cigarette smoking

Associations between cigarette smoking and neighborhood measures are shown in [Table 3](#). In model 2, the odds of smoking cigarettes occasionally were 32% (OR = 1.32, 95% CI = 1.11, 1.56) higher for participants living in the most deprived neighborhoods (fifth quintile) compared to those living in the least deprived neighborhoods (first quintile). After adjusting

Table 1. Characteristics of CanPath participants (N=134,404) who completed the follow-up questionnaire.

Characteristic	N (%) or mean (SD)
Age (years)	60 (9.8)
Female sex	87,497 (65.1)
Region	
British Columbia	22,580 (16.8)
Alberta	30,644 (22.8)
Ontario	42,203 (31.4)
Quebec	17,069 (12.7)
Atlantic Canada	21,908 (16.3)
Health status	
Very good-excellent	70,646 (53.4)
Good	39,027 (29.5)
Fair-poor	22,622 (17.1)
Household income	
<\$25,000	3,942 (4.9)
\$25,000-\$49,999	12,951 (16.1)
\$50,000-\$74,999	16,490 (20.5)
\$75,000-\$99,999	14,560 (18.1)
\$99,999-\$149,999	17,053 (21.2)
≥\$150,000	15,445 (19.2)
Education	
≤ High school	21,658 (16.9)
College	46,135 (36.0)
≥ Bachelor's degree	60,360 (47.1)
Marital status	
Partnered	99,781 (75.2)
Single	32,906 (24.8)
Ethnicity	
White	106,300 (93.2)
Non-white	7,756 (6.8)
Physical activity	
Low	25,098 (20.7)
Moderate	43,800 (35.3)
High	53,348 (44.0)
BMI	
<25 kg/m ²	30,277 (40.6)
25–29.9 kg/m ²	25,579 (34.3)
≥ 30 kg/m ²	18,718 (25.1)
Vegetable consumption, servings/d	2.8 (1.6)
Fruit consumption, servings/d	2.2 (1.4)
Prevalent cardiovascular disease, yes	26,406 (33.5)
Prevalent diabetes, yes	6,867 (8.7)
Prevalent cancer, yes	20,781 (15.9)
Neighborhood material deprivation	
Quintile 1 (least deprived)	37,795 (33.5)
Quintile 2	27,094 (24.0)
Quintile 3	21,227 (18.9)

(Continued)

Table 1. (Continued)

Characteristic	N (%) or mean (SD)
Quintile 4	16,578 (14.7)
Quintile 5 (most deprived)	
Neighborhood social deprivation	
Quintile 1 (least deprived)	22,210 (19.7)
Quintile 2	22,019 (19.5)
Quintile 3	23,585 (20.9)
Quintile 4	23,203 (20.6)
Quintile 5 (most deprived)	21,596 (19.3)
Living in a gentrified neighborhood	16,681 (17.9)
Neighborhood household security	
Quintile 1 (most secure)	22,312 (20.8)
Quintile 2	23,037 (21.4)
Quintile 3	22,597 (21.0)
Quintile 4	19,810 (18.4)
Quintile 5 (least secure)	19,720 (18.3)
Neighborhood material resources	
Quintile 1 (most resources)	38,661 (36.0)
Quintile 2	25,563 (23.8)
Quintile 3	18,619 (17.3)
Quintile 4	14,537 (12.5)
Quintile 5 (least resources)	10,096 (9.4)
Neighborhood labor force	
Quintile 1 (most employment)	20,647 (19.2)
Quintile 2	21,987 (20.5)
Quintile 3	22,040 (20.5)
Quintile 4	21,717 (20.2)
Quintile 5 (least employment)	21,085 (19.6)
Neighborhood IVM	
Quintile 1 (least IVM residents)	16,532 (15.4)
Quintile 2	21,710 (20.2)
Quintile 3	26,138 (24.3)
Quintile 4	25,936 (24.1)
Quintile 5 (most IVM residents)	17,160 (16.0)

<https://doi.org/10.1371/journal.pone.0320035.t001>

for confounders, the odds ratio of smoking cigarettes daily was higher in the second to fifth quintile of material deprivation compared to the least deprived quintile. For example, OR= 2.00, 95% CI=1.80, 2.22 (model 2), for participants living in the most deprived neighborhoods versus those living in the least deprived neighborhoods. For social deprivation, the odds of occasionally smoking cigarettes were 25% (OR = 1.25, CI=1.07, 1.46, model 2) and 36% (OR = 1.36, CI=1.16, 1.59, model 2) higher for participants living in neighborhoods in the fourth and fifth quintile of social deprivation, respectively, compared to participants living in neighborhoods in the first quintile. The odds of daily cigarette smoking were higher for participants living in neighborhoods from the second to fifth quintile of social deprivation than for participants living in neighborhoods in the first quintile in the unadjusted and adjusted models.

Quintile 1 represents least deprived (material and social deprivation), most secure, most employment, and least IVM residents. Model 1 was unadjusted. Model 2 adjusted for age, sex, and region and covariates that differed depending

Table 2. Descriptives of substance use for all CanPath participants who completed the follow-up questionnaire.

Substance use	N (%)
Past 30-d cigarette use	
None	120,669 (94.3)
Occasional	1,987 (1.6)
Daily	5,358 (4.2)
Past 30-d cannabis use	
None	71,377 (94.1)
Infrequent	1,652 (2.2)
Occasional	1,094 (1.4)
Frequent	1,723 (2.3)
Past 30-d e-cigarette use	
No	127,184 (99.0)
Yes	1,248 (1.0)

<https://doi.org/10.1371/journal.pone.0320035.t002>

on the neighborhood measure due to stepwise covariate selection. Material deprivation adjusted for health status, and education, social deprivation, gentrification, labor force and IVM adjusted for income and marital status. Reference is no cigarette use. IVM: immigration and visible minority.

