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Identifying patterns of alcohol use among secondary school students in Canada: a multilevel latent class analysis

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Abstract

Introduction: Harm from alcohol use depend not only on the volume of consumption but also on drinking patterns. This study identifies patterns of alcohol consumption in youth and investigates how these patterns vary across schools and whether individual- and school-level factors are associated with engagement in patterns of alcohol consumption.

Methods: The sample consists of 45,298 grade 9 to 12 students attending 89 secondary schools across Ontario and Alberta (Canada), who participated in the COMPASS study during the school year 2013-14. The frequency of drinking, the frequency of binge drinking, and age of alcohol-use initiation were used to characterize alcohol use patterns.

Results: The multilevel latent class analysis identified 4 student-level latent groups and 2 school-level latent groups. Student-level groups of youth were characterized as *non-drinkers* (44.2%), *light drinkers* (41.8%), *regular drinkers* (11.1%), and *heavy drinkers* (2.9%). Two groups of schools were characterized as either *low-use* (44.9%) or *high-use* (55.1%) schools, with significantly different probability of membership in each student-level group. Male students (OR 1.30) and upper grades (OR 1.93) were significantly associated with membership in higher use groups of individuals. The median household income and the number of off-premise alcohol outlets had no significant association with patterns of alcohol consumption within schools.

Conclusions: A large proportion of students reported a level of drinking, suggesting that, in addition to delaying the onset of alcohol use, interventions need to encourage drinker students to quit drinking or lower their consumption. Schools may need to select and/or alter external interventions according to the dominant patterns of alcohol use among their students.

Key words: Youth, alcohol consumption, substance use, school

1.1 Introduction

Youth consumption of alcohol is widely recognized as a critical public health concern globally (World Health Organization, 2018). In Canada, the prevalence of drinking among youth 15 to 19 years old is 60%, of drinkers 46% undertake binge drinking (Public Health Agency of Canada, Invalid date). Numerous consequences associated with underage drinking, including traffic accidents (Brubacher et al., 2016), unprotected sexual activity (Ellickson, Tucker, & Klein, 2003), suicide (Landberg, 2009), mental health disorders (Brière, Rohde, Seeley, Klein, & Lewinsohn, 2014), and poor academic performance (Patte, Qian, & Leatherdale, 2017), and impose significant costs on individuals and society. Moreover, the age at which youth start drinking is associated with subsequent trajectories; the earlier an individual start to drink, the greater the risk of higher levels of consumption later (Lee, Corte, & Stein, 2018).

The harms of alcohol consumption depend not only on the volume of consumption but also on drinking patterns (Degenhardt, Stockings, Patton, Hall, & Lynskey, 2016; Gilmore et al., 2016). How frequently and how much an individual drink can increase or decrease alcohol–related consequences. Past research identified between 3 to 6 distinct patterns of alcohol use among youth, including non-drinkers, light drinkers, and heavy/binge drinkers (Auerbach & Collins, 2006; Peterson, Davis, & Smith, 2018; Romelsjö, 2010), indicating that the youth population is heterogeneous with respect to drinking patterns. Therefore, this population can be classified into distinct subgroups, each representing a pattern of alcohol consumption, such as low frequency, low quantity, no heavy episode drinkers and high frequency, high quantity, heavy episode drinkers (Maldonado-Molina & Lanza, 2010).

Socioecological models suggest that alcohol use patterns are best understood as embedded within social contexts. These contexts can be proximal in terms of individual (e.g., early initiation of alcohol consumption), family (parental disciplines and family bonding) and peer groups (rates of use and attitude to alcohol). However, others are more distal, including schools (school environment and academic achievement), community (neighbourhood norms and average household income), and provincial and national (taxation and minimum legal drinking age) (Brooks-Russell, Simons-Morton, Haynie, Farhat, & Wang, 2014; Liang & Chikritzhs, 2015; Nash, McQueen, & Bray, 2005; Soloski, Kale Monk, & Durtschi, 2016). According to these models, students within the same school often share common socioeconomic and cultural

characteristics that may increase (or decrease) the likelihood of engagement in certain patterns of alcohol use compared to students attending other schools. Ignoring the clustering structure of individuals within schools may lead to misclassification of individuals into latent classes of alcohol use (Finch & French, 2014; Kaplan & Keller, 2011). To account for the clustering structure, past researchers either employed multilevel models (Chan, Leung, Connor, Hall, & Kelly, 2017; Duncan, Duncan, & Strycker, 2002; Rowland, Toumbourou, & Livingston, 2015; Stockwell et al., 2009) or included neighbourhood factors such as density of alcohol outlets in their modelling approach (Larsen et al., 2017; Ransome, Luan, Shi, Duncan, & Subramanian, 2018). For example, Rowland et al. (2015) used a multilevel regression model to explore the association between alcohol outlet density and youth purchasing and consumption of alcohol. In another study, Larsen et al. (2017) examined the link between access to alcohol in school neighbourhoods and binge drinking among youth in Ontario (Canada) using GIS data to measure the density of outlets and distance to outlets. However, few studies have accounted for the nested structure of students within schools when identifying latent classes of alcohol use. Moreover, there is a dearth of research on the effects of neighbourhood factors, such as the number of alcohol outlets and family income, on membership in alcohol use latent classes.

