



RESEARCH ARTICLE

Substance Use Problem Trajectories in Canadian Adolescents: A Longitudinal Study

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Abstract

Background. Adolescents experience rapid changes and are more vulnerable for developing substance use problems than other age groups. Many studies have focused on the trajectories of adolescent substance use *frequencies*, rather than *symptoms*. **Objective.** The present study examined the trajectory of substance use disorder symptoms, particularly beginning in early adolescence and within a Canadian context. **Methods.** Data were drawn from a Canadian longitudinal project, in which a province-wide survey was administered to students across three biennial waves starting in grades 7-8. The final sample was comprised of 765 adolescents (baseline $M_{age} = 12.73$, $SD = 0.67$, 49.7% female, 57.6% White). Latent class analysis was conducted to identify substance use disorder symptom classes based on participants' responses on a substance use disorder screener across the three waves. Group differences tests were also computed to examine if the substance use classes differed in participants' demographics. **Results.** Four classes were identified, labelled as low stable ($n = 538$, 70.3%), deteriorating ($n = 169$, 22.1%), recovered ($n = 12$, 1.6%), and high-risk relapse ($n = 46$, 6.0%) substance use. Among the demographic variables, non-White ethnicity, both parents being born outside of Canada, and parents' completion of post-secondary education were significantly associated with a less severe substance use class. **Conclusions.** Results fill a gap in the evidence on the trajectory of symptoms of substance use disorder among adolescents, using a Canadian sample, an area of limited study. Results highlight an at-risk group (i.e., high-risk relapse class) that warrants further tailored prevention and intervention efforts.

Key Words: *substance use problem, substance use trajectory, early onset, adolescents, longitudinal*

Résumé

Contexte: Les adolescents connaissent des changements rapides et sont plus vulnérables de développer des problèmes d'utilisation de substances que d'autres groupes d'âge. De nombreuses études ont porté sur les trajectoires des *fréquences* d'utilisation de substances chez les jeunes, plutôt que des *symptômes*. **Objectif:** La présente étude a examiné la trajectoire des symptômes du trouble d'utilisation de substances, particulièrement lorsque le trouble commence au début de l'adolescence et dans un contexte canadien. **Méthodes.** Les données ont été tirées d'un projet longitudinal canadien, dans lequel un sondage à l'échelle provinciale a été administré à des élèves sur trois vagues biennales à partir de la 7^e à la

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8^e année. L'échantillon final comptait 765 adolescents (à la base $M_{\text{âge}} = 12,73$, $ET = 0,67$, 49,7 % féminin, 57,6 % Blancs). L'analyse de classe latente a été menée pour identifier les classes de symptômes du trouble d'utilisation de substances selon les réponses des participants à un dépisteur du trouble d'utilisation de substances dans les trois vagues. Les tests de différences des groupes ont aussi été calculés pour examiner si les classes d'utilisation de substances différaient dans les données démographiques des participants. **Résultats:** Quatre classes ont été identifiées, étiquetées comme faibles stables ($n = 538$, 70,3 %), se détériorant ($n = 169$, 22,1 %), rétablies ($n = 12$, 1,6 %), et à risque élevé de rechute ($n = 46$, 6,0 %) d'utilisation de substances. Parmi les variables démographiques, l'ethnicité non-blanche, les deux parents étant nés hors du Canada, et les parents ayant une utilisation de substances, terminé l'éducation post-secondaire, étaient significativement associés avec une classe moins grave d'utilisation de substances. **Conclusions:** Les résultats comblent un vide dans les données probantes sur la trajectoire des symptômes du trouble d'utilisation de substances chez les adolescents, à l'aide d'un échantillon canadien, un domaine d'étude limité. Les résultats présentent un groupe à risque (c.-à-d., une classe à risque élevé de rechute) qui justifie des efforts plus ciblés de prévention et d'intervention.