In model 1 and 2, the odds of smoking cigarettes occasionally or daily were higher for participants living in gentrified neighborhoods than for participants living in non-gentrified neighborhoods. For instance, OR=1.33 (95% CI 1.18, 1.51) for occasional cigarette use in gentrified neighborhoods compared to non-gentrified. The odds of occasional cigarette smoking was lower among participants living in neighborhoods with lower labour force participation (quintiles 4 and 5), but estimates were attenuated in model 2. No associations were observed between daily cigarette use and labor force. Both model 1 and 2 found that the odds of smoking cigarettes daily were lower for participants who lived in neighborhoods in quintiles 3–5 of IVM relative to quintile 1. For example, adjusted OR = 0.75 (95% CI=0.67, 0.85) for participants living in neighborhoods in quintile five versus quintile one of IVM. There were no associations between occasional smoking and neighborhood IVM.

Cannabis use

Associations between cannabis use and neighborhood factors are shown in [Table 4](#). There were no significant associations between infrequently or occasionally using cannabis and living in a materially deprived neighborhood. After adjusting for confounders (model 2), the odds of frequently using cannabis were 24% (OR = 1.24, 95% CI=1.06, 1.46) and 48% (OR = 1.48, 95% CI=1.24, 1.77) higher for participants living in neighborhoods in the fourth and fifth quintiles of material deprivation, compared to participants living in neighborhoods in the first quintile. After adjusting for confounders, the odds of infrequently, occasionally, and frequently using cannabis were 94% (OR = 1.94, 95% CI=1.63, 2.31), 117% (OR = 2.17, 95% CI=1.74, 2.71), and 196% (OR = 2.96, 95% CI=2.43, 3.60) higher, respectively, for participants living in neighborhoods in the fifth quintile of social deprivation than for participants living in neighborhoods in the first quintile. The odds of infrequent, occasional and frequent cannabis use were all higher for participants living in gentrified neighborhoods than for participants living in non-gentrified neighborhoods (e.g., frequent use: OR = 2.04, 95% CI=1.79, 2.33, model 2). The odds of occasionally and frequently using cannabis were higher for participants living in neighborhoods in the second to fifth quintile of household security compared to participants living in neighborhoods in the first quintile, in both model 1 and 2. Associations between neighborhood labor force and cannabis use was not significant with adjustment for covariates in model 2. The odds of frequently using cannabis were 46% lower (OR = 0.54, 95% CI=0.44, 0.66) for participants living

Table 3. Odds ratios of cigarette use (95% CI) by neighborhood characteristics.

	Occasional cigarette use		Daily cigarette use	
	Model 1	Model 2	Model 1	Model 2
Material deprivation				
Quintile 1	Ref	Ref	Ref	Ref
Quintile 2	1.10 (0.96, 1.25)	1.03 (0.90, 1.18)	1.42 (1.29, 1.55)	1.20 (1.10, 1.32)
Quintile 3	1.19 (1.03, 1.36)	1.08 (0.94, 1.25)	1.73 (1.58, 1.90)	1.37 (1.25, 1.51)
Quintile 4	1.09 (0.94, 1.28)	0.98 (0.84, 1.15)	2.10 (1.92, 2.31)	1.58 (1.44, 1.74)
Quintile 5	1.54 (1.31, 1.82)	1.32 (1.11, 1.56)	2.86 (2.59, 3.17)	2.00 (1.80, 2.22)
Social deprivation				
Quintile 1	Ref	Ref	Ref	Ref
Quintile 2	1.02 (0.86, 1.20)	0.99 (0.84, 1.17)	1.36 (1.22, 1.53)	1.29 (1.15, 1.45)
Quintile 3	1.05 (0.89, 1.23)	0.97 (0.82, 1.15)	1.54 (1.38, 1.72)	1.38 (1.23, 1.54)
Quintile 4	1.42 (1.22, 1.66)	1.25 (1.07, 1.46)	1.90 (1.71, 2.11)	1.56 (1.40, 1.74)
Quintile 5	1.69 (1.45, 1.97)	1.36 (1.16, 1.59)	2.40 (2.17, 2.67)	1.77 (1.59, 1.97)
Gentrification				
No	Ref	Ref	Ref	Ref
Yes	1.49 (1.32, 1.69)	1.33 (1.18, 1.51)	1.22 (1.12, 1.33)	1.16 (1.07, 1.27)
Household security				
Quintile 1	Ref	Ref	Ref	Ref
Quintile 2	1.14 (0.97, 1.34)	1.19 (1.01, 1.40)	1.27 (1.13, 1.42)	1.28 (1.14, 1.43)
Quintile 3	1.18 (1.00, 1.39)	1.20 (1.01, 1.42)	1.56 (1.40, 1.74)	1.50 (1.35, 1.68)
Quintile 4	1.35 (1.15, 1.60)	1.30 (1.10, 1.54)	1.87 (1.68, 2.09)	1.68 (1.50, 1.87)
Quintile 5	1.76 (1.50, 2.05)	1.51 (1.28, 1.77)	1.96 (1.76, 2.18)	1.54 (1.37, 1.72)
Labor force				
Quintile 1	Ref	Ref	Ref	Ref
Quintile 2	0.83 (0.71, 0.97)	0.91 (0.78, 1.06)	0.89 (0.80, 0.98)	0.96 (0.86, 1.06)
Quintile 3	0.86 (0.74, 1.01)	0.97 (0.83, 1.13)	1.00 (0.91, 1.11)	1.09 (0.9, 1.21)
Quintile 4	0.79 (0.68, 0.92)	0.91 (0.78, 1.07)	0.94 (0.85, 1.04)	1.03 (0.93, 1.15)
Quintile 5	0.81 (0.69, 0.94)	0.95 (0.81, 1.12)	0.97 (0.88, 1.07)	1.05 (0.94, 1.17)
IVM				
Quintile 1	Ref	Ref	Ref	Ref
Quintile 2	0.97 (0.82, 1.14)	0.96 (0.81, 1.13)	0.90 (0.82, 1.00)	0.91 (0.82, 1.01)
Quintile 3	0.95 (0.81, 1.12)	0.94 (0.80, 1.10)	0.77 (0.70, 0.85)	0.78 (0.70, 0.86)
Quintile 4	0.92 (0.78, 1.07)	0.90 (0.76, 1.06)	0.70 (0.63, 0.77)	0.70 (0.63, 0.78)
Quintile 5	0.89 (0.75, 1.07)	0.83 (0.69, 1.01)	0.79 (0.71, 0.88)	0.75 (0.67, 0.85)

<https://doi.org/10.1371/journal.pone.0320035.t003>

in neighborhoods in the fifth quintile of IVM than for participants living in neighborhoods in the first quintile. The odds of frequent cannabis use were also lower for participants living in neighbourhoods in fourth quintile and third quintile of IVM. The odds of infrequent cannabis use were lower in the adjusted model for participants living in neighborhoods in the fifth and fourth quintile of IVM.