In this study, to address this knowledge gap, we used latent class analysis (LCA) to determine whether there is a latent structure that represents the heterogeneity in the drinking patterns of a sample of Canadian secondary school students. LCA is a person-centred approach that assumes individuals can be classified into distinct classes of an underlying categorical variable (Collins & Lanza, 2013). Individuals in the same class of this latent variable are similar and share common characteristics in terms of, in this study, their alcohol use. Understanding distinct patterns of alcohol use is important to public health interventions to reduce alcohol-related harm by targeting the highest-risk groups (Craig et al., 2012; Kaplan & Keller, 2011; Lanza & Rhoades, 2013). Specifically, the present study seeks to address research gaps by applying multilevel latent class analysis to a large sample of cross-sectional data from secondary school students in Ontario and Alberta, Canada to (1) identify distinct patterns (classes) of alcohol use among the youth population; (2) investigate the patterns of alcohol use among schools and classify schools according to students' alcohol use patterns; and (3) examine the effects of individual- and neighbourhood-level covariates on alcohol-use class memberships.

1.2 Materials and methods

1.2.1 Participants and procedures

Study participants were drawn from Year 2 (Y2: 2013-2014) of the COMPASS (Cannabis, Obesity, Mental health, Physical activity, Alcohol use, Smoking, and Sedentary behaviour) study. This longitudinal study was designed to collect hierarchical longitudinal data from a cohort of students in grades 9 through 12 in Ontario and Alberta, Canada. A full description of the COMPASS study can be found elsewhere (Leatherdale et al., 2014). In Y2, 45,298 students, representing an average participation rate of 70.2%, were recruited from 89 secondary schools across Ontario (n=79) and Alberta (n=10). The recruiting employed an active-information passive-consent procedure to recruit participants from the schools. The students completed the self-reported questionnaire during school time. The sample was evenly split in terms of gender (49.4% female) and school grades 26.2% (n=11,793) in Grade 9, 26.2% (n=11,817) in Grade 10, 24.9% (n=11,229) in Grade 11, and 22.7% (n=10,233) in Grade 12.

1.2.2 Instruments

Consistent with measures used in national surveillance tools for the youth population (Canadian Student Tobacco, Alcohol and Drug Survey, 2017), the study used three variables to quantify individuals' alcohol use patterns: (1) the frequency of alcohol consumption, (2) the frequency of binge drinking, and (3) age of alcohol-use initiation. The frequency of drinking 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 frequency of binge drinking was assessed by the question "In the last 12 months, how often did you have 5 drinks of alcohol or more on one occasion?" Because of a skewed distribution of responses and in keeping with the WHO alcohol use disorders identification test (AUDIT) (World Health Organization, 2001), the responses were coded into four outcomes: nonuser, up to 3 times a month, 1 to 3 times a week, and more than 3 times a week. Responses on binge drinking were also categorized into four outcomes: no binge drinking, once a month or less, 2 to 4 times a month, and more than once a week. The age of alcohol initiation, for the students who indicated alcohol consumption, was defined as occurring at before age 14, the age at which students generally begin secondary school, and age 14 or after.

The study included student-level characteristics of gender and grade (grade 9 to 12). Moreover, neighbourhood-level characteristics of median household income (MHI), as a proxy for the socioeconomic status of families, and the number of off-premise alcohol outlets were also included. MHIs were generated using the census divisions that corresponded with school postal codes according to data from the 2011 National Household Survey (Statistics Canada, 2013). The median of MHI within the COMPASS school communities was $61,830, with a range of $29,171 to $114,271. The number of alcohol outlets was quantified by the number of off-premise alcohol outlets within a 10 km buffer zone around schools. This buffer was chosen to reflect proximity in the sense of accessibility by driving. To examine the influence of buffer zone choice on the association between the number of alcohol outlets around schools and patterns of alcohol use, a sensitivity analysis was performed and the analysis repeated with 5 km and 2 km buffer zones. Locations of off-premise alcohol outlets were obtained from Enhanced Points of Interest (EPOI) databases (DMTI Spatial Inc, 2017); these vector GIS databases provide information on the location of specific services and businesses for all provinces/territories of Canada.