Mots clés: problème d'utilisation de substances, trajectoire d'utilisation de substances, début précoce, adolescents, longitudinal

Introduction

Adolescence is a period associated with rapid developmental changes, and adolescents are at a greater risk for developing substance use problems than other age groups (1). The most frequently used substances among adolescents are alcohol, cannabis, and tobacco, which commonly co-occur (2, 3). A U.S. study showed that about 42%, 21%, and 26% of high school students have used alcohol, cannabis, and tobacco over the past month, respectively (4). Heavy substance use is associated with negative social and health outcomes, such as substance-related injuries and illnesses, externalizing behaviour, involvement with the criminal justice system, and mental health challenges (5-8). Given widespread adolescent substance use and the harmful impact that problematic adolescent use can have, it is important to identify distinct developmental trajectories to understand the various pathways through which substance use problems develop.

Within the literature on the trajectories of substance use during adolescence, most have focused on alcohol and cannabis use *frequencies* over time. The majority of these studies are conducted within the United States (7-13), some from Europe (14-16), and few from Canada (17). Most studies have identified three to five trajectories for alcohol and cannabis use, almost all of which have at least one no/minimal use class and one high and stable frequency class, as well as some with an increasing use class.

Few studies have examined substance use trajectories that are focused on *symptoms* or disorder rather than frequency of use, the former of which may be a better indicator of substance use problems as it represents a group with more severe challenges. Substance use disorder symptoms capture the complexity of behaviour which include not only frequency of use, but also continued use despite negative

consequences and impaired functioning (18). Among these studies, some have examined substance use disorder trajectories in adults (19, 20) and from late adolescence to adulthood (21-24); however, very few studies have examined substance use disorder trajectories beginning in early adolescence (25, 26). One exception is Greenfield and colleagues (25) who examined alcohol use disorder trajectory in 673 Indigenous adolescents across five waves from ages 10 to 18, across Canada and the U.S.; the authors identified three trajectory classes, which they labelled as no symptoms (73%), later onset (18%), and high symptoms (10%). Similarly, Marti and colleagues (26) examined substance use disorder symptoms in 496 adolescent girls in the U.S. across eight waves from ages 13 to 20 and identified four symptom classes, including non-users (66%), moderate escalating (19%), moderate decreasing (10%), and heavy use only limited to adolescence (4%).

Among those studies that have included older children and young adolescents (13, 15, 25, 27), other common classes identified are early onset versus late onset. The differentiation between early onset and late onset substance use is important as early substance use (generally defined as before age 14) is associated with worse outcomes, such as an increased risk for heavier substance use, use of illicit substances, depression, poor academic performance, and risky sexual behaviour (5, 15, 27-30). Grant and Dawson (31) have found that, for each year that alcohol use was delayed in adolescence and early adulthood, the odds of lifetime alcohol abuse and dependence decreased by 8% and 14%, respectively. Nelson and colleagues (29) have argued that the association between early use and poor outcomes reflects individual (e.g., impulsivity, risk taking) and environmental (e.g., parental and peer substance use) factors.

Some demographic variables have been suggested as moderators of substance use trajectories, including sex, ethnicity, and socioeconomic status (SES) (5). Compared to females, males are more likely to be in the trajectory classes characterized by more severe substance use (2, 9, 16, 23, 29). Reasons that have been suggested for sex differences include differences in inhibition, depressed mood, and importance placed on family and peer relationships (5). The few studies that have examined ethnic differences found that White adolescents engage in higher levels of alcohol and cannabis use than Asian, Black, Hispanic, and multi-ethnic adolescents (6, 32). Furthermore, whereas some studies have found that adolescents from families with lower SES are more likely to be in classes characterized by more severe alcohol use (5, 28), others did not (33).

Objectives

The present study aims to fill a gap in the literature by identifying the trajectory of substance use disorder symptoms, particularly beginning in early adolescence and focusing on a Canadian context, areas of limited study. It is important to understand the developmental trajectory of substance use symptoms, in addition to frequency of use as commonly examined in other studies, as this likely represents a group of adolescents with more severe challenges. This is particularly crucial given the negative consequences associated with early onset substance use. Drawing from the data of a longitudinal study, which investigated mental health and substance use among 12-19 year old adolescents in Ontario, Canada, we examine (i) the trajectory of substance use disorder symptoms across three time points in adolescence; and (ii) whether substance use trajectory classes differ in participant demographics. In addition to sex, ethnicity, and family SES, other demographic variables which may differentiate among the substance use classes are explored in the present study.

