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Original quantitative research

Analysis of the geographical accessibility of vape shops in the vicinity of Quebec's secondary and college educational institutions

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Abstract

Introduction: A significant proportion of secondary school students and young adults in Quebec have experimented with electronic cigarettes (e-cigarettes). Both personal and environmental factors have been associated with the use of vaping products by youth. Geographical accessibility to the points of sale of these products may be one of these factors. The purpose of this study is to develop a profile of the spatial distribution of stores specializing in the sale of vaping products (vape shops) in the vicinity of secondary schools, colleges and CEGEPs in the province of Quebec.

Methods: We calculated the accessibility of businesses to account for geographical exposure. Analyses were conducted to provide a snapshot of the situation in Quebec and to identify associations between the characteristics of educational institutions and geographical accessibility to vape shops.

Results: A total of 299 vape shops were identified. Colleges are closer to a vape shop (median distance: 1.2 km) than are secondary schools (median distance: 2.3 km). Large private colleges located in urban areas are closer to specialized vape shops. Medium or large private secondary schools located in urban and more advantaged areas are also closer to a specialized vape shop.

Conclusion: This study is a step in developing an understanding of the location of vaping product shops and their geographical accessibility to young people. Important to consider is the geographical accessibility of young people to non-specialized shops that also sell e-cigarettes and then any potential connections between geographical accessibility to such non-specialized shops and the use of vaping products by young people.

Keywords: *electronic cigarette, e-cigarette, vaping, Geographic Information System (GIS), school, adolescents, young adults*

Introduction

Experimentation with electronic cigarettes (e-cigarettes) is widespread among secondary school students and young adults in Quebec. In 2014–2015, 27% of secondary school students in Quebec reported having used e-cigarettes in their lifetime, a proportion higher than in Canada overall (15% of students), and 8% reported having

used them within the last 30 days.¹ The same trends were observed in 2016–2017.² Of all the 18–24 year olds in Quebec in 2015, 32% had used e-cigarettes in their lifetime and 8% had used them recently.¹ Moreover, while the regular use of e-cigarettes among non-smoking adults over 35 years of age is a marginal phenomenon, a significant proportion of non-smokers among secondary school students use

Highlights

- In Quebec, we identified 299 points of sale specializing in vaping products (vape shops).
- Colleges are closer to a vape shop (median distance: 1.2 km) than secondary schools (median distance: 2.3 km).
- Area deprivation was not associated with the access to points of sale near college-level institutions.
- Quebec students attending private educational institutions, both college and secondary schools, and institutions located in urban areas have greater geographical accessibility to shops specializing in vaping products.

this product.¹ Recent longitudinal studies suggest that e-cigarette use among non-smoking youth may be an additional risk factor for smoking initiation.^{3–6}

Both personal and environmental factors have been associated with the use of vaping products by young people.⁷ Some studies suggest that, like tobacco products, geographical accessibility to the point of sale of these products may be one of the factors associated with their use. Access to as well as visibility of tobacco products through points of sale have been associated with their use among youth.^{8,9} Some American studies suggest that the same could be true for vaping products.^{10–12} Recent scientific investigations have focused

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on improving understanding of the spatial distribution of points of sale for vaping products in the USA,^{13,14} particularly in the vicinity of educational institutions.^{10-12,15,16}

Two US studies examined the impact of the geographical accessibility of the points of sale of vaping products on their use. One of these studies included shops specializing in the sale of vaping products alone (vape shops),^{10,11} while the other included both vape shops and tobacco outlets that also sell e-cigarettes.¹² The results of these analyses indicate a positive association between greater availability in shops selling vaping products that are near schools and the use of these products by students.

In Quebec as well as the rest of Canada, e-cigarettes are sold both in some non-specialized shops (such as convenience stores and gas stations) and in specialized shops (vape shops). In Quebec, points of sale specializing in vaping products, which are not accessible to minors, are authorized to display their products only indoors. However, since these shops remain visible from the outside, frequent exposure to them could provide an incentive for young people to use vaping products, for instance by increasing the perception of the accessibility of these products, a factor associated with e-cigarette use among secondary school students in Canada.¹⁷ Little data is currently available to capture this exposure in Quebec. Quebec organizations involved in tobacco control and public health have already mentioned the lack of valid information on the location of e-cigarette points of sale.^{18,19}

An analysis of the spatial distribution of specialized vape shops that are in the vicinity of Quebec educational institutions (secondary schools and colleges / CEGEPs*) will provide a better understanding of the geographical exposure of young people and young adults to the places where these products are sold. It will represent a first step in the development of knowledge on the geographical accessibility of young people to shops selling vaping products and the potential impact of this accessibility on the use of these products. Our article presents part of this analysis, which will be published in its entirety and

available on the Institut national de santé publique du Québec website.²⁰

Documenting the presence of specialized vape shops that are in the vicinity of secondary schools is important, as the school is the public place most frequented by adolescents. Colleges and CEGEPs are also attended by a significant proportion of minors, and the young adults who study there are also a priority for prevention of tobacco use in Quebec.²¹ Since November 2017, these post-secondary institutions have been required to have adopted a policy aimed at creating smoke-free environments.

Methods

Two steps were necessary to draw a portrait of geographical accessibility to specialized vaping product stores near educational institutions in Quebec: the development of a georeferenced directory of specialized vaping product shops in Quebec and of a georeferenced directory of educational institutions.

Directory of points of sale

Two main data sources were used to create the Quebec directory of stores specializing in vaping products: a list of stores from the Ministère de la Santé et des Services sociaux (MSSS) and a list based on an online search of business directories (via Yelp and Google). Figure 1 illustrates this process.

The list of 414 specialized vape shops supplied by the MSSS includes those that, after the adoption in 2015 of the province's *Tobacco Control Act*, applied to continue displaying their products inside their place of business, as permitted by the Act for establishments meeting certain criteria.²² As this list is not updated regularly, we verified whether the 414 vaping specialty shops were still in business using various online tools (Google Street View, Google, Yelp, Yellow Pages, Facebook, the online search tool of the Registraire des entreprises). In doing so, we reduced the list to 281 stores currently selling vaping products alone (Figure 1).

In the meantime, we conducted an online search to identify specialized vape shops open in Quebec at the time of our study (details of online search available on

request), via the Yelp (www.yelp.ca) and Google (www.google.ca) search engines. This methodology is based on the fact that government lists of the shops selling vaping products are rarely up-to-date.^{10,13,16,23} We obtained a list of 278 shops (Figure 1).

We merged these two lists (the MSSS and online search engine lists) and completed a final check of all 365 businesses found using the Google Street View online search engine and the Quebec Registraire des entreprises tool for some businesses, and telephone calls or a field visit for others (Figure 1). This data collection and verification process made it possible to identify 299 Quebec-based points of sale specialized exclusively in selling vaping products at the time of our study. These businesses were then geolocated using the Addresses Quebec website (<http://adressesquebec.gouv.qc.ca/index.asp>; n = 273) via their respective address or using Google Earth (<https://www.google.com/earth/>; n = 26).

Directory of institutions

For this analysis, we used files developed by the Ministère de l'éducation et de l'enseignement supérieur (Quebec Department of Education and Higher Education, MEES) that give the location of educational institutions in the Quebec school system to draw up lists of the secondary and college-level educational institutions.

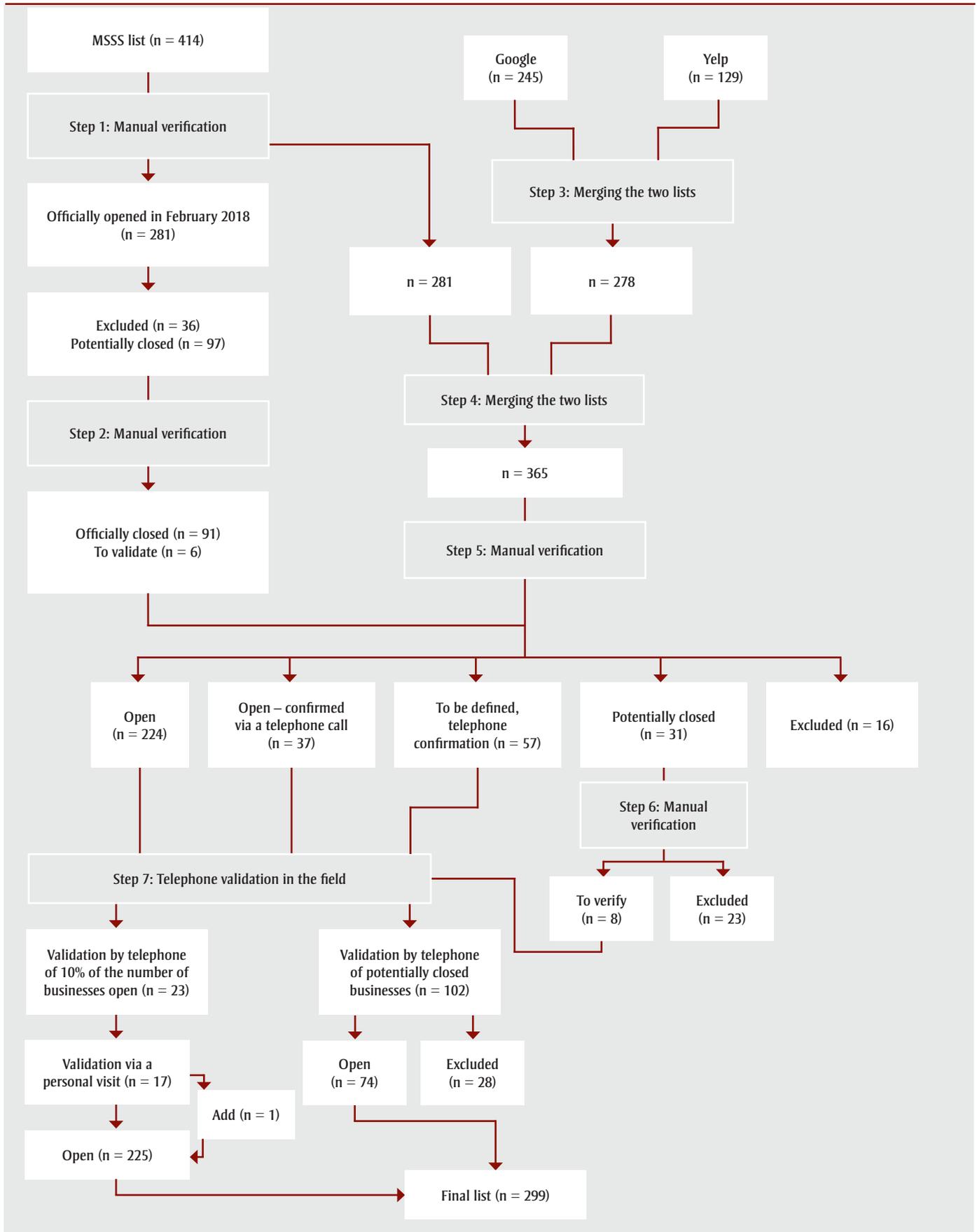
The MEES list of colleges obtained from the Quebec government's open data website identified 170 colleges at the time of this study, while the list of secondary schools includes 729 schools that were geolocated using their geographic coordinates (provided in the MEES list).