Quintile 1 represents least deprived (material and social deprivation), most secure, most employment, and least IVM residents. Model 1 was unadjusted. Model 2 adjusted for age, sex, and region and covariates that differed depending on the neighborhood measure due to stepwise covariate selection. Material deprivation adjusted for health, income, education and ethnicity, social deprivation: marital status, gentrification: education and marital status, household security, labor force and IVM: income and marital status. Reference is no cannabis use. IVM: immigration and visible minority.

Table 4. Odds ratios of cannabis use (95% CIs) by neighborhood characteristics.

	Infrequent		Occasional		Frequent	
	Model 1	Model 2	Model 1	Model 2	Model 1	Model 2
Material deprivation						
Quintile 1	Ref	Ref	Ref	Ref	Ref	Ref
Quintile 2	0.96 (0.84, 1.11)	0.89 (0.78, 1.03)	0.91 (0.76, 1.09)	0.83 (0.69, 0.99)	1.03 (0.88, 1.20)	0.87 (0.74, 1.02)
Quintile 3	0.86 (0.73, 1.00)	0.79 (0.68, 0.93)	0.99 (0.81, 1.19)	0.88 (0.73, 1.07)	1.28 (1.09, 1.49)	1.03 (0.87, 1.20)
Quintile 4	0.96 (0.81, 1.13)	0.89 (0.75, 1.05)	1.20 (0.99, 1.45)	1.07 (0.87, 1.30)	1.61 (1.37, 1.88)	1.24 (1.06, 1.46)
Quintile 5	1.01 (0.83, 1.23)	0.91 (0.75, 1.11)	1.10 (0.87, 1.40)	0.94 (0.74, 1.20)	2.10 (1.78, 2.49)	1.48 (1.24, 1.77)
Social deprivation						
Quintile 1	Ref	Ref	Ref	Ref	Ref	Ref
Quintile 2	1.05 (0.87, 1.27)	1.08 (0.89, 1.31)	1.13 (0.88, 1.44)	1.16 (0.91, 1.48)	1.74 (1.41, 2.15)	1.75 (1.42, 2.16)
Quintile 3	1.48 (1.24, 1.76)	1.51 (1.26, 1.80)	1.56 (1.25, 1.95)	1.60 (1.28, 2.00)	1.94 (1.58, 2.38)	1.90 (1.55, 2.34)
Quintile 4	1.50 (1.26, 1.79)	1.50 (1.25, 1.79)	1.76 (1.41, 2.19)	1.76 (1.41, 2.20)	2.74 (2.26, 3.33)	2.55 (2.09, 3.10)
Quintile 5	2.06 (1.73, 2.44)	1.94 (1.63, 2.31)	2.29 (1.84, 2.84)	2.17 (1.74, 2.71)	3.55 (2.93, 4.30)	2.96 (2.43, 3.60)
Gentrification						
No	Ref	Ref	Ref	Ref	Ref	Ref
Yes	2.08 (1.82, 2.36)	1.92 (1.68, 2.19)	1.99 (1.70, 2.34)	1.85 (1.57, 2.17)	2.27 (2.00, 2.58)	2.04 (1.79, 2.33)
Household security						
Quintile 1	Ref	Ref	Ref	Ref	Ref	Ref
Quintile 2	1.16 (0.96, 1.41)	1.20 (0.99, 1.45)	1.67 (1.31, 2.14)	1.74 (1.36, 2.22)	1.46 (1.19, 1.78)	1.48 (1.21, 1.82)
Quintile 3	1.50 (1.25, 1.80)	1.53 (1.27, 1.84)	1.94 (1.53, 2.47)	2.00 (1.57, 2.54)	2.12 (1.75, 2.57)	2.09 (1.72, 2.53)
Quintile 4	1.72 (1.43, 2.07)	1.71 (1.42, 2.06)	2.37 (1.87, 3.01)	2.39 (1.87, 3.04)	2.29 (1.89, 2.78)	2.13 (1.75, 2.59)
Quintile 5	2.30 (1.93, 2.75)	2.14 (1.79, 2.57)	2.96 (2.35, 3.74)	2.80 (2.20, 3.55)	3.22 (2.67, 3.87)	2.62 (2.16, 3.17)
Labor force						
Quintile 1	Ref	Ref	Ref	Ref	Ref	Ref
Quintile 2	0.89 (0.75, 1.05)	0.96 (0.81, 1.14)	0.83 (0.68, 1.02)	0.90 (0.73, 1.11)	1.01 (0.86, 1.19)	1.11 (0.94, 1.32)
Quintile 3	0.84 (0.71, 0.99)	0.95 (0.80, 1.13)	0.89 (0.73, 1.09)	1.02 (0.83, 1.25)	0.88 (0.74, 1.04)	1.02 (0.86, 1.22)
Quintile 4	0.83 (0.70, 0.98)	0.99 (0.83, 1.18)	0.82 (0.67, 1.01)	0.98 (0.80, 1.21)	0.80 (0.68, 0.95)	0.99 (0.83, 1.18)
Quintile 5	0.77 (0.65, 0.92)	0.99 (0.82, 1.18)	0.73 (0.59, 0.91)	0.94 (0.75, 1.17)	0.90 (0.76, 1.07)	1.16 (0.98, 1.39)
IVM						
Quintile 1	Ref	Ref	Ref	Ref	Ref	Ref
Quintile 2	1.15 (0.96, 1.37)	1.09 (0.91, 1.30)	0.83 (0.67, 1.02)	0.78 (0.63, 0.97)	0.94 (0.79, 1.11)	0.91 (0.76, 1.08)
Quintile 3	1.06 (0.89, 1.26)	0.95 (0.79, 1.13)	0.93 (0.76, 1.13)	0.82 (0.67, 1.01)	0.80 (0.68, 0.95)	0.73 (0.61, 0.87)
Quintile 4	0.97 (0.81, 1.16)	0.80 (0.67, 0.97)	0.84 (0.68, 1.03)	0.68 (0.55, 0.85)	0.83 (0.71, 0.98)	0.69 (0.58, 0.82)
Quintile 5	0.81 (0.66, 0.99)	0.60 (0.49, 0.74)	0.64 (0.50, 0.81)	0.46 (0.36, 0.60)	0.75 (0.62, 0.91)	0.54 (0.44, 0.66)