Methods

Participants

Data for the current study were derived from a Canadian longitudinal project (see Brownlie et al. (34) for the sampling and survey methodology), which was approved by the ethics review board of the Centre for Addiction and Mental Health. All participants provided informed, written consent to participate in the study. Participants were recruited when they were in either Grade 7 or 8 and followed up about every two years for a total of three waves (see Henderson et al. (35) for data collection and cleaning). Wave 1 was comprised of 765 adolescents, Wave 2 was comprised of 379 adolescents, and Wave 3 was comprised of 463 adolescents;

participants' demographic characteristics are described below.

Measures

Demographic information. All participants completed a demographic questionnaire at each wave, which included questions about age, sex, ethnicity, residing region, socioeconomic status (SES), and parental variables. Family SES was assessed based on self-report, with scores ranging from 1-10 (1 = *Worst off*, 5 = *Average*, 10 = *Best off*).

Global Appraisal of Individual Needs – Short Screener (GAIN-SS), Version 2.0.3. The GAIN-SS is a self-report measure comprised of four subscale screeners, which were labelled as Internalizing Disorder Screener, Externalizing Disorder Screener, Substance Disorder Screener, and Crime/Violence Screener, with five items each (36). Each subscale score ranges from 0-5, which is based on the number of items experienced in the past year. Within each scale, the endorsement of 0 items within the past year level indicates a low probability of having a diagnosis, a score of 1 to 2 items indicates the moderate probability of a diagnoses, and a score of 3 or more items indicates a high probability of a diagnoses (37). The GAIN-SS has been validated in adolescents with good sensitivity (0.70) and specificity (0.90) to detect clinical diagnoses (36, 37).

For this study, only the Substance Disorder Screener subscale was used, which assesses heavy use (*When was the last time that you used alcohol or other drugs weekly or more often? When was the last time that you spent a lot of time either getting alcohol or other drugs, using alcohol or other drugs, or feeling the effect of alcohol or other drugs?*), physiological impact (*When was the last time that you had withdrawal problems from alcohol or other drugs like shaking hands, throwing up, having trouble sitting still or sleeping, or that you used any alcohol or other drugs to stop being sick or avoid withdrawal problems*), and continued use despite negative consequences (*When was the last time that you kept using alcohol or other drugs even though it was causing social problems, leading to fights, or getting you into trouble with other people? When was the last time your use of alcohol or other drugs caused you to give up, reduce or have problems at important activities at work, school, home, or social events?*). These items are consistent with symptoms of a substance use disorder based on the Diagnostic and Statistical Manual of Mental Disorders, fifth edition (DSM-5) (38).

Data Analysis

Latent class analysis for substance use disorder symptoms trajectory. Similar to the previous study (35), latent class analysis (LCA) for repeated measures was computed in

MPLUS 8.1 (39) to identify the trajectory of substance use disorder symptoms based on the GAIN-SS Substance Disorder Screener subscale. The GAIN-SS subscale continuous score was used in the analysis, rather than its individual items, given that the subscale score is widely accepted and validated and used clinically (40, 41). Missing values in the outcomes were handled by Maximum Likelihood estimation (42) with robust standard errors equivalent to the Huber-White sandwich method (43-45). Maximum Likelihood estimation in the presence of missing data assumes that missing data are MAR (Missing at Random) and uses all available information; it is equivalent to multiple imputation for large samples (42). Given that the GAIN-SS subscale was a count variable, a negative binomial model was used, which accounted for non-normality of the data. The fit indices that were used to evaluate the latent class models included approximate fit criteria, such as Akaike Information Criterion (AIC), Bayesian Information Criterion (BIC), sample size-adjusted Bayesian Information Criterion (SABIC), Consistent Akaike Information Criterion (CAIC), and Approximate Weight of Evidence Criterion (AWE), in which lower values indicate superior fit (46). The Vuong-Lo-Mendell-Rubin adjusted Likelihood Ratio Test (VLMR-LRT) was also used, which provides *p* values assessing if the current model was significantly improved over the model with one fewer solution (46). Based on the model that was retained, using posterior probability scores, each participant was assigned to their respective class. Of note, errors associated with computing class scores were not accounted for in the analysis.