Institutional characteristics

In addition to the level of education (college or secondary school), we used two institutional characteristics in our analyses: the educational system (private or public) and the size of the student population. We also took into account the characteristics of the location of the institutions, namely the level of deprivation of the area in which the institutions are located as well as the rural or urban nature of the region.

* General and vocational college.

FIGURE 1
Steps in building the Quebec directory of points of sale specializing in vaping products



Institutions were broken down into four categories based on the size of their student population: very small, small, medium and large.

Each educational institution was assigned a dissemination area identifier based on its location. We linked this information to a material deprivation index used in public health surveillance.²⁴ This index is composed of indicators from Statistics Canada's 2011 National Household Survey: the proportion of people aged 15 and over without a secondary school certificate or diploma; the proportion of people aged 15 and over who are employed; and the average income of people aged 15 and over. We assigned a quintile from the material deprivation index²⁴ to the area in which each educational institution was located. We then divided the institutions into those in advantaged environments (quintiles 1, 2 and 3) and those in disadvantaged environments (quintiles 4 and 5).

We defined the rural or urban character of the area in which the institution was located based on whether it is located within or outside a population centre.[†]

Dependent variable

The dependent variable is a measure of geographical accessibility, that is, proximity to points of sale,²⁶ and corresponds to the distance (in metres) from an establishment to the nearest vape shop. This distance was calculated on the basis of the road network, using ArcGIS software version 10.5.1 (Esri Canada, Toronto, ON).

Statistical analyses

First, we conducted descriptive analyses in order to obtain the distribution of the variable of interest (distance in metres to the nearest shop) according to the various variables related to the characteristics of the educational institutions and their location. Subsequently, univariate and multivariate generalized linear models were used to measure the associations between the distance to the nearest shop and the characteristics of the institutions. Schools with missing data were excluded from the analysis of generalized linear models in order to use the same samples for model construction.

These statistical analyses were intended to identify associations to extract the type of institution and the category of student population, as these students are more exposed to the presence of a specialized shop near their educational institution.²⁷ We used a bottom-up step selection starting from an empty model and adding independent variables. Using the Akaike Information Criterion (AIC), we were able to select the model that best explained the data.²⁸ We used a logarithmic function to correct the asymmetry in the distribution of the dependent variable and reduce the weight dedicated to extreme values in the estimate of the parameters of the regression models. Multivariate statistical analyses were performed with SPSS version 19 (IBM, Chicago, IL, USA).

Results

This study identified 299 points of sale specializing exclusively in vaping products distributed across Quebec (Figure 2).

For the entire province of Quebec, the median distance of secondary schools to the nearest specialized vape shop is 2278 m (Table 1). More precisely, the median distance is 1993 m for private institutions and 2454 m for public institutions. The shortest median distance to the nearest shop is for educational institutions in advantaged areas (1979 m).

For the entire province of Quebec, the median distance of secondary schools to the nearest specialized point of sale is 1231 m (Table 2), specifically 1001 m for private educational institutions and 1381 m for public educational institutions. The median distance to the nearest shop is lower for educational institutions located in more advantaged areas (1231 m).

Distance to points of sale is treated as a continuous variable in a generalized linear regression model. Medium-sized (versus very small) and large (versus very small) educational institutions as well as urban (versus rural) institutions tend to have a specialized vape shop located closer. Private (versus public) educational institutions, as well as those located in disadvantaged (versus advantaged) areas, are geographically more distant from a vaping product shop (Table 3).

Public (versus private), small (versus very small) and medium-sized (versus very small) college institutions are significantly more geographically distant from a vaping product shop. Institutions located in rural areas are significantly further from a vape shop than urban institutions (Table 4).

Discussion

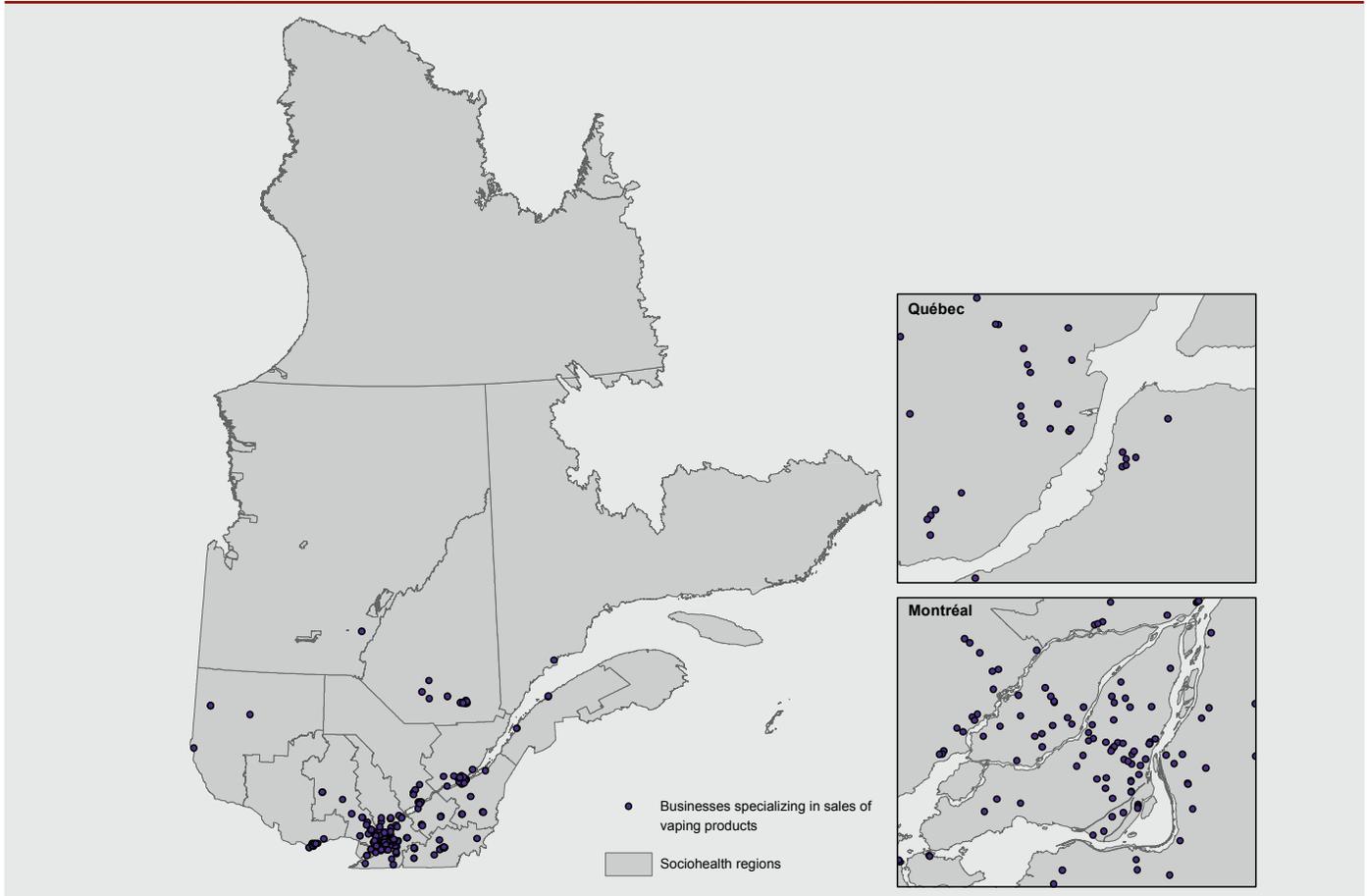
First, our study sought to build a georeferenced directory of specialized vape stores in Quebec, so that we could link them to educational institutions. We found that 299 businesses exclusively selling vaping products were open in Quebec in early 2018. Although a detailed analysis of the evolution of the presence of specialized shops in Quebec was beyond the scope of our study, the development and validation of our database leads us to believe that the number of this type of shop could be decreasing. The MSSS list compiled in 2015, which was used to build our directory, contained 414 businesses, while our final directory contains 299. A decrease in this type of business has been observed elsewhere, particularly in France.²⁹ The tightening of the legal framework and the decline of vaping as a fashion trend could be two factors that might explain this decline.

The main objective of our study was to examine, according to various characteristics, the geographical accessibility of specialized vape shops in Quebec that are in the vicinity of educational institutions. This analysis revealed that, in Quebec, colleges had greater accessibility to such specialized shops than did secondary schools. The same situation was observed in the USA: no specialized shop was found within 800 m of secondary schools in New Jersey,¹³ while 30% of all colleges across the USA were located within 1.6 km of a vape shop.¹⁶ However, the situation appears to vary across the USA: a study in California found that 28% of secondary schools had such a vape shop within an 800 m radius.¹⁰

A variety of reasons may explain why colleges and CEGEPs in Quebec tend to have greater geographical accessibility to this type of business. One explanation is that college campuses are generally located in more densely populated areas or urban agglomerations, which makes them more likely to be located near any business.

[†] "A population centre [is] an area with a population of at least 1,000 and a density of 400 or more persons per square kilometre. All areas outside population centres [are] defined as rural areas."²⁵

FIGURE 2
Spatial distribution of the 299 businesses specializing in the sale of vaping products in Quebec



Sources: MSSS, 2017; Yelp, 2018; Google, 2018. Compilation: INSPQ, 2018.