1.2.3 Data Analysis

Analyses proceeded through three phases. In Phase 1, we ignored the nested structure of students within schools and used traditional latent class analysis (LCA) to explore the number of alcohol-use patterns. We began model building by determining the optimum number of classes, starting with a one-class model. At each subsequent step, we fitted successive models with an increasing number of classes. Each model was refitted using 50 random sets of starting values to ensure that we found the global maximizer for the likelihood function (Nylund, Asparouhov, & Muthén, 2007). The relative fit of models was evaluated using the Bayesian information criterion (BIC) (Nylund et al., 2007). The quality of class separation was measured by the entropy statistics, which is a weighted average of class membership probabilities on the (0,1] scale (Ramaswamy, Desarbo, Reibstein, & Robinson, 1993). The closer the value of the entropy statistics is to 1 the more accurately each student can be classified into one of the classes.

In Phase 2 of the analysis, we used a nonparametric multilevel LCA (MLCA) to account for the hierarchy of students within schools. The nonparametric MLCA poses an additional between-school (Level 2) latent structure that is created using the prevalence of within-school (Level 1) latent classes. A brief description of the nonparametric MLCA is provided in the

Appendix. To find the optimum number of Level 2 latent classes, a series of latent class models was fitted to the prevalence values of Level 1 latent classes estimated in the previous phase.

In Phase 3, we included student- and school-level characteristics to in MLCA to evaluate their effects on membership of student- and school-level groups. Adjusted odds ratios and confidence intervals were used to summarize the effect of covariates. Nonparametric MLCA was performed in Mplus version 8.0 (Muthen & Muthen, 2017). The rates of non-response were 3.2%, 0.3%, and 5.7%, for the frequency of drinking, frequency of binge drinking, and age of drinking initiation, respectively. Mplus uses the full information maximum likelihood (FIML) (Schafer, 1997) and retains subjects with non-response items on the three alcohol variables, but cases with missing covariates are removed from the analysis. No values were missing for the two school-level variables of MHI and the number of the off-premise outlets. The missing rates for the student-level covariates of age (0.4%), grade (0.5%), and gender (0.1%) were very low, with no pattern, so removing the cases from the analysis would not change the results.

1.3 Results

Among participants in the study, 26,503 (58.5%) students reported some level of alcohol drinking during the past year, of which 9,512 students (35.9%) had consumed their first drink before age 14. Binge drinking was reported by 28,774 (63.5%) students. Table 1 presents the frequency of alcohol consumption and binge drinking according to baseline covariates. Males reported alcohol consumption and binge drinking more frequently than females. The results indicate that only 24.3% (n=2432) of Grade 12 students reported no drinking, which is less than half the rate among Grade 9 students (65.1%). Nearly 60% of Grade 12 students reported binge drinking during the past year, compared to 19.3% of students in Grade 9. Table 1 indicates that almost one in four Grade 12 students (24.3%) had remained non-drinkers up to the time of graduation. The results suggest that alcohol consumption and binge drinking rates among youth in Alberta and Ontario were comparable. Similar patterns of use were also reported by youth in different levels of household income and in communities with different number of alcohol outlets (Table 1).

Table **Error! No text of specified style in document.**1. Characteristics of secondary school students in Year 2 (school year 2013-14) of the COMPASS study (n=45,298)