Demographic variables and substance use classes. Following the LCA, five chi-square tests were computed in R 4.0.2 (47) to examine if participants from different substance use classes differed on the following categorical variables: (i) sex, (ii) ethnicity, (iii) whether one or more parents were born in Canada, (iv) mother's completion of post-secondary education, and (v) father's completion of post-secondary education. Given that the sampling design included schools (23 schools) as clusters and regions (4 regions) as strata, variance estimation was conducted using the Rao and Scott adjustment in the Survey Package in R 4.0.2. (48). Further, chi-square tests were adapted due to the adjustment in the Survey Package resulting in F statistics being reported in the output. Significant tests were followed by post-hoc chi-square tests for group differences based on adjusted standardized residual analysis that identified cells with greatest contribution to the results, and a more conservative cut-off value of $p < .01$ (+/- 2.58) was used to account for the multiple tests (49). It is important to note that, given the small sample size of ethnic minorities, participants' self-reported ethnicity was grouped into White versus non-White for data

analysis. In addition, multinomial logistic regression was computed in R 4.0.2 to explore how continuous variables of participants' age and family SES impacted substance use classes. Of note, multinomial logistic regression analyses did not account for clusters and strata as this is not an option in the Survey Package in R 4.0.2. Demographic analyses were computed separately, and missing values were excluded in each analysis.

Results

As noted above, the final sample for the present study was comprised of 765 adolescents ($M_{age} = 12.73$, $SD = 0.67$, age range = 11-15) at Wave 1, 379 adolescents ($M_{age} = 14.62$, $SD = 0.86$, age range = 13-16) at Wave 2, and 463 adolescents ($M_{age} = 17.12$, $SD = 0.73$, age range = 16-19) at Wave 3. See Table 1 for demographic characteristics across three waves.

Latent Class Analysis for Substance Use Disorder Symptom Trajectory

Results of latent class analysis revealed 2-5 class solutions that were differentially supported by fit indices (see Table 2). Given that there was no clear support for one solution, fit indices, model parsimony, and interpretability were all considered, which led to the 4-class solution being chosen as the best fitting model. The 4-class solution was supported by AIC, as well as only marginally lower BIC and SABIC than the 2- and 3-class solutions. Further, the 4-class solution was more meaningful than both the 2- and 3-class solutions, as well as more parsimonious than the 5-class solution, which represented minor variation from the 4-class model. Specifically, the 4-class solution included a small group of adolescents who "recovered" from substance use, as described in the following, which is important to capture as this represents a resilient group of individuals who were able to reduce their substance use and associated symptoms over time.