<https://doi.org/10.1371/journal.pone.0320035.t004>

E-cigarette use

After adjusting for covariates, the odds of past 30-day e-cigarette use were higher for participants who lived in neighborhoods in the fourth and fifth quintile of material deprivation (quintile 5, model 2: OR = 1.42, 95% CI = 1.15, 1.76, [Table 5](#)). The odds of e-cigarettes use were higher in quintile 4 and quintile 5 of socially deprived neighborhoods in model 1 and 2: quintile 4: OR = 1.28, 95% CI = 1.04, 1.58, and quintile 5: OR = 1.52, 95% CI = 1.24, 1.87. The odds of e-cigarette use was also higher in gentrified neighborhoods, but only in model 1. With respect to household security, the odds of e-cigarette use were 36% (OR = 1.36, 95% CI = 1.10, 1.68) and 30% (OR = 1.30, 95% CI = 1.05, 1.61) higher for participants living in neighborhoods in the fourth and fifth quintile of household security (model 2). Associations between e-cigarette

Table 5. Odds ratios of e-cigarette use (95% CIs) by neighborhood characteristics.

Substance use	Model 1	Model 2
Material deprivation		
Quintile 1	Ref	Ref
Quintile 2	1.25 (1.05, 1.50)	1.08 (0.90, 1.29)
Quintile 3	1.51 (1.26, 1.80)	1.20 (1.00, 1.44)
Quintile 4	1.60 (1.33, 1.94)	1.22 (1.01, 1.48)
Quintile 5	2.07 (1.69, 2.54)	1.42 (1.15, 1.76)
Social deprivation		
Quintile 1	Ref	Ref
Quintile 2	1.13 (0.91, 1.41)	1.11 (0.89, 1.38)
Quintile 3	1.31 (1.07, 1.62)	1.22 (0.99, 1.51)
Quintile 4	1.48 (1.21, 1.82)	1.28 (1.04, 1.58)
Quintile 5	1.92 (1.57, 2.33)	1.52 (1.24, 1.87)
Gentrification		
No	Ref	Ref
Yes	1.19 (1.01, 1.41)	1.13 (0.95, 1.33)
Household security		
Quintile 1	Ref	Ref
Quintile 2	1.18 (0.96, 1.46)	1.23 (0.99, 1.52)
Quintile 3	1.22 (0.99, 1.51)	1.23 (0.99, 1.53)
Quintile 4	1.43 (1.16, 1.76)	1.36 (1.10, 1.68)
Quintile 5	1.55 (1.26, 1.91)	1.30 (1.05, 1.61)
Labor force		
Quintile 1	Ref	Ref
Quintile 2	0.78 (0.64, 0.95)	0.85 (0.69, 1.04)
Quintile 3	0.87 (0.72, 1.05)	0.97 (0.79, 1.18)
Quintile 4	0.82 (0.68, 1.00)	0.94 (0.77, 1.15)
Quintile 5	0.78 (0.64, 0.96)	0.92 (0.74, 1.13)
IVM		
Quintile 1	Ref	Ref
Quintile 2	1.00 (0.81, 1.23)	0.99 (0.80, 1.23)
Quintile 3	1.03 (0.84, 1.26)	1.01 (0.82, 1.23)
Quintile 4	0.89 (0.72, 1.09)	0.87 (0.70, 1.09)
Quintile 5	0.76 (0.60, 0.97)	0.72 (0.56, 0.93)

<https://doi.org/10.1371/journal.pone.0320035.t005>

use and labor force were non-significant in model 2. For IVM, the odds of e-cigarette use were 28% lower (OR =0.72, 95% CI=0.56, 0.93) for participants living in neighborhoods in the fifth quintile of IVM than for participants living in neighborhoods in the first quintile.

Quintile 1 represents least deprived (material and social deprivation), most secure, most employment, and least IVM residents. Model 1 was unadjusted. Model 2 adjusted for age, sex, and region and covariates that differed depending on the neighborhood measure due to stepwise covariate selection. Material deprivation adjusted for health, income and education, social deprivation, household security, labor force and IVM: income and marital status, gentrification: income, education and marital status. Reference is no e-cigarette use. IVM: immigration and visible minority.

Discussion

The current study provides estimates of the prevalence of use of legal substances use among adults (age 30–85) from diverse geographical areas in Canada. Aside from surveys performed by Statistics Canada, there are limited contemporary estimates of the prevalence of cannabis and e-cigarette use in Canada. Data on the prevalence of the use of these substances in a large pan-Canadian adult population is important for surveillance and monitoring. This is also one of the few studies to examine multiple neighborhood-level risk factors for substance use in Canada. Notable findings include robust positive associations between neighborhood material and social deprivation with occasional and daily cigarette smoking, e-cigarette use and frequent cannabis use.

Previous research on neighborhood material and social deprivation and substance use in Canada is relatively scarce and few studies use indicators of deprivation that are comparable to the ones used in the current study. A study in the U.S. found that greater neighborhood socioeconomic disadvantage was associated with a greater likelihood of cigarette smoking [39]. Similarly, another study in the U.S. found that participants living in neighborhoods with high levels of socio-economic disadvantage were more likely to smoke cigarettes [20]. The measures of socioeconomic disadvantage had similarities to the measure of material deprivation used in the current study, with overlapping metrics being the education and income level of neighborhood residents. Research in the U.S. has also found an association between living in neighborhoods with greater social capital, assessed based on individual perceptions of the neighborhood social environment, and less cigarette and alcohol use [20]. This agrees with our findings of greater use of these substances for participants living in more socially deprived neighborhoods. Another study in the U.S. found that neighborhood disadvantage was associated with illicit drug use, which included cannabis use [21]. In a secondary analysis, the previously mentioned study found that the relationship between neighborhood disadvantage and illicit drug use largely acted through individuals' exposure to social stressors and feelings of psychological distress [21].