Characteristic	N	Frequency of alcohol consumption				Frequency of binge drinking			
		None	3- times a month	1-3 times a week	3+ times a week	None	1- times a month	2-4 times a month	2+ a week
Gender									
Female	22,149	9260 (42.5[a])	10541 (48.3)	1742 (8.0)	271 (1.2)	13309 (60.3)	5786 (26.2)	2554 (11.6)	434 (2.0)
Male	22,712	9384 (42.6)	9382 (42.6)	2489 (11.3)	781 (3.5)	13279 (58.7)	5274 (23.3)	367 (13.6)	998 (4.4)
Grade									
9	11,793	7482 (65.1)	3396 (29.5)	424 (3.7)	199 (1.7)	9485 (80.7)	1549 (13.2)	515 (4.4)	199 (1.7)
10	11,817	5215 (45.1)	5,204 (45.0)	903 (7.8)	238 (2.1)	7442 (63.2)	2809 (23.9)	1224 (10.4)	296 (2.5)
11	11,229	3597 (32.8)	5,707 (51.9)	1346 (12.3)	330 (3.0)	5642 (50.4)	3269 (29.2)	1800 (16.1)	479 (4.3)
12	10,233	2432 (24.3)	5,695 (56.9)	1577 (15.7)	313 (3.1)	4136 (40.6)	3463 (33.9)	2108 (20.7)	494 (4.8)
Province									
Ontario	41,734	17,592 (43.2)	18322 (45.0)	3837 (9.4)	975 (2.4)	25070 (60.3)	10103 (24.3)	5099 (12.3)	1305 (3.1)
Alberta	3,564	1203 (34.2)	1750 (49.8)	442 (12.6)	118 (3.4)	1771 (49.8)	1030 (29.0)	579 (16.3)	175 (4.9)
Household income									
<=$61.830[b]	22,350	9377 (43.0)	9930 (45.5)	1996 (9.2)	500 (2.3)	13277 (59.6)	5553 (24.9)	2754 (12.4)	686 (3.1)
>$61,830	22,948	9418 (42.0)	10142 (45.2)	2283 (10.2)	593 (2.6)	13564 (59.3)	5580 (24.4)	2924 (12.8)	794 (3.5)
Alcohol outlets									
<=8[c]	23,457	9031 (39.4)	10749 (46.8)	2555 (11.1)	611 (2.7)	13077 (56.0)	6042 (25.9)	3345 (14.3)	890 (3.8)
>8	21,841	9764 (45.9)	9323 (43.8)	1724 (8.1)	482 (2.2)	13764 (63.2)	5091 (23.4)	2333 (10.7)	590 (2.7)

[a] percent, [b] the median of household income, [c] the median number of off-premise alcohol outlets within 10 km buffer around schools

Latent class identification began with examining the 1-through 5-class models. Table 2 represents the overall fit statistics and model comparisons. BIC decreased substantially from the 1-class model to the 4-class model, and then began to increase. Entropy of the 4-class model was 0.93 compared to 0.87 for the 5-class model. The mean posterior probabilities for classes of the 4-class model were 0.94, 0.96, 0.96, and 0.82, showing a high separation of latent classes. According to the fit indices, as well as considerations of model interpretability and parsimony, we selected the 4-latent class model as the best representation of alcohol patterns of participating youth in the study.

Table **Error! No text of specified style in document.**2. Fit statistics for latent class models at Level 1 and Level 2 for alcohol use of youth participating in Year 2 (school year 2013-14) of the COMPASS study (n=45,298)

	Log-Likelihood	Degrees of Freedom	AIC	BIC	Entropy
Level 1 models					
1	-138,298	40	276,613.2	276,683.1	1.00
2	-103,749	30	207,532.8	207,681.1	0.97
3	-98,727	21	197,506.1	197,732.8	0.94
4	-97,931	12	195,932.5	196,237.7	0.93
5	-98,341	3	196,770.7	197,154.5	0.87
Level 2 models (nonparametric model with 4 classes of Level 1)					
2	-97,566	8	195210.3	195550.4	0.91
3	-114,480	4	229047.5	229422.5	0.91

Table 3 shows the item-response probabilities and the size of each pattern in the 4-class model. We labeled the latent classes as: non-drinkers (had never consumed alcohol or did not drink in past year, size 44.2%), light drinkers (initiated alcohol consumption at age 14 or later and consumed alcohol up to 3 times a month with one time binge drinking, size 41.8%), regular drinkers (initiated drinking before age 14 and consumed alcohol 1 to 3 times a week and undertook binge drinking 2 to 4 times a month, size 11.1%), heavy drinkers (initiated drinking before age 14 and consumed alcohol more than three times a week with binge drinking more than once a week, size 2.9%). Figure 1 describes how the four identified alcohol patterns were distributed across schools. Although, the heavy-drinker class was the smallest of the four classes, this class was identified in all schools, with a range of 2.2% to 9.3%.

In the next step, we conducted a nonparametric multilevel LCA to account for the nested structure of students within schools. In this model, a Level 2 latent variable was added based on the size of Level 1 latent classes. Comparison of BICs between the 2-class and 3-class nonparametric models (Table 2) indicates that the 2-class model adequately represents the school-level latent classes. With the addition of Level 2 latent classes, the BIC of the model declined by $\Delta_{BIC} = 687$, and the entropy of the model improved from 0.89 to 0.91. Furthermore,

the average posterior probabilities for eight combinations of classes (four individual classes and two school classes) were greater than 0.76. All of these measures suggested that adding the Level

Table **Error! No text of specified style in document.**3. Conditional item-response probabilities and the prevalence of latent classes of youth alcohol-use behaviours in Y2 (school year 2013-14) of the COMPASS study (n=45,298)