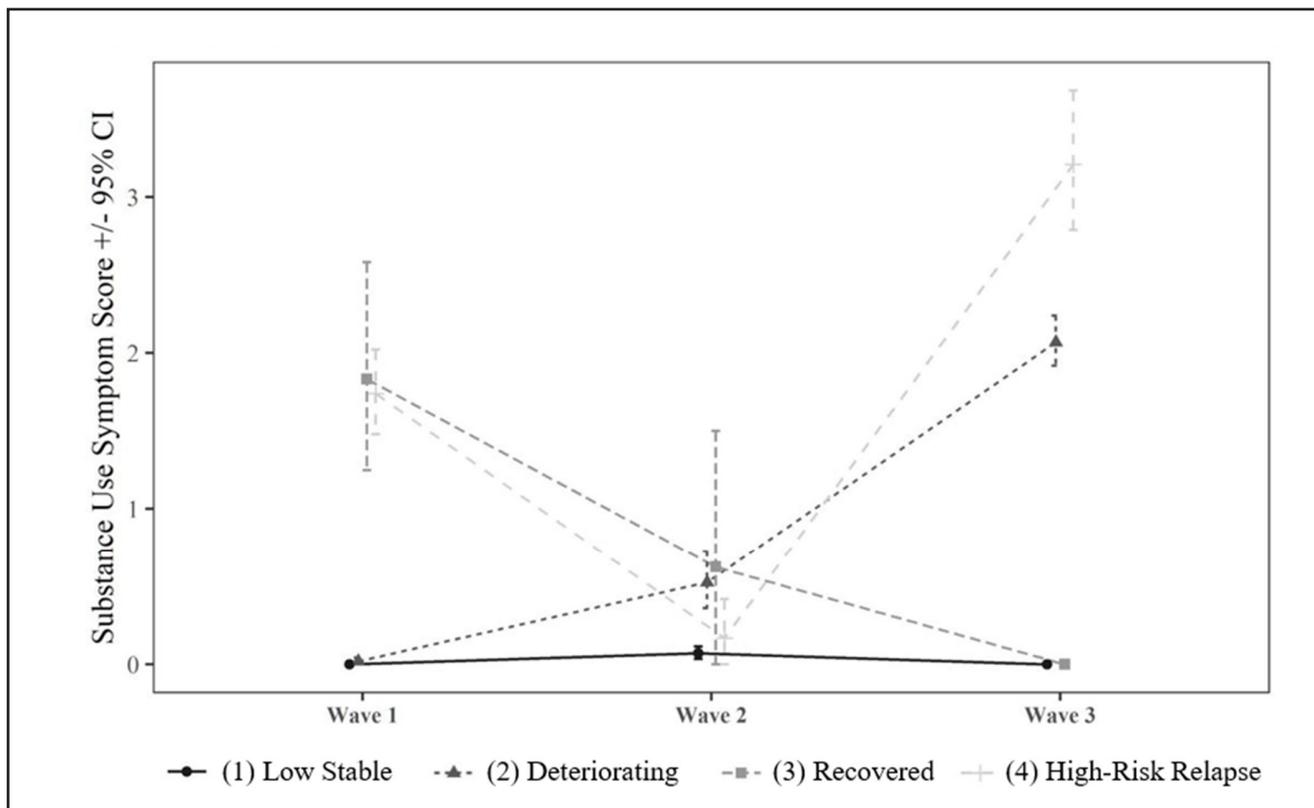
Based on visual inspection of the line graph of the 4-class solution (see Figure 1), the four class groups identified were labeled as: (i) Low Stable, characterized by minimal substance use symptoms across all three waves ($n = 538$, 70.3%); (ii) Deteriorating, characterized by low substance use symptom score at Wave 1 that increased to a moderate score at Wave 3 ($n = 169$, 22.1%); (iii) Recovered, characterized by moderate symptom score at Wave 1 that decreased to a low score at Wave 3 ($n = 12$, 1.6%); and (iv) High-Risk Relapse, characterized by moderate symptom score at Wave 1 that decreased to a low score at Wave 2, that then increased to high score at Wave 3 ($n = 46$, 6.0%). The symptom scores were derived based on means and standard errors of the GAIN-SS, after participants were assigned to

Table 1. Demographic Characteristics across Waves			
	Wave 1 (Baseline) (n = 765)	Wave 2 (n = 379)	Wave 3 (n = 463)
	M (SD)	M (SD)	M (SD)
Age	12.73 (.67)	16.62 (.86)	17.12 (.73)
Family Socioeconomic Status	7.1 (1.5)	6.8 (1.4)	6.1 (1.5)
	% (n)	% (n)	% (n)
Sex			
Male	50.5 (385)	49.1 (186)	48.1 (221)
Female	49.5 (378)	50.9 (193)	51.9 (238)
Did not indicate	0.3 (2)	0.0 (0)	0.9 (4)
Ethnicity			
Caucasian/White	62.6 (441)	58.7 (206)	60.4 (262)
Asian/Pacific Islander	18.2 (128)	23.3 (82)	21.4 (93)
Black	6.3 (44)	8.0 (28)	7.1 (31)
Indigenous	1.4 (10)	0.6 (2)	0.5 (2)
Hispanic/Latinx	2.1 (15)	2.0 (7)	1.6 (7)
Multiple	9.4 (66)	7.4 (26)	9.0 (39)
Did not indicate	8.0 (61)	7.4 (28)	6.3 (29)
Parents born in Canada			
Neither	29.7 (222)	37.9 (142)	33.6 (155)
One or more	70.3 (526)	62.1 (233)	66.4 (306)
Did not indicate	2.2 (17)	1.1 (4)	0.4 (2)
Mother's post-secondary education			
Graduated	69.5 (369)	71.7 (228)	65.9 (278)
Did not graduate	30.5 (162)	28.3 (90)	34.1 (144)
Did not indicate/No mother	30.6 (234)	16.1 (61)	8.9 (41)
Father's post-secondary education			
Graduated	66.1 (318)	65.3 (194)	58.8 (240)
Did not graduate	33.9 (163)	34.7 (103)	41.2 (168)
Did not indicate/No father	37.1 (284)	21.6 (82)	11.9 (55)