One plausible explanation for these observed associations between substance use and neighborhood factors draws upon the structural hypothesis [14]. This hypothesis would suggest that health behaviors, in this case substance use behaviors, differ between more and less deprived neighborhoods due to differences in social norms and the built environment [14]. There may be differences in the social environment of neighborhoods with greater material and social deprivation, which could shape the attitudes and beliefs that residents adopt and affect the supports, resources, and information available to residents [40]. Built structures within neighborhoods with greater material and social deprivation could also differ, which may influence how public resources (e.g., community centers, parks, etc.), retail spaces (including those for cigarettes, cannabis, and e-cigarettes), and other institutions and organizations are accessible to neighborhood residents [14]. For example, more cannabis retailers are located in socially deprived neighborhoods (quintiles 4 and 5) than in non-socially deprived neighborhoods in Canada [41]. Although the private sector may also themselves influence the social, physical and cultural environments, also known as commercial determinants of health [42].

Our study found that living in a gentrified neighborhood is associated with higher odds of cigarette, cannabis, and e-cigarette use which is novel within the Canadian context. Qualitative research has found that living in a gentrified neighborhood can impact health by causing housing and financial insecurity, socio-cultural displacement, and a loss of amenities for residents [43]. Those living in gentrified neighborhoods are also more likely to experience psychological stress [43]. These negative effects of gentrification are typically observed in marginalized groups; residents with low-income, racial and ethnic minorities, and older residents [43].

Few previous studies have examined associations between neighborhood household security and health behaviors. One study in the U.S. found that neighborhood residential stability, a measure similar to household security, was not associated with cigarette or alcohol use [20]. A study in Ontario found that neighborhood household security was positively associated with avoidable mortality, which included premature deaths from health conditions linked to substance use [44]. The measure of household security in this study reflects neighborhood cohesion and support using multiple indicators of

household security. It is therefore difficult to make assumptions about what factors may be driving the associations with substance use that were observed in the current study.

Living in a neighborhood with a higher proportion of residents who are recent immigrants and/or visible minorities was associated with lower odds of cigarette, cannabis, and e-cigarette use. Previous research has found that immigrants to Canada have lower levels of alcohol, cigarette, and cannabis use compared to non-immigrants [45]. The findings of this study support the “healthy immigrant effect”, which suggests recent immigrants to Canada have better health than those born in Canada [46]. Using social-interactive theory, it is possible that living in a neighborhood with a higher proportion of immigrants may lead individuals to have greater social contact with people who are not often using substances, resulting in lower substance use behaviors among all neighborhood residents [40]. There is no research on immigrant or visible minority populations and e-cigarette use in Canada. Evidence from the current study suggests that trends of e-cigarette use among recent immigrants to Canada may be similar to those observed for cigarette and cannabis use.

In contrast to the other neighborhood factors, the proportion of residents in a neighborhood participating in the labor force was not associated with cigarette, cannabis, or e-cigarette use. As our study looked at general non-participation in the labor force, it is possible there was no observed association with substance use because of the variety of reasons people may be unemployed. Future research that incorporates different reasons for unemployment into analyses could be important to elucidate the relationship between neighborhood labor force and substance use.

A strength of this study is the large number of individuals from diverse geographical areas in Canada that differ with respect to demographics, population density and structural factors. There is very little research using similar data in Canada and studies from the U.S. tend to focus on select cities or regions. Another strength is the information on a wide range of demographic, lifestyle, and health characteristics for participants. This allowed for consideration of multiple potential confounders in models. The main strength of this study was our ability to connect data on participants’ substance use behaviors to multiple measures of their neighborhood environment. Compared to individual-level risk factors, our understanding of how neighborhood characteristics are associated with substance use behaviors is limited. Multiple studies in Canada have however observed greater mortality risk for individuals living in more materially and socially deprived neighborhoods [47,48], although reasons why were unclear. Findings from the current study suggest that increased substance use could be a potential explanation.

A limitation of this study is the cross-sectional design. Although, it is unlikely that an individual’s substance use patterns would lead them to live in a certain neighborhood [14]. Another limitation is that the CanPath cohort is not representative of the Canadian population. Selection bias could impact the generalizability of our findings. Compared to the Canadian population, our study population contained a higher proportion of females (65.1% vs. 50.3%), was older (mean age of 60 vs 41) and was more likely to be white (93.2% vs. 73.5%) than the general Canadian population [49]. Compared to the 2020 Statistics Canada census, study participants had higher incomes and were more likely to have a bachelor’s degree or higher education [49]. Although, the distribution of BMI was similar (~35% of Canadian adults with overweight BMI vs. 35% in the study population). There was no representation of participants from Saskatchewan, Manitoba, Nunavut, Yukon, or the Northwest Territories in the CanPath study at the time of the follow-up questionnaire. As a result of the demographics of the CanPath study population, the use of cigarettes, cannabis, and e-cigarettes was lower than in the Canadian general population, which may have reduced statistical power and biased findings towards the null. The use of a stepwise approach to select covariates in the models may bias estimates, although it is well suited to the exploratory nature of the analyses and large number of potential variables. Neighborhood measures were generated using 2016 census data and substance use behaviors were reported in the 2016–2018 follow-up questionnaire. The potential disconnect could have resulted in misclassification of participants’ neighborhood environment exposures at the time when they reported on their current substance use patterns, although neighborhoods are considered to be relatively stable over time [30,27]. Neighborhoods were defined using DA boundaries which may not reflect how participants perceive their neighborhood. Studies that consider geospatial

and perceived measures of neighborhood may provide further insight on connections with substance use. The neighborhood measures were also limited to those available in CANUE and linkable to CanPath. As such, measures like neighborhood violence could not be explored in relation to substance use. The numerous analyses examining associations between neighborhood factors and substance use increased the likelihood of spurious associations being found. Statistical approaches to adjust for multiple comparisons through approaches like the Bonferroni correction and the q-value were not performed due to the exploratory nature of the study, particularly with respect to neighborhood-level factors and substance use.