Our analysis also showed that more educational institutions in urban areas than in rural areas are located near specialized vape shops in Quebec. The same situation

has been observed in the United States. According to a study conducted across the USA, there is a greater availability of specialized vape shops in urban census areas

(0.47 average availability) than in rural areas (0.23 average availability).¹⁴ According to another US study, greater proximity to speciality shops is associated with urban areas: median distance from the nearest shop is 1.1 miles in the city; 1.9 miles in the suburbs; 6.3 miles in a smaller town or village; and 7.9 miles in rural areas).¹⁶

TABLE 1
Number, median distance, mean and standard deviation at the nearest point of sale, according to the characteristics of the secondary institution and its location

Secondary schools	Number	Median distance (m)	Mean distance (m)	Standard deviation
Characteristics				
Private institution	169	1 993	5 452	19 051
Public institution	543	2 454	47 591	145 594
Very small (1–115 students)	164	3 380	89 307	218 183
Small (118–429 students)	172	3 036	42 601	103 782
Medium (431–863 students)	177	2 054	19 609	84 505
Large (868–2540 students)	176	1 970	6 506	35 341
Environment				
Advantaged area	442	1 979	20 081	87 599
Disadvantaged area	270	3 711	66 249	172 858
Urban	578	1 914	15 219	60 705
Rural	134	33 492	134 076	247 027
Combined	712	2 278	37 589	128 712

Our study revealed that private educational institutions are located closer to specialized vape shops in Quebec. This situation was also observed in the USA: vape shops were more likely to be closer to private colleges (2.6 km for median proximity) than public ones (3.2 km for median proximity). The authors suggested that one of the reasons is that this type of trade potentially targets populations that are more socioeconomically advantaged and therefore more likely to attend private schools.¹⁶

One of the objectives of our analysis was to examine the proximity of specialized vape shops to educational institutions

TABLE 2
Number, median distance, mean and standard deviation at the nearest point of sale, according to the characteristics of the college and its location

College	Number	Median distance (m)	Mean distance (m)	Standard deviation
Characteristics				
Private institution	78	1 001	2 033	2 695
Public institution	92	1 381	30 624	98 290
Very small (5–106 students)	37	942	1 406	1 261
Small (107–497 students)	36	927	47 375	138 623
Medium (502–1930 students)	37	1 750	27 180	70 820
Large (1944–11 062 students)	36	1 122	1 236	685
Environment				
Advantaged area	102	1 231	12 326	44 607
Disadvantaged area	47	1 750	36 101	122 346
Urban	152	1 077	12 100	48 727
Rural	18	7 104	63 154	173 837
Combined	170	1 231	17 506	73 549

according to the level of material deprivation of the area. Our analysis revealed that vape stores are closer to secondary schools in advantaged areas, but area deprivation was not associated with accessibility to points of sale in conjunction with colleges.

A similar situation exists in the USA. A study conducted in New Jersey, USA, showed that neighbourhoods with an average median household income—as opposed to the lowest—were more likely to be associated with a higher number of specialized vape shops.¹³ In another study

conducted in New Jersey, USA,³⁰ more shops (specialized and non-specialized) selling e-cigarettes were identified near schools with fewer students eligible for free school meals than near less advantaged schools.

Some researchers have hypothesized that this type of business potentially targets populations that are more socioeconomically advantaged and yet still have high proportions of smokers.¹⁶ In fact, the e-cigarette, especially the starting device, is more expensive than tobacco and therefore requires, to a certain extent, more resources. As we have seen, more private educational institutions are located near such shops in Quebec, probably also because a more affluent clientele attends these schools.

It is important to note, however, that across the USA there appears to be a greater availability of specialized vape shops in both urban and rural census areas where fewer people own their own homes, an indicator of lesser socioeconomic advantage. Similarly, the availability of specialized vape stores would be expected to be more prevalent in areas where fewer people have a level of education equal to or higher than college level; however, the associations between the proportion of people living below the poverty line in an area and the availability of vape shops were not significant.¹⁴

TABLE 3
Generalized linear regression model: distance from the 689 secondary schools in Quebec to the nearest specialized shop selling vaping products

Log (distance to the nearest point of sale ^a , in meters)	Univariate model		Final multivariate model	
	B ^a	95% CI	B ^a	95% CI
Intercepted			4.49***	4.35 to 4.64
Characteristics				
Private institution	Ref.	–	Ref.	–
Public institution	0.34***	0.21 to 0.47	0.23***	0.11 to 0.34
Very small	Ref.	–	Ref.	–
Small	–0.10	–0.25 to –0.07	–0.00	–0.13 to 0.13
Medium	–0.43***	–0.59 to –0.27	–0.25***	–0.38 to –0.11
Large	–0.59***	–0.75 to –0.43	–0.36***	–0.50 to –0.28
Environment				
Urban	Ref.	–	Ref.	–
Rural	–1.1***	–1.21 to –0.97	–0.92***	–1.04 to –0.79
Advantaged area	Ref.	–	Ref.	–
Disadvantaged area	0.46***	0.35 to 0.57	0.21***	0.11 to 0.31

Abbreviations: CI, confidence interval; ref., reference.

^a Distance (in metres) from the educational institution to the nearest point of sale. B is the regression coefficient in the multivariate analysis. A high positive coefficient is related to an increase in the log (distance) of the point of sale closest to the educational institution. A negative coefficient is related to a decrease in the log (distance) of the point of sale closest to the educational institution.

* $p < 0.05$.

** $p < 0.01$.

*** $p < 0.001$.

Strengths and limitations

To our knowledge, this is one of the only profiles of the spatial distribution of businesses specializing in the sale of vaping products in Quebec and Canada. The presence of specialized vape shops in the study area was carefully validated (by phone, in person and through the use of various databases). We included several types of schools (private and public, secondary schools and colleges), with variable enrolment. We also took into account the characteristics of the location of these institutions, namely the types of environment (urban or rural, disadvantaged or advantaged). From this point of view, there seems to be an interaction between the urban or rural character and the type of education (private or public), and between the type of education and level of deprivation. Such analysis is beyond the scope of this article, and further research is recommended.

TABLE 4
Generalized linear regression model: distance from the 126 colleges in Quebec to the nearest specialized shop selling vaping products

Log (distance to the nearest point of sale ^a , in meters)	Univariate model		Final multivariate model	
	B ^a	95% CI	B ^a	95% CI
Intercepted			3.50***	3.07 to 3.93
Characteristics				
Private institution	Ref.	–	Ref.	–
Public institution	0.48***	0.22 to 0.74	0.51***	0.26 to 0.75
Very small	Ref.	–	Ref.	–
Small	0.42*	0.06 to 0.77	0.27	–0.01 to 0.56
Medium	0.52**	0.17 to 0.88	0.20	–0.10 to 0.51
Large	–0.22	–0.38 to 0.34	–0.31	–0.64 to 0.02
Location				
Urban	Ref.	–	Ref.	–
Rural	–0.86***	–1.30 to –0.42	–0.66***	–1.04 to –0.27
Advantaged area	Ref.	–	N/A	N/A
Disadvantaged area	0.19	–0.09 to 0.47	N/A	N/A

Abbreviations: CI, confidence interval; ref., reference.

^a Distance (in metres) from the educational institution to the nearest point of sale. B is the regression coefficient in the multivariate analysis. A high positive coefficient is related to an increase in the log (distance) of the point of sale closest to the educational institution. A negative coefficient is related to a decrease in the log (distance) of the point of sale closest to the educational institution.

* $p < 0.05$.

** $p < 0.01$.

*** $p < 0.001$.

Some limitations should also be mentioned. Specialist vape shops are only a part of e-cigarette business in Quebec: vaping products are also available in other stores, in particular, in convenience stores, tobacconists and gas stations. Unlike specialized vape shops, minors can enter these places, although they cannot legally buy e-cigarettes; and like tobacco products, vaping products must not be visible to customers. Since not all of these businesses sell vaping products, a field visit would have been necessary to identify them, which was beyond the scope of our analysis. Thus, our profile underestimates the true geographical accessibility of points of sale for vaping products to young people near schools.

It would be relevant to continue this analysis to include these points of sale, not least because research in the USA has shown that they are present near schools.^{12,15} Moreover, the geographical accessibility of young people to the points of sale of various products (including tobacco and vaping products) can be defined differently from schools: near places of residence or near other places that youth frequent (e.g. sports, cultural

and recreational centres). In fact, it is increasingly recognized that research must also include several of these places simultaneously.³¹ Considering only accessibility near schools means that only a portion of the geographical accessibility of young people to the points of sale of these products is taken into account, even if the school is the public place most frequented by young people over the longest period. It would therefore be appropriate to expand on this research given that studies have shown that young people's accessibility to tobacco sales outlets in the vicinity of their homes is associated with the consumption of these products.³² Our analysis was not intended to examine the use of vaping products by young Quebecers based on the geographical accessibility of specialized vape shops that are near educational institutions.

Conclusion

Experimentation with e-cigarettes is widespread among young adults in Quebec and among many secondary school students. The factors associated with the use of vaping devices by youth are currently the subject of scientific research. It is

possible that geographical accessibility to shops selling these products may be one of these factors, as is the case for tobacco products. As these factors are still largely unknown in Quebec, we have undertaken to provide a snapshot of the geographical accessibility of points of sale specializing in vaping products that are in the vicinity of educational institutions.

Our analysis suggests that specialized vape shops are more easily accessible to students attending college than secondary school. They also appear to be more accessible to students attending private institutions than public ones. For secondary schools, those located in more advantaged areas are closer to a specialized vaping product point of sale. Speciality stores are closer to schools in urban areas than in rural areas.

Future investigations should examine geographical accessibility to all businesses that sell e-cigarettes (such as some convenience stores, tobacco stores and gas stations) and studying the impact of this accessibility on the use of vaping products by young people.

Public health experts agree on the need to limit the use of vaping products among young people in order not to induce nicotine dependence or to provide an incentive for the subsequent use of tobacco products. It is important to continue to improve scientific knowledge about vaping products, their use and marketing and the places where they are sold. In Quebec and Canada overall, legislation has been passed in an attempt to restrict young people's access to vaping products while allowing adults who want to quit smoking access to them. It is relevant and worthwhile to continue research in this changing regulatory environment.

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Conflict of interest

The authors declare that there are no conflicts of interest.