	Non-drinker	Light Drinker	Regular drinker	Heavy drinker
Prevalence	44.2%	41.8%	11.1%	2.9%
Alcohol consumption				
Non-user	0.988	0.004	0.000	0.001
Up to 3 times a month	0.012	0.996	0.199	0.000
1 to 3 times a week	0.000	0.000	0.780	0.269
3+ times a week	0.000	0.000	0.021	0.730
Binge drinking				
No binge drinking	0.998	0.348	0.056	0.024
Once a month or less	0.002	0.531	0.209	0.047
2-4 times a month	0.000	0.121	0.646	0.135
More than once a week	0.000	0.000	0.089	0.794
Age of alcohol initiation				
No use	0.991	0.060	0.052	0.102
Age 13 or before	0.009	0.323	0.485	0.808
After age 13	0.000	0.617	0.462	0.090

2 latent classes improved the fit of the model and produced fairly robust results with a high degree of latent structure recognition.

Figure 2 illustrates the distribution of individual-level latent classes within the two school-level classes. The class of low-use schools (n=40, 44.9% of schools) is comprised of schools with a relatively large number of nonusers. The average of non-drinkers in this group of schools is 14% higher than the average of high-use schools. In contrast, the class of high-use schools (n=49, 55.1% of schools) is comprised of schools that have higher rates of regular and heavy drinkers. The proportions of regular and heavy drinkers in high-use schools were nearly double the proportions in low-use schools: 11.8% and 7.2% compared to 6.0% and 4.6%, respectively.

Table **Error! No text of specified style in document.**4. Estimated Odds ratios from a multilevel latent class analysis reflecting the effects of covariates on membership of latent classes of youth alcohol drinking in Y 2 (school year 2013-14) of the COMPASS study (n=45,298)

Characteristic		Latent class		
Individual-Level	Non-drinkers	Light drinkers	Regular drinkers	Heavy drinkers
Gender (male)	Reference class	2.82 (2.38, 3.36)	1.24 (1.18, 1.31)	1.30 (1.19, 1.42)
Grade	Reference class	1.44 (1.29, 1.61)	1.07 (0.98, 1.18)	1.93 (1.77, 2.10)
School-Level	Low use	High use		
Median household income	Reference class	1.53 (0.64, 3.70)		
Number of alcohol outlets	Reference class	1.01 (0.98, 1.03)		

We then extended the MLCA model to incorporate the student-level (i.e., gender and grade) and school-level covariates (i.e., median household income and the number of off-premise alcohol outlets). Table 4 shows the estimates of odds ratios that compare the baseline group of non-drinkers with the other three groups at Level 1 (individual-level classes) and compare the baseline group of low-use schools with the group of high-use schools at Level 2 (school-level classes). As can be seen, both the gender and grade of individuals significantly were associated with student-level latent class membership. The likelihood of being a heavy drinker compared to a non-drinker for male students was 1.3 (95% CI:1.19-1.42) greater than that of female students. Grade comparisons indicate that the odds of the membership in light drinker class (OR=1.44, 95% CI:1.29-1.61) and heavy drinker class (OR=1.93, 95% CI: 1.77-2.10) increased as students moved to upper grades. However, the difference in the odds of membership in the regular drinker class was not significant (OR=1.07, 95% CI:0.98-1.18). Table 4 indicates that the number of off-premise alcohol outlets within a 10 km buffer was not significantly associated with latent class memberships (OR=1.01, 95% CI:0.98-1.03). The results of the sensitivity analysis confirmed this finding; the ORs for the number of alcohol outlets within 5 km buffer (median 3, range 0-32 outlets) and within 2 km buffer (median 1, range 0-10 outlets) were 1.01 (95% CI:0.98-1.03) and 1.03 (95% CI:0.78-1.35), respectively. The median household income of neighbourhood also had no significant association with latent class memberships (OR=1.53, 95% CI:0.64-3.70).
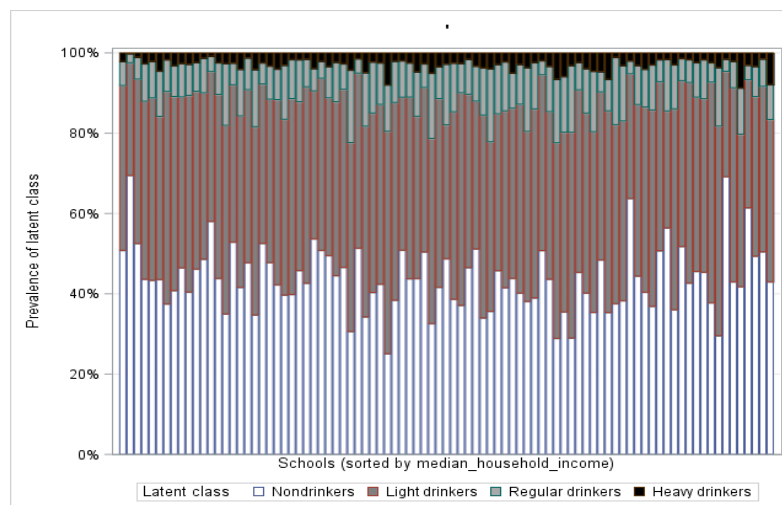
Figure **Error! No text of specified style in document.**1. The proportion of latent classes of youth alcohol drinking (n=45,298) across schools participating in the COMPASS study in Ontario (n=70) and Alberta (n=10). Schools are sorted by median household income, from lowest (Left) to highest (Right)