Conclusions

As we provide evidence that neighborhood characteristics are associated with substance use, it follows that interventions aimed at the neighborhood or community level may also be effective for reducing or preventing substance use. Specifically, interventions aimed at reducing or preventing the use of these substances could be directed at individuals living in more materially or socially deprived neighborhoods. The evidence presented in this study could be used to inform policy makers and urban planners in Canada about neighborhood gentrification and potentially inform zoning, or neighborhood development. These findings also provide rational for researchers to conduct further studies on gentrification and health in Canada, ideally research that advances our understanding of the scope of the issue and which groups or regions are most affected. Collectively, the findings could help identifying populations who are at an increased risk of using substances and ensure accessibility of resources.

Supporting information

S1 Fig. Participant sample size for a given neighborhood measure and cigarette use.

(PDF)

S2 Fig. Participant sample size for a given neighborhood measure and cannabis use.

(PDF)

S3 Fig. Participant sample size for a given neighborhood measure and e-cigarette use.

(PDF)

S1 Table. Demographic, lifestyle, and health characteristics for participants who did not smoke (none), smoked cigarettes occasionally or daily.

(PDF)

S2 Table. Demographic, lifestyle, and health characteristics for participants who used cannabis frequently, occasionally, infrequently, or not at all during the past 30 days.

(PDF)

S3 Table. Demographic, lifestyle, and health characteristics for participants who reported using or not using an e-cigarette in the past 30 days.

(PDF)

S4 Table. Descriptive statistics, N (%), for the prevalence of neighborhood factors within levels of cigarette use.

(PDF)

S5 Table. Descriptive statistics, N (%), for the prevalence of neighborhood factors within levels of past 30-day cannabis use.

(PDF)

S6 Table. Descriptive statistics, N (%), for the prevalence of neighborhood factors among participants who did and did not use an e-cigarette in the past 30-days.

(PDF)

Acknowledgments

A version of this work was published as part of TFW's Master's thesis. <https://doi.org/10.14288/1.0442427>. The Canadian Partnership for Tomorrow's Health (CanPath) research is only possible with the commitment of its research participants, its staff, and its funders. The data used in this research were made available by CanPath and BC Generations Project, Alberta's Tomorrow Project, the Ontario Health Study, CARTaGENE, and the Atlantic Partnership for Tomorrow's Health.

Author contributions

Conceptualization: Truman Fraser Wood.

Formal analysis: Truman Fraser Wood.

Funding acquisition: Rachel A. Murphy.

Methodology: Truman Fraser Wood, Rachel A. Murphy.

Resources: Trevor J.B. Dummer, Rachel A. Murphy.

Supervision: Trevor J.B. Dummer, Cheryl E. Peters, Rachel A. Murphy.

Writing – original draft: Truman Fraser Wood, Rachel A Murphy.

Writing – review & editing: Trevor J.B. Dummer, Cheryl E. Peters.

References

1. Canada H. Canadian Alcohol and Drugs Survey (CADS): summary of results for 2019 [Internet]. 2021 [cited 2023 Jul 18]. [Accessed 18 Jul 2023]. <https://www.canada.ca/en/health-canada/services/canadian-alcohol-drugs-survey/2019-summary.html>
2. Canadian Tobacco and Nicotine Survey (CTNS): summary of results for 2021 [Internet]. 2023 [cited 2023 Jul 18]. [Accessed 18 Jul 2023]. <https://www.canada.ca/en/health-canada/services/canadian-tobacco-nicotine-survey/2021-summary.html>
3. Canada H. Federal Tobacco Control Strategy 2001-2011- Horizontal Evaluation [Internet]. 2013 [cited 2023 Aug 9]. [Accessed 9 Aug 2023]. <https://www.canada.ca/en/health-canada/corporate/about-health-canada/accountability-performance-financial-reporting/evaluation-reports/federal-tobacco-control-strategy-2001-2011-horizontal-evaluation.html>
4. Government of Canada SC. Cigarette production, sales, smoking rates trending down [Internet]. 2023 [cited 2023 Aug 9]. [Accessed 9 Aug 2023]. <https://www.statcan.gc.ca/o1/en/plus/3230-cigarette-production-sales-smoking-rates-trending-down>
5. Chaiton M, Callard C. Mind the Gap: Disparities in Cigarette Smoking in Canada. *Tob Use Insights*. 2019;12:1179173X19839058. <https://doi.org/10.1177/1179173X19839058> PMID: 30944522
6. Government of Canada SC. Looking back from 2020, how cannabis use and related behaviours changed in Canada [Internet]. 2021 [cited 2023 Aug 9]. [Accessed 9 Aug 2023]. <https://www150.statcan.gc.ca/n1/pub/82-003-x/2021004/article/00001-eng.htm>
7. Canada H. Canadian Cannabis Survey 2020: Summary [Internet]. 2020 [cited 2022 Nov 6]. [Accessed 6 Nov 2022]. <https://www.canada.ca/en/health-canada/services/drugs-medication/cannabis/research-data/canadian-cannabis-survey-2020-summary.html>
8. Canada H. Tobacco and premature death [Internet]. 2011 [cited 2023 Aug 9]. [Accessed 9 Aug 2023]. <https://www.canada.ca/en/health-canada/services/health-concerns/tobacco/legislation/tobacco-product-labelling/smoking-mortality.html>
9. Dai X, Gil GF, Reitsma MB, Ahmad NS, Anderson JA, Bisignano C, et al. Health effects associated with smoking: a Burden of Proof study. *Nat Med*. 2022;28(10):2045–55. <https://doi.org/10.1038/s41591-022-01978-x> PMID: 36216941
10. Brenner DR, Weir HK, Demers AA, Ellison LF, Louzado C, Shaw A, et al. Projected estimates of cancer in Canada in 2020. *CMAJ*. 2020;192(9):E199–205. <https://doi.org/10.1503/cmaj.191292> PMID: 32122974
11. Page RL 2nd, Allen LA, Kloner RA, Carricker CR, Martel C, Morris AA, et al. Medical Marijuana, Recreational Cannabis, and Cardiovascular Health: A Scientific Statement From the American Heart Association. *Circulation*. 2020;142(10):e131–52. <https://doi.org/10.1161/CIR.0000000000000883> PMID: 32752884
12. Golden SD, McLeroy KR, Green LW, Earp JAL, Lieberman LD. Upending the social ecological model to guide health promotion efforts toward policy and environmental change. *Health Educ Behav*. 2015;42(1 Suppl):8S-14S. <https://doi.org/10.1177/1090198115575098> PMID: 25829123