Missing values (i.e., those who did not indicate a response) were not included in calculating proportions

Table 2. Fit Statistics for Substance Use Latent Class Analysis Models								
K	LL	AIC	BIC	SABIC	CAIC	AWE	Entropy	VLMR-LRT
1	-1074	2160.0	2188.0	2169.0	2193.8	2245.7		
2	-1042	2104.0	2151.0	2119.0	2160.4	2246.8	0.448	<0.0001
3	-1039	2106.0	2171.0	2126.0	2185.0	2305.9	0.474	0.0008
4	-1034	2103.0	2187.0	2130.0	2205.5	2361.0	0.627	0.2227
5	-1030	2104.0	2206.0	2136.0	2228.1	2418.2	0.586	0.0377
6	-1027	2105.0	2226.0	2144.0	2252.6	2477.3	0.592	0.1781

LL = Log Likelihood; AIC = Akaike Information Criterion; BIC = Bayesian Information Criterion; SABIC = sample size-adjusted Bayesian Information Criterion; CAIC = Consistent Akaike Information Criterion; AWE = Approximate Weight of Evidence Criterion; VLMR-LRT = Vuong-Lo-Mendell-Rubin adjusted Likelihood Ratio Test.

Figure 1: Four-Class Solutions for Substance Use Trajectories

the classes to which they had the highest membership probability. The average probabilities of class membership are 71.3%, 94.0%, 71.4%, and 67.3%, respectively, for Classes 1, 2, 3, and 4.

Of note, given that the 3-class solution was also supported by fit indices, as well as the small sample size of one of the classes in the 4-class solution (i.e., recovered), results for the 3-class solution are additionally presented in supplemental materials.

Demographic Variables and Substance Use Classes

Results of the chi-square tests and multinomial logistic regressions revealed that participants in the different substance use classes (low stable, deteriorating, recovered, and high-risk relapse) differed significantly on ethnicity, whether both parents were born in Canada, and parents' completion of post-secondary education (see Table 3). In particular, non-White ethnicity, having both parents born outside of Canada, and having either mother or father who completed post-secondary education were associated with a less severe substance use class. In addition, substance use

classes were not significantly associated with age, sex, or family SES (see Table 3).

Discussion

The purpose of the study was twofold: (i) to examine the trajectory of symptoms of substance use disorder across development among adolescents; and (ii) to explore whether participants from different substance use classes differed in their demographics. Using the data from a Canadian longitudinal study, results of the current study revealed a four-class solution as the best fitting model for substance use trajectory, which were labelled as low stable, deteriorating, recovered, and high-risk relapse. Results contribute to the scant literature on the trajectory of substance use problems beginning in early adolescence (25, 26), particularly in a Canadian context.

The specific substance use disorder symptom classes found in the present study are aligned with the previous evidence, including a low stable class, an escalating problem class (i.e., deteriorating), a high problem class (i.e., high-risk relapse), and early onset classes (i.e., recovered, high-risk relapse). Results revealed that the majority of adolescents do not experience substance use problems, and for some,

Table 3. Demographic Characteristics across Substance Use Classes (Wave 1)