Authors' contributions and statement

ER and PB designed the project. ER, PB and MH designed the study. MH undertook

the data collection. ER and MH conducted the data analysis. ER wrote the manuscript. ER and PB contributed to the synthesis of the data. All the authors contributed to the discussion of the findings and their interpretation, as well as to the writing of the manuscript and approval of its final version. The content and views expressed in this article are those of the authors and do not necessarily reflect those of the Government of Canada.

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Original quantitative research

Identifying trajectories of alcohol use in a sample of secondary school students in Ontario and Alberta: longitudinal evidence from the COMPASS study

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Abstract

Introduction: Despite evidence indicating a rapid progression in use of alcohol during adolescence, little is known about the ways patterns of drinking develop over time. This study investigated patterns of alcohol use within a cohort of youth in Ontario and Alberta and the probability of changes between patterns.

Methods: The sample consists of two-year linked longitudinal data (school year 2013/14 to 2014/15) from 19 492 students in Grades 9 to 12 in 89 secondary schools across Ontario and Alberta, Canada, who participated in the COMPASS study. The latent class analysis used two self-reported items about the frequency of drinking (measured as none, monthly, weekly, or daily use) and the frequency of binge drinking (measured as none, less than or once a month, 2–4 times a month, or more than once week) to characterize patterns of alcohol use. The effects of gender, ethnicity and cannabis and cigarette use on alcohol use patterns were examined.

Results: The study identified four drinking patterns: non-drinker, periodic drinker (reported monthly drinking and no binge drinking), low-risk drinker (reported monthly drinking and limited binge drinking) and high-risk regular drinker (reported drinking 1–3 times a week and binge drinking 2–4 times a month). Non-drinker was the most prevalent pattern at baseline (55.7%) and follow-up (39.7%). Periodic drinkers had the highest likelihood of an increase in alcohol consumption, with 40% moving to the low-risk pattern. A notable proportion of participants returned to a lower severity pattern or transitioning out of drinking.

Conclusion: There are four distinct youth alcohol-use patterns. The high probability of transitioning to drinking during the secondary school years suggests the need for preventive interventions in earlier stages of use, before drinking becomes habitual.

Keywords: *youth substance use, alcohol use, latent transition analysis, longitudinal study*

Introduction

Alcohol use is common among Canadian youth and its excessive consumption is a major public health concern. By the time they graduate from secondary school 60% of Canadian students report consuming alcohol in the past year, 46% of whom undertake binge drinking (5 or more drinks

on one occasion).¹ Youth who drink alcohol are more likely than others to experience health and social consequences, including motor vehicle accidents,² unprotected sexual activity,³ suicide,⁴ and mental health disorders.⁵ Furthermore, longitudinal studies indicate that alcohol-related consequences are not limited to adolescence; early drinkers tend to drink

Highlights

- Four distinct classes of youth alcohol use were identified: non-drinkers, periodic drinkers, low-risk drinkers and high-risk regular drinkers.
- Youth had a moderate likelihood of staying in the same class of drink consumption from baseline to follow-up.
- Periodic drinkers had the highest risk of increasing alcohol consumption.
- A notable proportion of drinkers returned to a lower alcohol-use class or quit drinking.
- Cigarette use and cannabis use were associated with membership in high alcohol-use classes.

more as adults and therefore continue to be at higher risk of adverse outcomes,⁶ and of using other substances such as cigarette and cannabis.⁷

Existing empirical evidence indicates that youth alcohol-use behaviours are not static over time and consumption of alcohol typically increases throughout adolescence.⁸ Recent longitudinal studies have captured such developmental changes in alcohol-use patterns and suggest this progression differs greatly between individuals in terms of timing and severity of escalation. For example, Peterson and colleagues⁹ identified five trajectories among students in Grades 5 to 10: non-drinkers, middle onset drinkers, late onset drinkers,

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moderate drinkers and early high drinkers. Shin and colleagues¹⁰ explored trajectories of drinking among students at 29 secondary schools in the USA and found four prominent alcohol patterns: non-drinker, potential drinker, experimenter and regular drinker. Such alcohol patterns are distinguished by frequency and quantity of alcohol use (e.g., number of days the individual undertakes drinking or binge drinking).¹¹

Although longitudinal research has characterized developmental patterns of alcohol use in youth over time, the number and types of identified patterns (or classes) are inconsistent. In addition, individuals may transition between classes over time, for example, a non-drinker may begin drinking, a drinker may cease drinking, or an individual may move from a high-risk to a lower-risk drinking class. Youth-related substance use theories and models of development such as the gateway theory¹² and the common liability model¹³ emphasize understanding youth alcohol-use classes and how distinct classes develop over time. This knowledge is critical for establishing interventions that aim to help youth stay in the non-drinker class or promote transitions to lower-risk or non-drinker classes. Despite longitudinal studies documenting youth alcohol trajectories, only a few studies have investigated transitions between classes.¹⁴⁻¹⁵ Moreover, most of the relevant studies examined American or European youth populations and not among Canadian youth. In Canada, Rawana and Ames¹⁶ studied protective factors of the alcohol-use trajectories in a sample of Aboriginal youth aged 12 to 23. They found a relatively stable frequency of heavy drinking over time with the peak at age 21 and the lowest rate at age 16. Since alcohol trajectories are extremely dependent on contextual factors, such as alcohol control and access policies and cultural norms, identifying changes in drinking patterns of Canadian youth is a key step to informing future intervention development.

This study adds to the literature by investigating whether there are distinct patterns of alcohol use within a cohort of youth in Ontario and Alberta, and, if so, what the likelihoods are of maintaining or changing drinking patterns over time. We used latent transition analysis (LTA) to characterize the profiles of drinking based on the frequency of alcohol use and binge

drinking. LTA is a longitudinal extension of latent class modelling in which unobserved heterogeneity in the population is allowed by identifying homogenous groups of individuals in a sample based on similar responses to a set of questions.¹⁷ LTA, as a person-oriented modelling approach, can model changes in drinking behaviours over time and predict for whom, and in what direction, a change may occur.¹⁸ This knowledge can be used by prevention programs to target the individuals at the highest risk of problematic drinking and to test the effectiveness of an intervention.

Considering previous research, we expected that a large proportion of youth would abstain during their secondary school years, but also that a considerable proportion would be engaged in drinking at different levels of consumption. We also hypothesized that a notable proportion of youth would either reduce their levels of alcohol use or quit drinking. As some previous studies documented higher rates of alcohol use among higher-grade students and male students,¹⁹⁻²⁰ we assessed the influence of these factors on subgroup membership and transitions between different latent classes. Furthermore, as it has been shown that changes in alcohol-use behaviour may be influenced by the use of other substances such as cigarettes and cannabis,²¹⁻²² we evaluated the effect of other substance use on the likelihood of transitions between latent classes over the two years of follow-up.

Methods

Sample

The sample was drawn from year 2 (baseline; school year 2013-2014) and year 3 (follow-up, school year 2014-15) of the COMPASS study. COMPASS is a longitudinal study designed to annually collect hierarchical data from a cohort of Canadian students in Grades 9 through 12. A full description of the COMPASS study and its methods are available in print²³ or online (www.compass.uwaterloo.ca).

The COMPASS study purposefully recruited 89 secondary schools across Ontario (n = 79) and Alberta (n = 10). Participants from the schools were recruited using an active-information passive-consent procedure. The resulting baseline sample consisted of 34 839 students in Grades 9 to 11. The average participation

rate was 79.2% across schools. The sample in the follow-up year consisted of 31 060 students in Grades 10 to 12 with an average participation rate of 78.7%. The main reasons for non-participation were absenteeism and spare or co-op education periods; a small number of parents or students refused participation (1.2%). Data were linked between two consecutive years based on responses of participants to six questions that was used to create a unique code for each student.²⁴ The linkage algorithm merged 19 492 students' data over two years, but could not match 11 568 (33.2%) individuals. In addition, 554 (1.6%) individuals were excluded because they reported being in the same grade as the previous year. As previously reported, students with non-linked data were more likely to use alcohol, cigarettes, or cannabis compared to the linked students (data not shown).²⁴ The linked data was evenly distributed in terms of gender (53.1% female) and school years: 38.8% (n = 7556) in Grade 9, 34.6% (n = 6738) in Grade 10, and 26.6% (n = 5165) in Grade 11.

Alcohol measures

The study used two self-reported items about the frequency of drinking and frequency of binge drinking that are currently used in Canadian surveillance of youth substance use.²⁵ The frequency of drinking alcohol was measured by responses to the question, "In the last 12 months, how often did you have a drink of alcohol that was more than just a sip?" The response options were on a scale of 1 to 10. Considering the distribution of responses and in keeping with the World Health Organization alcohol use identification test (AUDIT) system of recording the frequency of drinking,²⁶ the responses were classified into four outcomes: no drink; up to 3 times a month (monthly use); 1 to 3 times a week (weekly use); and more than 3 times a week (nearly daily use). Binge drinking was assessed using the question, "In the last 12 months, how often did you have 5 drinks of alcohol or more on one occasion?" Responses in an original scale of 8 options were coded into four outcomes: no binge drinking; less than or once a month; 2 to 4 times a month; and more than once a week.

Students self-reported their demographic characteristics, including gender (female = 1, male = 2); school year (Grades 9 to 12); and ethnicity (White, Black, Asian, Aboriginal,

Latin American, Other). Ethnicity was classified as a binary variable (White = 1, non-White = 0) because of the low frequency of students that were Black (n = 617, 3.2%); Asian (n = 993, 5.1%); Aboriginal (n = 490, 2.5%), Latin American (n = 308, 1.6%); or other ethnicities (n = 1965, 10.2%). Students' cigarette use was assessed by asking students, "On how many of the last 30 days did you smoke one or more cigarettes?" Responses were recorded for analysis into a binary variable (none = 0, use in any day during the past 30 days = 1). Cannabis use was assessed by asking students, "In the last 12 months, how often did you use marijuana or cannabis?" Responses were also classified into a binary variable (none = 0, use in any day during the last year = 1).