13. Sudhinaraset M, Wigglesworth C, Takeuchi DT. Social and cultural contexts of alcohol use. *Alcohol Res.* 2016;38:35–45.
14. Stimpson JP, Ju H, Raji MA, Eschbach K. Neighborhood deprivation and health risk behaviors in NHANES III. *Am J Health Behav.* 2007;31(2):215–22. <https://doi.org/10.5555/ajhb.2007.31.2.215> PMID: 17269911
15. Steptoe A, Feldman PJ. Neighborhood problems as sources of chronic stress: development of a measure of neighborhood problems, and associations with socioeconomic status and health. *Ann Behav Med.* 2001;23(3):177–85. https://doi.org/10.1207/S15324796ABM2303_5 PMID: 11495218
16. Arbour-Nicitopoulos KP, Kwan MYW, Lowe D, Taman S, Faulkner GEJ. Social norms of alcohol, smoking, and marijuana use within a Canadian university setting. *J Am Coll Health.* 2010;59(3):191–6. <https://doi.org/10.1080/07448481.2010.502194> PMID: 21186449
17. Merrill JE, Thomas SE. Interactions between adaptive coping and drinking to cope in predicting naturalistic drinking and drinking following a lab-based psychosocial stressor. *Addictive Behaviors.* 2013;38(3):1672–8. <https://doi.org/10.1016/j.addbeh.2012.10.003>
18. Wiley ER, Stranges S, Gilliland JA, Anderson KK, Seabrook JA. Residential greenness and substance use among youth and young adults: Associations with alcohol, tobacco, and marijuana use. *Environ Res.* 2022;212(Pt A):113124. <https://doi.org/10.1016/j.envres.2022.113124> PMID: 35339465
19. Auchincloss AH, Niamatullah S, Adams M, Melly SJ, Li J, Lazo M. Alcohol outlets and alcohol consumption in changing environments: prevalence and changes over time. *Subst Abuse Treat Prev Policy.* 2022;17(1):7. <https://doi.org/10.1186/s13011-021-00430-6> PMID: 35120532
20. Carpiano RM. Neighborhood social capital and adult health: an empirical test of a Bourdieu-based model. *Health Place.* 2007;13(3):639–55. <https://doi.org/10.1016/j.healthplace.2006.09.001> PMID: 17084655
21. Boardman JD, Finch BK, Ellison CG, Williams DR, Jackson JS. Neighborhood Disadvantage, Stress, and Drug Use among Adults. *Journal of Health and Social Behavior.* 2001;42(2):151. <https://doi.org/10.2307/3090175>
22. Cunningham JK, Saleh AA. Structural Stigma, Racism, and Sexism Studies on Substance Use and Mental Health: A Review of Measures and Designs. *Alcohol Res.* 2024;44(1):08. <https://doi.org/10.35946/arcr.v44.1.08> PMID: 39713741
23. Simha A, Ahmed S, Prasad R, Dinesh AS, Kandasamy A, Rao NP. Effect of national cultural dimensions and consumption rates on stigma toward alcohol and substance use disorders. *Int J Soc Psychiatry.* 2022;68(7):1411–7. <https://doi.org/10.1177/00207640211028611> PMID: 34213385
24. Rushovich T, Arwady MA, Salisbury-Afshar E, Arunkumar P, Aks S, Prachand N. Opioid-related overdose deaths by race and neighborhood economic hardship in Chicago. *J Ethn Subst Abuse.* 2022;21(1):22–35. <https://doi.org/10.1080/15332640.2019.1704335> PMID: 31990245
25. Stokes EK, Pickens CM, Wilt G, Liu S, David F. County-level social vulnerability and nonfatal drug overdose emergency department visits and hospitalizations, January 2018–December 2020. *Drug Alcohol Depend.* 2023;247:109889. <https://doi.org/10.1016/j.drugalcdep.2023.109889> PMID: 37148633
26. Dummer TJB, Awadalla P, Boileau C, Craig C, Fortier I, Goel V, et al. The Canadian Partnership for Tomorrow Project: a pan-Canadian platform for research on chronic disease prevention. *CMAJ.* 2018;190(23):E710–7. <https://doi.org/10.1503/cmaj.170292> PMID: 29891475
27. Brook JR, Setton EM, Seed E, Shooshtari M, Doiron D, CANUE – The Canadian Urban Environmental Health Research Consortium. The Canadian Urban Environmental Health Research Consortium - a protocol for building a national environmental exposure data platform for integrated analyses of urban form and health. *BMC Public Health.* 2018;18(1):114. <https://doi.org/10.1186/s12889-017-5001-5> PMID: 29310629
28. Government of Canada SC. Dictionary, Census of Population, 2021 – Dissemination area (DA) [Internet]. 2021 [cited 2024 Feb 20]. [Accessed 20 Feb 2024]. <https://www12.statcan.gc.ca/census-recensement/2021/ref/dict/az/Definition-eng.cfm?ID=geo021>
29. Canada S. Guide to the Census of Population, 2021, Chapter 9 – Data quality evaluation [Internet]. [cited 2024 Mar 5]. [Accessed 5 Mar 2024]. <https://www12.statcan.gc.ca/census-recensement/2021/ref/98-304/2021001/chap9-eng.cfm>
30. Pampalon R, Hamel D, Gamache P, Philibert MD, Raymond G, Simpson A. An area-based material and social deprivation index for public health in Québec and Canada. *Can J Public Health.* 2012;103(8 Suppl 2):S17–22. <https://doi.org/10.1007/BF03403824> PMID: 23618066
31. Firth CL, Thierry B, Fuller D, Winters M, Kestens Y. Gentrification, Urban Interventions and Equity (GENUINE): A map-based gentrification tool for Canadian metropolitan areas. *Health Rep.* 2021;32(5):15–28. <https://doi.org/10.25318/82-003-x20210050002-eng> PMID: 34008929
32. Matheson FI, Dunn JR, Smith KLW, Moineddin R, Glazier RH. Development of the Canadian Marginalization Index: a new tool for the study of inequality. *Can J Public Health.* 2012;103(8 Suppl 2):S12–6. <https://doi.org/10.1007/BF03403823> PMID: 23618065
33. National Academies of Sciences E, Division H and M, Practice B on PH and PH, Agenda C on the HE of MAER and R. Cannabis: Prevalence of Use, Regulation, and Current Policy Landscape. The Health Effects of Cannabis and Cannabinoids: The Current State of Evidence and Recommendations for Research [Internet]. National Academies Press (US); 2017 [cited 2023 Nov 21]. [Accessed 21 Nov 2023]. <https://www.ncbi.nlm.nih.gov/books/NBK425763/>
34. Cerdá M, Mauro C, Hamilton A, Levy NS, Santaella-Tenorio J, Hasin D, et al. Association Between Recreational Marijuana Legalization in the United States and Changes in Marijuana Use and Cannabis Use Disorder From 2008 to 2016. *JAMA Psychiatry.* 2020;77(2):165–71. <https://doi.org/10.1001/jamapsychiatry.2019.3254> PMID: 31722000
35. Gilham K, Gu Q, Dummer TJB, Spinelli JJ, Murphy RA. Diet Quality and Neighborhood Environment in the Atlantic Partnership for Tomorrow's Health Project. *Nutrients.* 2020;12(10):3217. <https://doi.org/10.3390/nu12103217> PMID: 33096731
36. Gu Q, Dummer TBJ, Spinelli JJ, Murphy RA. Diet Quality among Cancer Survivors and Participants without Cancer: A Population-Based, Cross-Sectional Study in the Atlantic Partnership for Tomorrow's Health Project. *Nutrients.* 2019;11(12):3027. <https://doi.org/10.3390/nu11123027> PMID: 31835839