1.4 Discussion

This study has explored the patterns of alcohol consumption among a sample of Canadian secondary school students from Ontario and Alberta. Employing multilevel latent class analysis, the study identified four subpopulations of individuals characterized as non-drinkers, light drinkers, regular drinkers, or heavy drinkers. Male and upper grade students had greater likelihood of engaging in high-level patterns of alcohol consumption. The model also identified two groups of schools: low-use (schools with a relatively large number of non-drinkers) and high-use (schools with higher rates of regular and heavy drinkers). Neighborhood factors of median household income and number of off-premise alcohol outlets had no significant association with patterns of alcohol consumption.

Levels of alcohol consumption and binge drinking show that three out of four groups were engaged in binge drinking. This finding supports previous research indicating that binge drinking is a common pattern of alcohol use among youth who drink and accounts for large proportion of drinking occasions among Canadian youth (Flewelling, Paschall, & Ringwalt, 2004; Miller, Naimi, Brewer, & Jones, 2007).
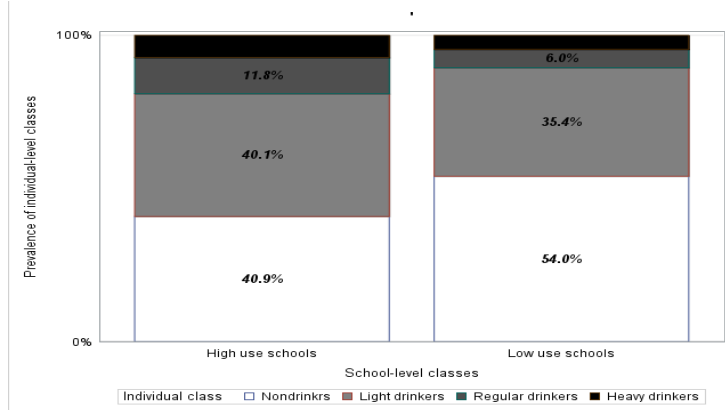
Figure **Error! No text of specified style in document.**2. The proportion of latent classes of youth alcohol drinking (n=45,298) across schools participating in the COMPASS schools in Ontario (n=70) and Alberta (n=10) within the two classes of schools identified by nonparametric multilevel latent class analysis

Past research suggests that youth drinking is likely to be binge drinking for different reasons, including unmatured impulse control, peer pressure, and unawareness of consequences (Deas, Riggs, Langenbucher, Goldman, & Brown, 2000; Gray, 2017; Soloski et al., 2016), and is associated with a high risk of immediate and long-term harms. Therefore, for a large proportion of youth drinkers, we can expect alcohol-related consequences that could be prevented or at least limited if alcohol consumption was delayed as long as possible.

Consistent with past research addressing a direct association between early initiation of alcohol consumption and an increased likelihood of heavy drinking (Gruber, DiClemente, Anderson, & Lodico, 1996; Kim et al., 2017; Liang & Chikritzhs, 2015), this study found that the heavy drinker group is characterized by alcohol-consumption initiation before age 14. This finding indicates that early initiation to alcohol consumption increases the risk of later engagement in heavy drinking. This increased risk could be because early drinkers have more time to increase their consumption, or because early drinkers are more likely to become involved with other substances (e.g., tobacco and cannabis) that often leads to greater alcohol consumption (Gruber et al., 1996; Peleg- Oren, Saint- Jean, Cardenas, Tammara, & Pierre, 2009). This result underscores the need for screening for alcohol consumption in early adolescence, even before youth start secondary school, to reduce alcohol-related harm (Peleg-

Oren et al., 2009). Although the majority of regular drinkers began drinking before secondary school, the high proportion of regular drinkers who started drinking at age 14 or after suggests that even those who start later are at risk of heavy drinking.