Statistical analysis

We employed LTA on frequency of drinking and frequency of binge drinking in past year to group similar individuals based on their levels of drinking and binge drinking. A two-stage analytical approach was used. In the first stage, two to six class solutions were tested. These models were compared using the Bayesian information criteria (BIC) as the goodness-of-fit statistic, which includes a penalty for over-fitting; lower BIC values are therefore indicative of a better model for the data. To ensure that global, rather than local, maxima was found for the likelihood function, we ran each model with 50 different starting values for the parameters.²⁷ The quality of group separation was measured in terms of entropy statistics, which is a weighted average of group membership probabilities on a (0,1) scale.²⁸ The closer the entropy statistic is to 1, the greater the distinction between latent classes. Once the most appropriate latent class model was selected, we examined the measurement invariance of latent classes over the two years of the study to see if the structure of latent classes remained stable over time.

In the second stage, we investigated the association between latent class membership and covariates of gender, ethnicity and cigarette and cannabis use. We also explored the association between probability of transitions between different latent classes and gender and school grade. To test the effect of covariates, individuals were assigned to latent classes based on the maximum posterior probability

of class membership. A set of multinomial logistic regressions was then fitted. The outcome variable in the multinomial regression was membership in each class with the non-drinker class as the reference category. All models were fitted using PROC LTA in SAS 9.4.1.²⁹ Procedure LTA allows for missing values on the outcome variables, but excludes participants with missing covariate data. In the current study, LTA with covariates excluded 368 participants out of 19492 linked data because of missing data on gender or other substance use (78 missing gender, 290 missing other substance use and 31 missing both covariates). The structure of the latent classes did not change as a result of this reduction.

Results

Table 1 presents the levels of alcohol and other substance use by participants in the study. The number of alcohol users and binge drinkers had increased at the follow-up. The rate of binge drinking increased from 28.7% in the baseline year to 43% in the follow-up year. At the baseline, 5.7% of participants reported use of cigarettes, which increased to 9.5% at the follow-up. During the two years, the rate of cannabis use increased by 67.2%, rising from 15.6% at the baseline to 26.1% at the follow-up.

Table 2 reports changes in the levels of alcohol use and binge drinking between the two waves of the study according to school years (Grade 9, 10 or 11). Of 5083 Grade 9 non-drinkers, 3374 (66.4%) reported

abstinence when they moved to Grade 10. The results in Table 2 indicate that the rate of abstinence between baseline and follow-up years was quite similar over the school years with rates of 66.4%, 62.2% and 61.4% for Grades 9, 10 and 11, respectively. During the two years, rates of increase in the frequency of drinking changed similarly. For example, non-drinkers in Grades 9, 10 and 11 initiated monthly drinking at rates of 31.0%, 35.1% and 35.6%.

Identifying alcohol use patterns

LTAs were conducted to identify distinct latent classes of drinking characterized by alcohol use patterns at the baseline. The model fitting procedure began with fitting latent transition models ranging from two to six latent classes to the data. Our decision on the number of latent classes was made according to goodness-of-fit statistics of BIC and also parsimony and interpretability of latent class structure (Table 3 represents fit statistics). BIC decreased substantially from 2- to 5-class solutions and then began to increase from the 6-class solution (BIC₂ = 8809, BIC₃ = 2665, BIC₄ = 1306, BIC₅ = 919, BIC₆ = 1012). Despite the lower BIC value, there was considerable overlap between two latent classes identified by the 5-class model. Comparing the degree to which the latent classes were distinguished by 4-class and 5-class models using average posterior probabilities indicated a slightly better recognition of classes by the 4-class model. The overall entropy estimates for the 4-class model were 0.91 and 0.89 at baseline and

TABLE 1
Frequency and per cent of self-reported levels of alcohol and other substance use in baseline and follow-up years of the study (n = 19 492)

Variable	Baseline 2013-14 (%)	Follow-up 2014-15 (%)	Relative change
Alcohol drinking			
None	10 327 (53.9)	7386 (38.4)	-28.5%
Up to 3 times a month	7534 (39.3)	9740 (50.6)	29.3%
1-3 times a week	1116 (5.8)	1804 (9.4)	61.6%
3+ times a week	186 (1.0)	302 (1.6)	62.4%
Binge drinking			
None	13 848 (71.3)	11 082 (57.0)	-20.0%
Less than or once a month	3855 (19.8)	5439 (28.0)	41.1%
2-4 times a month	1492 (7.7)	2512 (12.9)	68.4%
More than once a week	242 (1.2)	405 (2.1)	67.4%
Cigarette use	1115 (5.7)	1860 (9.5)	66.8%
Cannabis use	2999 (15.6)	5015 (26.1)	67.2%

follow-up, respectively (range: 0.45–0.99), compared to the 5-class estimates of 0.91 and 0.87, respectively (range: 0.35–0.99). We also found that the classes identified by the 4-class model were more conceptually meaningful and interpretable relative to those of the 5-class model. We examined the local independence of latent variable items following Reboussin's³⁰ approach. The results of a correlation analysis of latent variable items showed that despite the presence of structural zero in binge drinking responses for non-drinkers, standardized residuals decreased substantially from the 2-class model to the 4-class model (Figure 1), indicating that local independence is not violated for the final model. Given these considerations, we selected the 4-class model, which generates clearly distinct and interpretable classes of alcohol use with substantial class sizes.

According to the conditional probabilities of the final model, shown in Table 4, we assigned the following labels to the latent classes: *non-drinkers* (had never drunk or did not use alcohol in past year); *periodic drinkers* (reported monthly drinking and no binge drinking); *low-risk drinkers* (reported some steady monthly drinking but limited binge drinking); and *high-risk regular drinkers* (reported drinking 1 to 3 times a week and binge drinking 2 to 4 times a month). Non-drinkers were the largest subgroup in both waves (55.7% of baseline to 39.7% of follow-up), although the prevalence of this group decreased by 16% at follow-up. The number of periodic drinkers increased slightly from 22.9% at baseline to 26.3% at follow-up. The prevalence of the remaining of the two classes of low-risk drinkers and high-risk regular drinkers increased approximately 50% at follow-up.

To examine the stability of identified latent classes over time, we compared the fit of the 4-class model, constraining item-response probabilities to be equivalent across two years with the unconstrained model. The BIC of the restricted model (1509.6) was lower than the BIC of the unrestricted model (1640.1), indicating that the same classes across waves would represent the same characteristics.

Transition probabilities in alcohol-use patterns

Table 5 shows latent transition probabilities based on the LTA model adjusted for

TABLE 2
Changes in the frequency of youth alcohol drinking and binge drinking by school years in baseline and follow-up years of the study (n = 19 492)^a

Drinking	Follow-up (2014-15) levels of drinking											
	Grade 9 to 10 n (%)			Grade 10 to 11 n (%)			Grade 11 to 12 n (%)					
	None	Monthly	Weekly	Daily	None	Monthly	Weekly	Daily	None	Monthly	Weekly	Daily
None	3374 (66.4)	1576 (31.0)	100 (2.0)	33 (0.6)	2021 (62.2)	1142 (35.1)	65 (2.0)	22 (0.7)	1122 (61.4)	651 (35.6)	46 (2.5)	8 (0.5)
Up to 3 times month (monthly)	232 (11.6)	1452 (72.4)	292 (14.5)	30 (1.5)	238 (8.5)	2149 (76.7)	366 (13.1)	48 (1.7)	183 (6.9)	2086 (79.1)	330 (12.5)	38 (1.5)
1–3 times a week (weekly)	15 (7.6)	85 (42.9)	83 (41.9)	15 (7.6)	15 (3.7)	167 (40.8)	202 (49.4)	25 (6.1)	13 (2.7)	202 (41.5)	238 (48.9)	34 (6.9)
3+ times a week (daily)	11 (29.0)	8 (21.0)	12 (31.6)	7 (18.4)	7 (10.6)	33 (50.0)	14 (21.2)	12 (18.2)	5 (6.6)	23 (30.3)	29 (38.1)	19 (25.0)
Binge drinking	None	Up to 3 times a month	1–3 times a week	3+ times a week	None	Up to 3 times a month	1–3 times a week	3+ times a week	None	Up to 3 times a month	1–3 times a week	3+ times a week
None	4889 (76.9)	1136 (17.9)	283 (4.4)	52 (0.8)	3300 (71.7)	1032 (22.4)	232 (5.0)	40 (0.9)	2021 (71.5)	651 (23.0)	127 (4.5)	27 (1.0)
Less than or once a month	184 (21.2)	405 (46.5)	260 (29.9)	21 (2.4)	232 (16.1)	813 (56.3)	365 (25.3)	34 (2.3)	233 (15.3)	897 (59.0)	362 (23.8)	29 (1.9)
2–4 times a month	34 (13.7)	77 (31.0)	115 (46.4)	22 (8.9)	57 (10.1)	170 (30.0)	290 (51.2)	49 (8.7)	57 (8.5)	189 (28.2)	367 (54.9)	56 (8.4)
More than once a week	13 (32.5)	5 (12.5)	12 (30.0)	10 (25.0)	12 (14.1)	16 (18.8)	35 (41.2)	22 (25.9)	14 (11.9)	18 (15.4)	45 (38.5)	40 (34.2)

^a Table shows changes in levels of alcohol consumption from baseline (distribution based on the row headers in the first column) to follow-up (shaded columns).

TABLE 3
Fit statistics for latent class models of alcohol drinking
and binge drinking for youth participating in the COMPASS study (n = 19 492)

Model	Log-Likelihood	df	Adjusted BIC	BIC	Entropy	BLRT ^a p value
2-class	-56 561	240	8761.4	8809.1	0.95	< .001
3-class	-53 434	229	2582.9	2665.5	0.95	< .001
4-class	-52 778	216	1357.0	1480.9	0.93	< .001
5-class	-52 401	201	703.1	874.5	0.91	.302
6-class	-52 377	148	1011.7	1351.7	0.88	.950

Abbreviations: BIC, Bayesian information criteria; BLRT, bootstrap likelihood ratio test.

^a A non-significant value of the BLRT suggests that the model with one fewer classes is accepted.

the school year and cigarette and cannabis use. The probabilities on the diagonal reflect the probability of membership in the same latent class at both time points, which is high for all classes. Low-risk drinkers and high-risk regular drinkers had a higher likelihood of maintaining the same class at follow-up relative to non-drinkers and periodic drinkers. In contrast, the periodic drinkers were most likely to transition into the low-risk drinker class. In particular, 40% of the students in the periodic drinker class at baseline moved to the low-risk drinker class at follow-up. Non-drinkers demonstrated a 24% chance of transitioning to periodic drinking. Also, despite 65% of high-risk regular drinkers maintaining

their class at follow-up, a notable proportion of individuals in this group lowered their alcohol consumption. Specifically, 18% of high-risk regular drinkers moved to the low-risk class and 8% reported complete cessation of alcohol drinking (Table 5). Individuals within the low-risk drinker and high-risk regular drinker classes had the same probability (8%) of becoming non-drinkers at follow-up. In total, 17% of drinkers at baseline quit drinking at follow-up.