37. Craig CL, Marshall AL, Sjöström M, Bauman AE, Booth ML, Ainsworth BE, et al. International physical activity questionnaire: 12-country reliability and validity. *Med Sci Sports Exerc.* 2003;35(8):1381–95. <https://doi.org/10.1249/01.MSS.0000078924.61453.FB> PMID: 12900694
38. R Core Team. R: A language and environment for statistical computing. Vienna, Austria: R Foundation for Statistical Computing; 2023.
39. Walter AW, Lee J-W, Streck JM, Gareen IF, Herman BA, Kircher SM, et al. The effect of neighborhood socioeconomic disadvantage on smoking status, quit attempts, and receipt of cessation support among adults with cancer: Results from nine ECOG-ACRIN Cancer Research Group trials. *Cancer.* 2024;130(3):439–52. <https://doi.org/10.1002/cncr.35039> PMID: 37795845
40. Miltenburg EM. The Conditionality of Neighbourhood Effects upon Social Neighbourhood Embeddedness: A Critical Examination of the Resources and Socialisation Mechanisms. *Housing Studies.* 2015;30(2):272–94. <https://doi.org/10.1080/02673037.2014.995071>
41. Fataar F, Driezen P, Owusu-Bempah A, Hammond D. Distribution of legal retail cannabis stores in Canada by neighbourhood deprivation. *J Cannabis Res.* 2024;6(1):5. <https://doi.org/10.1186/s42238-023-00211-x> PMID: 38351142
42. Gilmore AB, Fabbri A, Baum F, Bertscher A, Bondy K, Chang H-J, et al. Defining and conceptualising the commercial determinants of health. *Lancet.* 2023;401(10383):1194–213. [https://doi.org/10.1016/S0140-6736\(23\)00013-2](https://doi.org/10.1016/S0140-6736(23)00013-2) PMID: 36966782
43. Anguelovski I, Cole HVS, O'Neill E, Baró F, Kotsila P, Sekulova F, et al. Gentrification pathways and their health impacts on historically marginalized residents in Europe and North America: Global qualitative evidence from 14 cities. *Health Place.* 2021;72:102698. <https://doi.org/10.1016/j.healthplace.2021.102698> PMID: 34717079
44. Zygmunt A, Tanuseputro P, James P, Lima I, Tuna M, Kendall CE. Neighbourhood-level marginalization and avoidable mortality in Ontario, Canada: a population-based study. *Can J Public Health.* 2020;111(2):169–81. <https://doi.org/10.17269/s41997-019-00270-9> PMID: 31828730
45. Ru S, Li Y. Differences in Substance Use Among Immigrants and the Canadian-Born Population. *Can Stud Popul.* 2021;48(2–3):335–59. <https://doi.org/10.1007/s42650-021-00047-x>
46. McDonald JT, Kennedy S. Insights into the “healthy immigrant effect”: health status and health service use of immigrants to Canada. *Soc Sci Med.* 2004;59(8):1613–27. <https://doi.org/10.1016/j.socscimed.2004.02.004> PMID: 15279920
47. Saint-Jacques N, Dewar R, Cui Y, Parker L, Dummer TJ. Premature mortality due to social and material deprivation in Nova Scotia, Canada. *Int J Equity Health.* 2014;13(1):94. <https://doi.org/10.1186/s12939-014-0094-2> PMID: 25344438
48. Ross NA, Oliver LN, Villeneuve PJ. The contribution of neighbourhood material and social deprivation to survival: a 22-year follow-up of more than 500,000 Canadians. *Int J Environ Res Public Health.* 2013;10(4):1378–91. <https://doi.org/10.3390/ijerph10041378> PMID: 23549228
49. Government of Canada SC. Census Profile, 2021 Census of Population [Internet]. 2022 [cited 2024 Feb 7]. [Accessed 7 Feb 2024]. <https://www12.statcan.gc.ca/census-recensement/2021/dp-pd/prof/index.cfm?Lang=E>