	Low Stable (n = 538)	Deteriorating (n = 169)	Recovered (n = 12)	High-Risk Relapse (n = 46)			
	M (SD)	M (SD)	M (SD)	M (SD)	χ^2	p	Effect size ^b
Age	12.71 (.66)	12.70 (.67)	12.83 (.58)	12.93 (.71)	8.16	.772	.062
Family socio-economic status	7.05 (1.52)	7.24 (1.46)	5.92 (1.78)	6.61 (1.50)	39.95	.428	.140
	% (n)	% (n)	% (n)	% (n)	F	p	Effect size ^b
Sex					.20	.878	.030
Male	71.4 (275)	21.6 (83)	1.3 (5)	5.7 (22)			
Female	69.3 (262)	22.5 (85)	1.9 (7)	6.3 (24)			
Ethnicity ^a					3.96	.014	.130
Caucasian/White	66.7 (294)*	24.7 (109)*	2.3 (10)	6.3 (28)			
Asian/Pacific							
Islander	81.3 (104)	15.6 (20)	0.0 (0)	3.1 (4)			
Black	79.5 (35)	18.2 (8)	2.3 (1)	0.0 (0)			
Indigenous	60.0 (6)	0.0 (0)	0.0 (0)	40.0 (4)			
Hispanic/							
Latinx	73.3 (11)	20.0 (3)	0.0 (0)	6.7 (1)			
Multiple	72.7 (48)	18.2 (12)	0.0 (0)	9.1 (6)			
Parents born in Canada					7.12	.001	.162
Neither	80.2 (178)*	17.6 (39)	0.5 (1)	1.8 (4)*			
One or more	66.0 (347)*	24.0 (126)	2.1 (11)	8.0 (42)*			
Mother's post-secondary education					3.96	.021	.135
Graduated	70.7 (261)	23.8 (88)	1.6 (6)	3.8 (14)*			
Did not graduate	67.9 (110)	19.8 (32)	1.9 (3)	10.5 (17)*			
Father's post-secondary education					5.69	.002	.171
Graduated	70.8 (225)	24.2 (77)	1.3 (4)	3.8 (12)*			
Did not graduate	65.6 (107)	19.6 (32)	2.5 (4)	12.3 (20)*			

^aSignificance test conducted on Caucasian/White versus other ethnic groups due to sample sizes; ^bEffect size: Cramer's V; *Post-hoc tests show significant differences at $p < .01$.

substance use problems develop in later adolescent years. Specifically, similar to other studies, the low stable class has the largest class membership, and the escalating problem class represented about a quarter of the total sample. This pattern extends the findings of Boak and colleagues (50), which found higher drug use in higher grades of secondary school, with 21.9% of those in Grade 12 meeting the criterion for a drug use problem based on a self-report screener, compared to 6.3% of those in Grade 9.

While most adolescents do not experience substance use problems, particularly until late adolescence, results of the current study reveal that a smaller percentage of adolescents

were early initiators of substance use and demonstrated a moderate symptom level of substance use disorder at around age 12-13 (both recovered and high-risk relapse symptom classes). These participants may reflect a high-risk group, as there are consistent research findings to suggest that early initiation of substance use (e.g., before ages 14) is associated with not only later substance use problems, but other psychosocial problems (30, 50, 51).

In particular, the high-risk relapse substance use class is characterized by early onset of substance use symptoms that escalated to a high problem level at age 17. Of note, the worsening of symptoms among this group is not linear,

such that there is an improvement in symptoms at Wave 2 around ages 14-15. This specific pattern of trajectory was not found in other studies and may be captured through examining substance use disorder symptoms that included not only frequency of use but also continued use despite negative consequences and impairments. Reasons for this dip in symptom trajectory is unclear, and more research is needed to understand this pattern. In general, the association between early substance use and escalating substance use problem at a later time can be explained by both individual and environmental factors. It is possible that those who engage in substance use at a young age (prior to high school), a non-typical behaviour, are more likely to share certain psychological or behavioural characteristics such as impulsivity and risk taking, which are likely to contribute to continuation or escalation of use (29). Those exposed to early use may also self-organize into friendship groups of other adolescents using substances, which in turn creates more opportunities to use (29). Furthermore, it is possible that heightened substance use problems around age 17 was due to increased stresses during later adolescent years that resulted from navigating relationship and role transitions (e.g., from high school to postsecondary or employment, from adolescents to emerging adulthood), as well as using substances as a means of coping with the negative emotional states (52, 53).