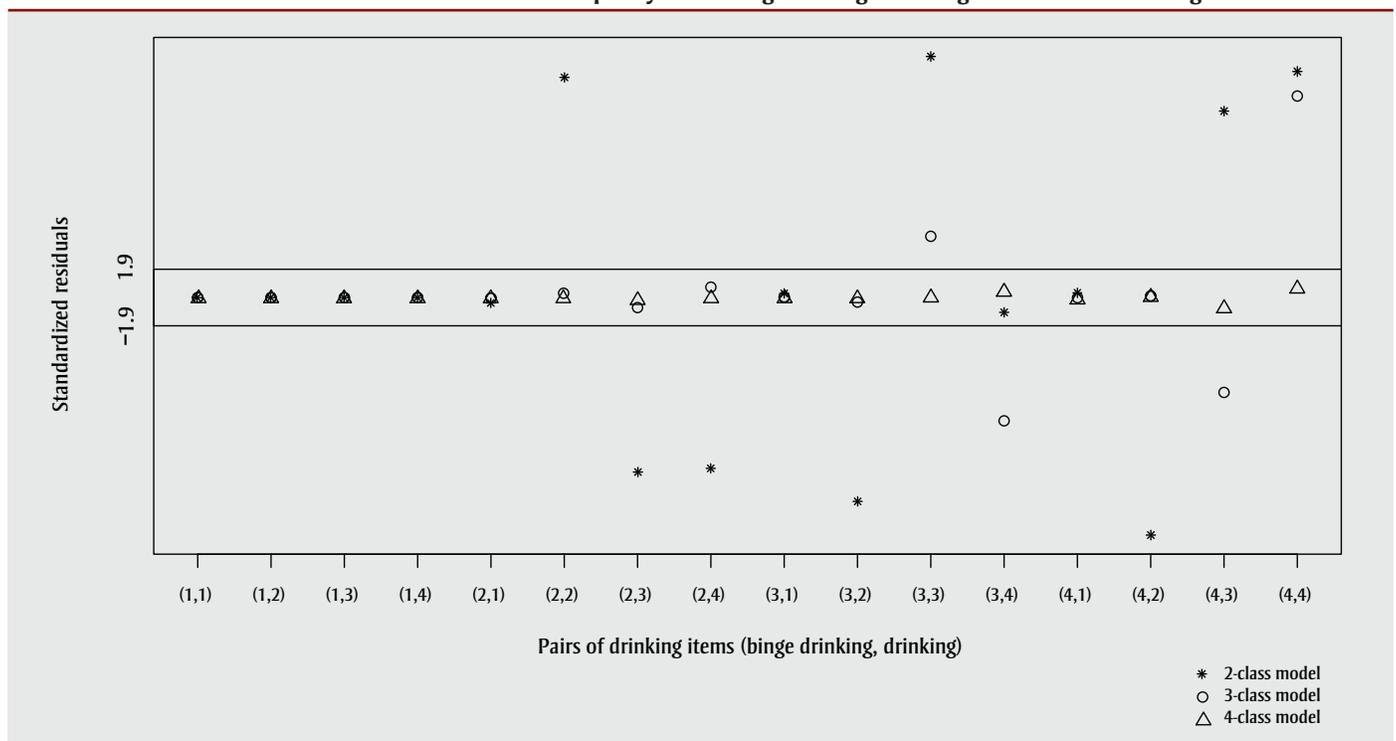
Predictors of membership in latent class and transition probabilities

After determining latent classes, we examined the potential effects of gender and

ethnicity in predicting the membership of individuals in the four latent classes at the baseline. Comparison fit of the model with gender and without gender showed that gender significantly related to latent class membership ($2(\loglikelihood_{without\ gender} - likelihood_{with\ gender}) = 58.2, df = 3, p < .001$). The odds ratios (ORs) in Table 6 suggest that male students were more likely to be in the high-risk regular drinker class than female students (OR = 1.2, 95% confidence interval [CI]: 1.04–1.36). Ethnicity was also found to be a significant predictor of class membership ($2(likelihood_{without\ ethnicity} - likelihood_{with\ ethnicity}) = 37.2, df = 3, p < .001$), and White students were at a significantly higher risk of engaging in alcohol use than their non-White peers.

Table 6 presents the OR associated with transitions from each latent class relative to remaining in the same class. Male non-drinkers had a 2.4 (95% CI: 1.76–3.27) times greater chance of engaging in high-risk regular drinking. The odds ratio transition from the high-risk drinking to abstinence was also higher for male students (OR = 1.33, 95% CI: 0.78–2.28). Results of Table 6 indicate that Grade 9 students were more likely to move to higher-risk drinking classes than Grade 11 students, while there were no significant

FIGURE 1
Standardized residuals of bivariate correlations in frequency of drinking and binge-drinking levels used for creating latent classes



differences between Grade 10 and Grade 11 students in transitioning to higher-risk drinking classes.

Discussion

This study characterized patterns of alcohol use in a large sample of secondary school students, identifying four latent classes. These distinct classes align with previous research indicating the presence of an underlying grouping structure to youth alcohol use.³¹⁻³² Consistent with other studies,³¹ we found that the most prevalent class was non-drinkers. The size of this group decreased by 16% at follow-up but remained the dominant group. Individuals in the low-risk drinker and high-risk regular drinker classes engaged in some levels of binge drinking, indicating that a considerable proportion of youth is at risk of immediate and long-term consequences of alcohol consumption. This finding is supported by evidence that suggests that when youth do drink alcohol, they are more likely to binge drink.¹

LTA allowed us to characterize the homogeneous group of alcohol users and also to understand the developmental process of their alcohol use over time. In particular, the data showed that youth were highly likely to maintain their alcohol-use behaviour between baseline and follow-up. The low-risk drinker class was the most stable of the four identified. Furthermore, we found a high degree of transitioning between latent classes from baseline to the following year. Individuals mainly moved into the expected increasing direction and consumed more at follow-up. Periodic drinkers demonstrated the highest likelihood of an increase in alcohol consumption by moving to the low-risk drinker class. This high transition probability suggests that many of those who drink a few times a month increase their frequency of drinking to weekly while also starting to engage in binge drinking. Estimated transition probabilities indicated that alcohol consumption increases incrementally and most of the transitions occurred into the next-higher level of consumption.¹⁰

Although most youth moved to a higher alcohol-use class, a notable proportion returned to a lower severity class or transitioned out of drinking. Nearly one out of 10 low-risk or high-risk regular drinkers was likely to stop drinking. Drinking

TABLE 4
Structure and prevalence of latent classes of youth alcohol-use behaviours in baseline and follow-up years of the study (n = 19 492)

Latent class characteristics	Non-drinker	Periodic drinker	Low-risk drinker	High-risk regular drinker
Prevalence at baseline [2013-14] (%)	55.7	22.9	15.8	5.6
Prevalence at follow-up [2014-15] (%)	39.7	26.2	24.6	9.4
Drinking				
None	0.963	0.007	0.001	0.000
Up to 3 times a month	0.036	0.970	0.943	0.400
1-3 times a week	0.000	0.019	0.053	0.585
More than 3 times a week	0.000	0.004	0.002	0.015
Binge drinking				
None	0.999	0.701	0.000	0.031
Less than or once a month	0.001	0.287	0.864	0.127
2-4 times a month	0.000	0.011	0.136	0.827
More than once a week	0.000	0.003	0.000	0.014

cessation by individuals in these two classes was more likely than by periodic drinkers, possibly because students using alcohol at such a high frequency can be severely affected in their daily lives, with poorer academic engagement and performance.³³ In comparison, the likelihood of cessation by periodic drinkers was only 1%, suggesting that most students in the early stages of alcohol consumption continue to drink. Future research needs to determine the characteristics of the youth that reduce their consumption and to investigate the factors that influenced this decrease.

As in previous research,³² we found that school grade was associated with transitions between latent classes. The results of this study show that the odds of transitioning from the non-drinking class to other classes are similar for students in different grades, indicating a stable chance of starting alcohol drinking between school years. On the other hand, periodic drinkers and low-risk drinkers in Grade 9

are more likely to escalate their alcohol use than students in Grade 11. This finding indicates that initiation and escalation of alcohol consumption by secondary school students are more likely to happen during the first two years of secondary school and that behaviours of students become more stable as they move to higher grades, suggesting that the prevention programs would be more efficient if they targeted Grade 9 and 10 students.

The results of this study confirmed previous research that male youth have higher odds than female youth of engaging in, transitioning to and remaining in problematic drinking.³⁴⁻³⁵ Also, male students indicated a higher probability of quitting drinking. Consistent with problem behaviour theory that posits an interrelation between use of different substances,^{21-22,36} the results of the current study demonstrated the relevance of cigarette and cannabis use in relation to heightening the probability of membership in the higher-risk drinking classes. The odds of

TABLE 5
Transition probabilities for the four-latent class model of youth alcohol consumptions in baseline and follow-up years of the study (n = 19 124)

Baseline (2013-14) class	Follow-up (2014-15) class			
	Non-drinker	Periodic drinker	Low-risk drinker	High-risk regular drinker
Non-drinker	0.64	0.24	0.09	0.03
Periodic drinker	0.01	0.54	0.40	0.05
Low-risk drinker	0.08	0.02	0.69	0.20
High-risk regular drinker	0.08	0.09	0.18	0.65

Note: Adjusted for school year, cigarette and cannabis use.