Similar to previous research (Jackson & Schulenberg, 2013), we found a significant association between gender and alcohol class membership, where being male was associated with increased odds of membership in risky drinking groups; nonetheless, there are still a considerable number of females in the heavier drinking groups. Our study also confirms the significant increase in rates of heavy drinking from grade 9 to grade 12 reported by others (Freeman, King, & Picket, 2016; Leatherdale & Rynard, 2013).

In addition to the individual-level latent classes, the study identified two groups of schools (i.e., low-use schools and high-use schools), indicating that the probability of engagement in a certain pattern of alcohol use significantly differed between schools. This finding suggests that those initiating prevention programs may require more intensive efforts in high-use schools.

To describe part of the variation across schools, we incorporated the median household income and the number of off-premise alcohol outlets into the model. Household income was not significantly associated with group membership across schools. This finding supports past research that indicated a null association between the amount of alcohol consumption among youth and family socioeconomic status (Åslund & Nilsson, 2013; Brenner, Bauermeister, & Zimmerman, 2011; Cambron, Kosterman, Catalano, Guttmannova, & Hawkins, 2018). This nonsignificant association may be explained by the high variability of family income within each neighborhood and the fact that the family income has a greater association with youth alcohol use compared to neighborhood-level median household income (Leventhal & Brooks-Gunn, 2000; Wodtke, Harding, & Elwert, 2011). For example, youth in high income families in disadvantaged communities may have heavier drinking patterns than youth in low income families (or vice versa), which attenuates the effect of family income on youth alcohol use patterns (Cambron et al., 2018). Another explanation for this finding could be that the small size of the class of heavy drinkers and close distribution of patterns across the two groups of schools make the effect of income statistically nonsignificant. Moreover, given the possibility that families may live in different socioeconomic neighborhoods over time, accounting for only the

current neighborhood income may lead to bias toward underestimation of the impact of neighborhood context (Cambron et al., 2018).

The number of off-premise alcohol outlets also had no significant association with youth drinking patterns, supporting past research in which the density of off-premise alcohol outlets around schools had no impact on student alcohol consumption (Larsen et al., 2017). Part of this nonsignificant effect can be attributed to the fact that there were no COMPASS schools without an alcohol outlet nearby, which indicates how available alcohol is to the youth population. Similar to research on tobacco that suggests density of tobacco outlets may not be important to the smoking behaviour of established/regular smokers (Adams, Jason, Pokorny, & Hunt, 2013; Marsh et al., 2016), this finding indicates that the presence or absence of alcohol-selling outlets is more relevant than the total number because the neighbourhood population could be served by a single outlet (Wagenaar, 1995). This result suggest that policy and programs need to reduce the current availability of alcohol to youth.

To the best of our knowledge, this research is among the few studies that have examined how patterns of youth alcohol consumption may vary across schools. The multilevel LCA used has the ability to adjust estimates of group-membership probabilities based on the hierarchy of students within schools. The method also allows researchers to investigate the association between distal and proximal factors in membership in both level 1 (individual) and level 2 (school) latent classes (Henry & Muthén, 2010; Vermunt, 2003). The data from 89 schools dispersed across Ontario and Alberta provided a heterogeneous sample of schools and students that enhanced the accuracy of identifying the alcohol use patterns. The large sample of secondary school students also ensured our ability to identify latent groups more precisely. Moreover, alcohol use indicators in the COMPASS questionnaire collect data on a multiple option response basis that enabled tracking of changes in consumption level rather than changes in less informative outcomes, such as use vs. no use, most commonly employed by previous studies (Jackson & Schulenberg, 2013; Malone, Van Eck, Flory, & Lamis, 2010).

This study is subject to some limitations. First, the research relied on self-reports of alcohol use, which may be subject to measurement errors and recall and social desirability biases that may lead to underreporting of alcohol use (Butt, Beirness, Gliksman, Paradis, & Stockwell, 2011). However, self-reported alcohol use measures have previously been demonstrated to be

reliable and valid and have been widely used in national surveys (Canadian Student Tobacco, Alcohol and Drug Survey, 2017). Moreover, the applied analytical method of LCA partially addressed the measurement errors by probabilistic assignment of individuals to latent classes (Collins & Lanza, 2013). Second, the binary boundary used for distances of both urban and rural schools from grocery stores may result in biased correlation between alcohol use patterns and proximity of alcohol outlets because, for example, 10 km in an urban region can be a long distance, whereas it might be a short distance in rural area. Third, in this study we relied on neighbourhood median household income to measure the association between household income and youth alcohol consumption which may underestimate the association compared to more the reliable measure of individual family income (Cambron et al., 2018; Wodtke et al., 2011). Finally, because that the students data were drawn from a non-random sample of schools, the results of this study are not representative of the general youth population in Ontario and Alberta. However, given the large sample size, the results will have important implications for current research and practice. Furthermore, the COMPASS study employs a passive-consent approach for enrolling students into the study, which results in a higher rate of participation and lower nonresponse bias in survey data than an active-consent approach would (Courser, Shamblen, Lavrakas, Collins, & Ditterline, 2009).