TABLE 6
Estimated odds ratios reflecting the effects of covariates on membership and transitions between latent classes of youth alcohol drinking in baseline and follow-up years of the study (n = 19 124)

Covariate	Non-drinker	Periodic drinker	Low-risk drinker	High-risk regular drinker
	OR (95% CI)	OR (95% CI)	OR (95% CI)	OR (95% CI)
Class membership covariate				
Males	Reference	0.85 (0.79–0.93)	0.86 (0.80–0.93)	1.20 (1.04–1.36)
White	Reference	1.51 (1.37–1.65)	1.72 (1.57–1.89)	1.26 (1.08–1.49)
Smoking	Reference	4.44 (3.50–5.63)	12.63 (10.31–15.47)	22.85 (14.24–33.62)
Cannabis	Reference	5.98 (5.17–6.91)	10.88 (8.34–13.75)	19.24 (9.81–30.47)
Transition covariates				
Males				
Non-drinker	Reference	0.83 (0.76–0.90)	1.15 (0.89–1.49)	2.40 (1.76–3.27)
Periodic drinker	1.64 (1.21–2.22)	Reference	1.00 (0.87–1.16)	1.90 (1.33–2.71)
Low-risk drinker	1.42 (0.80–2.51)	0.00 ^a	Reference	1.77 (1.51–2.08)
High-risk regular drinker	1.33 (0.78–2.28)	0.75 (0.38–1.48)	0.80 (0.57–1.14)	Reference
Grade 9 (relative to Grade 11)				
Non-drinker	Reference	0.84 (0.77–0.91)	0.95 (0.74–1.22)	0.87 (0.65–1.16)
Periodic drinker	1.11 (0.80–1.55)	Reference	1.47 (1.26–1.71)	1.91 (1.34–2.74)
Low-risk drinker	1.52 (0.80–2.89)	0.00 ^a	Reference	1.37 (1.14–1.65)
High-risk regular drinker	2.56 (1.42–4.61)	2.06 (0.94–4.53)	1.14 (0.71–1.83)	Reference
Grade 10 (relative to Grade 11)				
Non-drinker	Reference	1.11 (1.02–1.22)	1.12 (0.83–1.52)	1.01 (0.77–1.33)
Periodic drinker	0.92 (0.67–1.26)	Reference	0.98 (0.84–1.13)	0.84 (0.58–1.22)
Low-risk drinker	0.82 (0.45–1.49)	0.00 ^a	Reference	0.97 (0.83–1.15)
High-risk regular drinker	0.91 (0.52–1.58)	0.68 (0.32–1.43)	1.21 (0.85–1.72)	Reference

Abbreviations: CI, confidence interval; OR, odds ratio.

Note: Baseline was the 2013-14 school year and follow-up was the 2014-15 school year.

^a There was no transitioning from the low-risk to periodic class.

membership in the periodic drinker class for cigarette smokers was more than four times that of non-smokers. Similar patterns were observed for cannabis users, for whom the odds of engaging in higher levels of drinking were greater than for non-drinkers. This finding supports the existing literature, which shows that a high level of alcohol consumption co-occurs with cigarette or cannabis use.³⁷ However, based on the current study it is unclear which of these substances serves as a gateway for the use of the others. Future research is needed to examine the sequencing of initiation between different substances. Theoretical models such as the gateway theory³⁸ and the common liability theory^{13,39} and empirical evidence⁴⁰ suggest that youth deciding on the use of any of alcohol, cigarette and cannabis is associated with a higher risk of the use of others, regardless of use sequences. The findings of our study confirm the previous research and suggest that prevention interventions need to focus on all of the most common substances simultaneously.

The LTA that is used in the current research is a person-centred approach that can model individuals' changes based on their patterns of responses on an outcome of interest. Therefore, it can be used to understand the patterns in data and to explore if individuals are different from one another with respect to the outcome of interest. Moreover, LTA is able to account for the measurement errors typically associated with self-report surveys.¹⁷ In this method, each individual with an empirical response has a probability of membership in every latent class and the model assigns individuals to a class with the highest probability of membership. The results from the LTA need to be applied with awareness of its limitations. One of the main limitations of LTA is that subgroups detected in a study sample are not necessarily the same as real underlying subgroups in the population and the number of subgroups identified by LTA can be greater than the actual number.⁴¹ Another limitation of LTA is the assumption that the underlying latent variable

describes any observed association between indicators of the latent variable. This assumption may be hard to meet in some real applications and may cause biases in parameter estimation, such as overestimation of the number of classes.⁴²⁻⁴³

The results of this study should be considered in light of its limitations. The main limitation of this study was reliance on self-reported measures of alcohol use. Youth reports on alcohol and other substance use are potentially associated with underreporting and measurement errors. Secondly, the linkage process could not link a portion of students' data over two years of follow-up. The non-linked data appear not to be a random collection, but data from students who are more likely to drink, smoke cigarettes and use cannabis. As a result, the linked data can underestimate the size and probability of transitioning to high-risk groups. In addition, the developmental course of alcohol consumption was investigated with one year

of follow-up. More comprehensive knowledge about changes in youth drinking behaviour would require a longer follow-up time. Finally, measurement time points were about one year apart, so students' alcohol behaviours could have changed several times over this period. Because of these types of potentially missed transitions, the transition probabilities should be interpreted with caution.¹⁷

Future research can evaluate to what extent transitioning between different identified patterns of alcohol use may be influenced by a change to any prevention programs or policies on alcohol control. For example, our research team is examining, using four years of data in a quasi-experimental setting, the impact on youth alcohol-use patterns of the new Liquor Control Board of Ontario (LCBO) policy that authorizes up to 450 grocery stores across Ontario to sell alcohol. Evaluating the effect of this natural experiment (or for researchers evaluating other forms of alcohol policy) would be better served by examining the impact on the more nuanced alcohol-use transition patterns presented here rather than simply evaluating the impact on a less informative outcome such as use versus no use. In addition, future research may implement and assess the impact of behavioural change interventions, such as Alcohol Brief Intervention⁴⁴ and Motivational Enhancement Therapy,⁴⁵ to motivate problematic drinkers to quit alcohol or decrease their consumption. The transition modelling approach used here can also be applied to other risk behaviour or substance use domains, such as cannabis and cigarettes, and may serve as a template for guiding future evaluations of prevention policies, such as the new federal cannabis regulations in Canada or any potential changes to tobacco control efforts.

Conclusion

The study suggests that alcohol consumption tends to increase in those youth who start, but the volume of increase is not the same across all populations of youth. The large transition from periodic drinker class to higher levels of drinking we observed indicates the need for preventive interventions in the earlier stages of use, before drinking becomes habitual. In addition, there is more need for interventions that target current alcohol users to increase the likelihood of transitions from alcohol

drinker classes to the non-drinker class. The study demonstrated that cigarette or cannabis use was associated with membership in classes with high levels of alcohol consumption, suggesting that efforts that address polysubstance use may be more efficient than single alcohol programs.

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Conflicts of interest

The authors have no conflicts of interest to disclose.

Authors' contributions and statement

MG devised the project, performed the analyses, interpreted the results, and wrote the first draft of the manuscript. SL led the COMPASS host study. RC and JD provided methodological advice for data analyses. SL, RC and JD contributed to interpretation of data and revised the manuscript. All authors read and approved the final version of the manuscript.

The content and views expressed in this article are those of the authors and do not necessarily reflect those of the Government of Canada.

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Release notice

The Canadian Paediatric Surveillance Program 2018 Results

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The Canadian Paediatric Society (CPS) and the Public Health Agency of Canada are pleased to announce the release of *The Canadian Paediatric Surveillance Program 2018 Results*.

The Canadian Paediatric Surveillance Program (CPSP) conducts active, national child health surveillance that monitors rare or emerging diseases and conditions that are of public health importance.

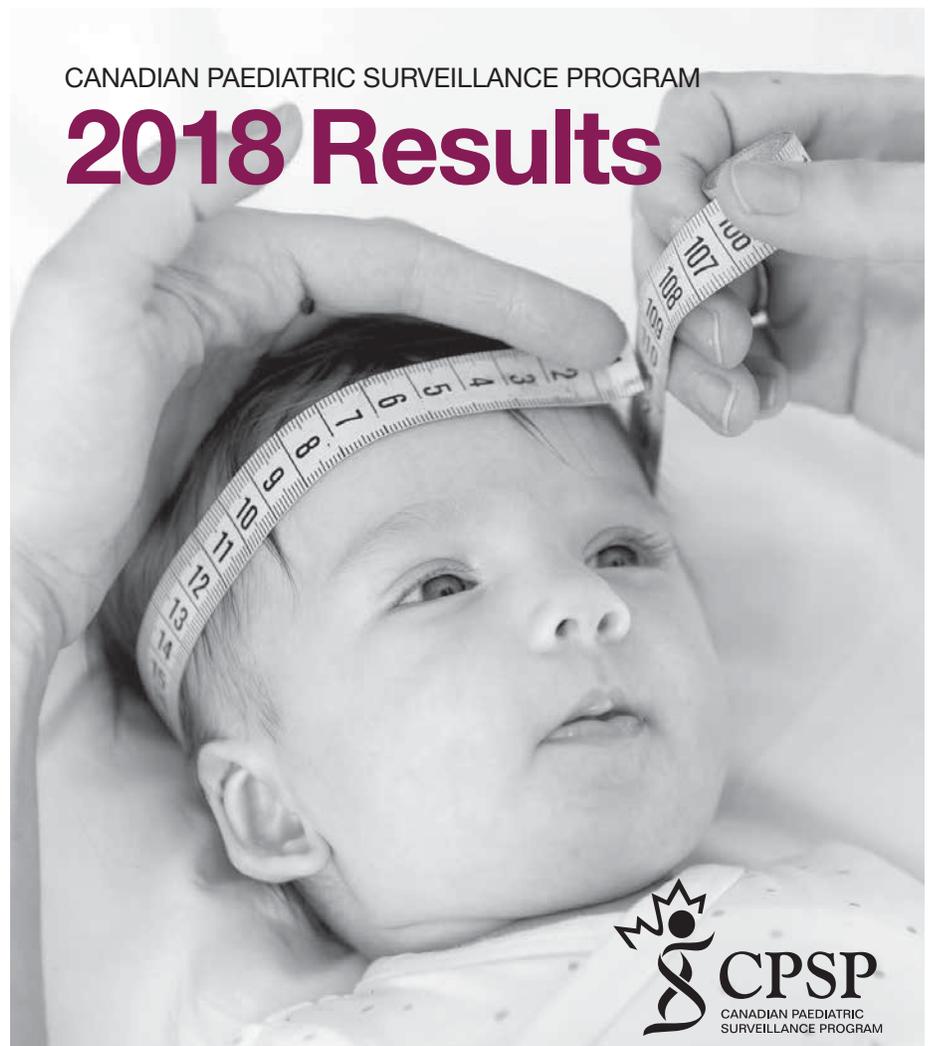
This annual report summarizes the program's studies and one-time surveys carried out in 2018. Full studies examined type 2 diabetes, medication-induced diabetes and monogenic diabetes; serious and life-threatening events associated with non-medical (recreational) cannabis use in children and youth; medically serious self-harm in youth requiring Intensive Care Unit (ICU) admission; severe microcephaly; congenital Zika syndrome in infants; severe obesity and global developmental delay in preschool children; acute flaccid paralysis (polio); adverse drug reactions; Pompe disease; complex regional pain syndrome; ophthalmia neonatorum; and Rh sensitization.

One-time surveys conducted in 2018 covered neonatal abstinence syndrome; teething necklaces and bracelets worn by infants and toddlers; and a national profile of procedural skill needs for Canadian paediatricians.

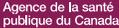
The report also contains an update on international developments in the surveillance, research and knowledge translation concerning rare paediatric diseases and conditions, as well as a list of recent presentations and publications related to current and previous CPSP studies.

The CPSP provides an innovative means of identifying and obtaining data on rare diseases and conditions from over 2800 participants. The process for applying to launch a new study or survey is available at: <https://www.cpsp.cps.ca/apply-proposez>.

The *Canadian Paediatric Surveillance Program Results* have been published annually since 1999 and can be accessed at: <https://www.cpsp.cps.ca/publications>.



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Release notice

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Produced through a partnership between the Public Health Agency of Canada, Statistics Canada and the Canadian Cancer Society, and in collaboration with the provincial/territorial cancer registries, the *Canadian Cancer Statistics 2019* publication provides current estimates (projections) of cancer incidence and mortality counts and rates across the country by cancer type, age group and sex. The publication also includes the probability of developing and dying from cancer, incidence and mortality trends over time, and net survival by cancer type.

Highlights from the 2019 publication:

- Cancer remains the leading cause of death in Canada. Nearly 1 in 2 Canadians will develop cancer in their lifetime and about 1 in 4 will die from cancer.
- In 2019, an estimated 220 400 Canadians will be diagnosed with cancer and 82 100 will die from cancer.
- Lung, breast, colorectal and prostate cancers are expected to remain the most commonly diagnosed cancers, accounting for 48% of all diagnoses in 2019.
- One-quarter of all cancer deaths are expected to be due to lung cancer. Colorectal, pancreatic and breast cancers are the next leading causes of cancer death.
- Current five-year net cancer survival is estimated to be 63% for all cancers combined. Survival is very high for some cancer types such as thyroid (98%) and testicular (97%) and very low for others such as esophageal (15%) and pancreatic (8%).
- The biggest increases in survival since the early 1990s were for blood-related cancers (non-Hodgkin lymphoma, leukemia and multiple myeloma).



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Corrigendum

Obesity and healthy aging: social, functional and mental well-being among older Canadians

This corrigendum is being published to correct a number of errors and imprecisions, on pages 437-442, of the following article:

Rao DP, Patel P, Roberts KC, Thompson W. Obesity and healthy aging: social, functional and mental well-being among older Canadians. *Health Promot Chronic Dis Prev Can.* 2018;38(12):437-44. doi: 10.24095/hpcdp.38.12.01.

1. p. 437 (*Abstract, Results*)

Before correction

While happiness and life satisfaction were not associated with obesity status, older females living with obesity reported negative impressions of whether their aging was healthy.

After correction

While happiness and life satisfaction were not associated with obesity status, older females living with obesity reported negative impressions of whether their aging was healthy, to a greater extent than males.

2. p. 439 (*Methods, Variables, Mental health and well-being*)

Before correction

We determined mental health status based on self-report of a mood or anxiety disorder diagnosed by a physician. Various measures were used for mental wellbeing. We identified happiness as feeling happy 3 or more days per week versus fewer. While this measure is not a substitute for specific mental health assessment, it has been validated as a useful one to measure general mental health.²⁸ Self-reported measures of happiness have been shown to associate with lower mortality, which may be mediated by physical activity and comorbidity, in the elderly.²⁹ Life satisfaction was derived from reports of feeling slightly satisfied or better with life versus neutral or dissatisfied. These measures (self-rated mental health and self-rated healthy aging) were each coded as binary variables based on self-report responses of “fair” or “poor” versus “good,” “very good” or “excellent,” respectively.

After correction

We determined mental health status based on self-report of a mood or anxiety disorder diagnosed by a physician. Various measures were used for mental wellbeing. We identified happiness as feeling happy 3 or more days per week versus fewer. Self-reported measures of happiness have been shown to associate with lower mortality, which may be mediated by physical activity and comorbidity, in the elderly.²⁹ Life satisfaction was derived from reports of feeling slightly satisfied or better with life versus neutral or dissatisfied. Respondents were asked the following two questions to assess mental health and healthy aging, respectively: "In general, would you say your mental health is excellent, very good, good, fair, or poor?" and "In terms of your own healthy aging, would you say it is excellent, very good, good, fair, or poor?" While self-rated mental health is not a substitute for specific mental health assessment, it has been validated as a useful one to measure general health.²⁸ These measures (self-rated mental health and self-rated healthy aging) were each coded as binary variables based on self-report responses of “fair” or “poor” versus “good,” “very good” or “excellent,” respectively.

3. p. 439 (*Results, 2nd paragraph*)

Before correction

The consumption of 4 or more alcoholic beverages per week differed significantly between the sexes, and also decreased significantly with increasing age groups. Obesity was significantly higher among males and decreased with age, until age 75 to 85, where more females lived with obesity than males, despite their own age-related decreases. Finally, significantly more females than males reported having multimorbidity at ages 55 to 64, with differences disappearing by ages 75 to 85 years (Table 1).

After correction

The consumption of 4 or more alcoholic beverages per week differed significantly between the sexes, and also across age groups. Statistically significant differences across age groups were found for obesity for both males and females. Obesity was significantly higher among males than females in the 55-64-year age group, while in the 75-85-year age group, the prevalence of obesity was higher among females than males, though this latter result was not statistically significant. Finally, significantly more females than males reported having multimorbidity at ages 55 to 64, with differences disappearing by ages 75 to 85 years (Table 1).

4. p. 439 (Results, 3rd paragraph)**Before correction**

Reduced physical functioning was strongly associated with obesity for both males and females, with differences between the sexes being significant only among those aged 65 to 74 years old. The strength of this association between reduced physical functioning and obesity increased with age for both sexes. Similarly, impairments in activities of daily life were significantly associated with obesity for both sexes, with the strength of association increasing with age. The difference between sexes was significant across all age group, with females living with obesity reporting more impairments than males living with obesity.

After correction

Reduced physical functioning was strongly associated with obesity for both males and females, with differences between the sexes being significant only among those aged 65 to 74 years old. Similarly, impairments in activities of daily life were significantly associated with obesity for both sexes. The difference between sexes was significant across all age group, with females living with obesity reporting more impairments than males living with obesity.

5. p. 439 (Discussion, 1st paragraph)**Before correction**

While studies have suggested that poor financial health is linked with disease,³² we observed that CLSA participants had strong subjective financial well-being.

After correction

We observed that among CLSA participants in every age group, a lower proportion of females than males had personal incomes equal to or greater than \$50,000, or lived in their own home. Yet, poor financial health has been linked with disease.³² We also observed a higher prevalence of multimorbidity among females, compared to males, in all but the oldest age group.

6. p. 442 (Discussion, 4th paragraph)**Before correction**

The low perception of good mental health among older females is noteworthy, although this improves with age.

After correction

The low perception of good mental health among older obese females is noteworthy.

Call for papers – 2020 special issue

Problematic substance use in Canada: trends and emerging issues in public health

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Editors: Robert Geneau (Editor-in-Chief, Public Health Agency of Canada); Dr. Tim Stockwell, Dr. Cecilia Benoit, Dr. Kiffer Card and Dr. Adam Sherk (Guest Editors, Canadian Institute for Substance Use Research, University of Victoria)

Substances, such as alcohol, cannabis and other drugs pose serious challenges for public health, public safety and the health and well-being of Canadians through their potential to cause dependence, illness and/or harm.

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Health Promotion and Chronic Disease Prevention in Canada: Research, Policy and Practice is seeking relevant topical research articles that:

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- Examine trends or explore emerging issues in problematic use of cannabis, opioids, alcohol, tobacco and other emerging substances;
- Synthesize and/or review evidence on substance-related policies and interventions in the Canadian context.

Article submissions may also address at-risk, marginalized or under-studied populations, stigma and discrimination, social determinants, lifecourse epidemiology, marketing, retail and accessibility of substances, and prevention across different settings. Substances of interest include cannabis, alcohol, tobacco, opioids, and other psychoactive substances. In addition, we welcome articles that examine the use of new e-cigarette (“vaping”) products.

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Auger N, Arbour L, **Luo W**, et al. Maternal proximity to extremely low frequency electromagnetic fields and risk of birth defects. *Eur J Epidemiol.* 2019;34(7):689-97. doi: 10.1007/s10654-019-00518-1.

Bixby H, Bentham J, Zhou B, [...] **Robitaille C**, [...] **Wang MD**, et al; NCD Risk Factor Collaboration (NCD-RisC). Rising rural body-mass index is the main driver of the global obesity epidemic in adults. *Nature.* 2019;569(7755):260-4. doi: 10.1038/s41586-019-1171-x.

Carpiano RM, Polonijo AN, **Gilbert N**, **Cantin L**, et al. Socioeconomic status differences in parental immunization attitudes and child immunization in Canada: findings from the 2013 Childhood National Immunization Coverage Survey (CNICS). *Prev Med.* 2019; 123:278-87. doi: 10.1016/j.ypmed.2019.03.033.

Dzakpasu S, **Deb-Rinker P**, Arbour L, [...] **Liu S**, **Luo W**, [...] **Nelson C**, et al., for the **Canadian Perinatal Surveillance System**. Severe maternal morbidity in Canada: temporal trends and regional variations, 2003-2016. *J Obstet Gynaecol Can.* 2019; pii: S1701-2163(19)30089-1. doi: 10.1016/j.jogc.2019.02.014.

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