1.5 Conclusions

Our study identified four distinct latent alcohol use patterns among secondary school students; three of the patterns identified students who reported a level of drinking. This finding indicates that, in addition to prevention efforts that aim at delaying the onset of alcohol use as long as possible, we need intervention programs to encourage drinkers, especially regular and heavy drinkers, to quit drinking or lower their consumption. Significant differences in the size of alcohol use classes among schools suggest that global programs may not be effective for all schools. Schools need to select and/or alter external (national, provincial, or local) prevention programs according to the dominant patterns of alcohol use among their students.

Conflict of Interest The authors declare that they have no conflict of interest.

Appendix: Multilevel latent class model

Let Y_{ijk} denote the response of individual i, $1,2,\ldots,n$, within a cluster k, $1,2,\ldots,\mathrm{K}$, on the jth question, and let each question j, $1,2,\ldots,M$, have a possible discrete response $r_j, 1,2,\ldots,\mathrm{R_j}$. The latent class model can be written as follows (Collins & Lanza, 2013):

$$p(Y_{ik1} = r_1, Y_{ik2} = r_2, \ldots, Y_{ikM} = r_M | X_{ik})$$

$$= \sum_{c=1}^{L} p(C_{ik} = c | X_{ik}) \prod_{j=1}^{M} \prod_{r_j=1}^{R_j} p(Y_{ikj} = r_j | C_{ik} = c)^{I(y_{ikj} = r_j)}$$

where C_{ij} is the latent class membership, c is used to refer to a particular latent class, $C_{ik} = 1,2,\ldots,L$, $I(y_{ikj} = r_j)$ is an indicator function that equals 1 if the response to question $j = r_j$ and equals zero otherwise, and X_{ik} is a vector of individual covariates. The parameters of the model are estimated using the expectation-maximization (EM) algorithm. Traditional LCA assumes that observations are independent of one another. In the current research, however, students are classified into schools and the independent assumption is violated. As such, a multilevel LCA was used.

Multilevel LCA (MLCA) considers the two-level structure of data and allows latent class memberships to vary across schools (Finch & French, 2014; Henry & Muthén, 2010). For the nonparametric approach of MLCA used in this dissertation, between-cluster variations are expressed through assuming an additional latent structure for level 2 units. That is, similar to the level 1 latent structure that is defined using observed indicator variables, the between–cluster structure is created using the prevalence of level 1 class memberships. Thus, clusters belong to one of T cluster-level mixture components, and each class of level 2 consists of clusters with similar prevalence of within-cluster level 1 classes. The MLCA can be now be expressed as

$$p(Y_{ik1} = r_1, Y_{ik2} = r_2, \ldots, Y_{ikM} = r_M | W_k, X_{ik}, Z_k)$$

$$= \sum_{c=1}^{L} p(C_{ik} = c | W_k = w, X_{ik}, Z_k) \prod_{j=1}^{M} \prod_{r_j=1}^{R_j} p(Y_{ikj} = r_j | C_{ik} = c)$$

where Z_j denotes the vector of level 2 covariates, W_k represents the level 2 class membership for cluster k, and $w, 1, 2, ..., T$ is a particular level 2 class. In this representation, the probability of class membership can be defined as follows:

$$p(C_{ik} = c | W_k = w, X_{ik}, Z_k) = \frac{\exp(\gamma_c + \beta_c x_{ik} + \alpha_c z_k + \alpha_{cw})}{1 + \sum_{r=2}^{L} \exp(\gamma_c + \beta_r x_{ik} + \alpha_r z_k + \alpha_{rw})}$$

where $c = 2, 3, ..., L$, and α_{cw},, is a random latent variable associated with clusters in class w.

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Highlights

- Four distinct patterns of youth alcohol consumption were identified
- 44.2 % non-drinkers, 41.8% light drinkers, 11.1% regular drinkers, 2.9% heavy drinkers
- Schools were classified into two latent groups, 55.1% high use schools
- Gender and school grade were associated with youth alcohol consumption patterns
- The number of off-premise alcohol outlets and the neighbourhood median household income were not associated with patterns of alcohol consumption within schools