Results of the study highlight the importance of prevention and intervention measures aimed at problematic substance use. For example, preventative efforts previously shown to be effective in reducing later substance use, such as prenatal and infancy visitation (54), early childhood education supporting social and cognitive development in preschool children (54), parenting skills building (54, 55), mentoring relationships (54), and programs targeting psychosocial functioning and social competence (54, 55) should be implemented. Given the findings that a subset of adolescents initiate substance use early and the association between early substance use (e.g., ages 12-13) and later negative psychological and physical health outcomes (28, 29), routine screening of substance use and mental health problems among late elementary school and middle school students may be warranted. Evidence-based treatment approaches for adolescent substance use include motivational interviewing (56), individual and group cognitive behavior therapy (56), and family-based treatment (55, 56).

Importantly, this study identified a small percentage of participants who may be resilient, specifically, those who displayed early onset of moderate substance use disorder symptoms that declined over time. In line with the developmental psychopathology perspective (57), it is possible that both risk and protective factors interacted in such a way to

mitigate the negative effect of early initiation of problematic substance use on future problematic use for this sample. For example, the present study found that non-White ethnicity and having both parents born outside of Canada were associated with a less severe symptom use class (i.e., low stable), as well as that having parents who completed post-secondary education was associated with being less likely to be in the high risk class (i.e., high-risk relapse). With respect to the former, it is possible that there are cultural differences in factors such as peer influences, parental expectations, parenting practices, family connectedness, and individualism versus collectivism (6, 32), which may impact adolescents' decisions to use substances across different developmental stages. Further attention is warranted.

Strengths and Limitations

There are several strengths to the present study. First, the study used a longitudinal approach and followed the same participants across three biennial waves, which allowed for a closer look at developmental trajectories across time among the same participants. Second, the study included participants that are younger than most other studies, specifically older children and young adolescents (ages 11-14), which provided information on early onset substance use problems. Third, the study recruited a diverse group of students across schools in different regions of Ontario, Canada, which enhanced the generalizability of the study results. Finally, although more than 50% of participants identified as White/Caucasian, the proportion of participants who identified with ethnic minority groups exceeded the rates in the Ontario as well as the overall Canadian population (58).

There are also several limitations to the present study to consider. First, the GAIN-SS self-report measure was used to screen for problematic substance use. Participants were not assessed on whether they met the diagnostic criteria for a substance use disorder, which may have impacted the trajectory classes revealed in the study. This measure also grouped experiences across substances together, without differentiating among the different substances. Second, while the study sample is diverse, the small sample size of each of the ethnic minority groups prevented further comparisons among the different ethnic groups on substance use trajectory classes. In addition, the attrition rate of the study may have impacted the findings, such that only those with certain profiles continued to participate in the study. Future studies are necessary to replicate the current study findings and to address the above-mentioned limitations. Future studies could also explore protective factors that may serve to mitigate the negative consequences associated with early onset problematic substance use.

Conclusions

The results of this study fill a gap in the evidence on the trajectory of substance use disorder symptoms among Canadian adolescents. In particular, the findings of the current study reveal that the majority of adolescents do not report substance use symptoms, and those who do are more likely to endorse such symptoms during late adolescence. A small percentage of participants displayed early onset of substance use symptoms (around ages 12-13), and given the association between early substance use onset and poor psychosocial outcomes, further implementation of prevention and intervention measures are warranted. In addition, this study identified a small group of individuals who displayed resilience despite early onset of problematic use; further research is needed to understand and differentiate between early-onset adolescents who are resilient and those who follow a trajectory associated with poor outcomes.

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Conflicts of Interest

The authors have no financial relationships or other ties to disclose.

Ethics Approval

All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards. The study was approved by the Centre for Addiction and Mental Health (CAMH) Research Ethics Board (#074-210).

Informed Consent

Informed consent was obtained from all individual participants included in the study.

Availability of Data and Material

Available from the corresponding author on reasonable request.

Authors' Contributions

NZ conceived of the study, participated in the design, statistical analysis, and interpretation of the data, and drafted the manuscript; LDH contributed to the study design, participated in the design and interpretation of the data, and helped to draft the manuscript; JH contributed to the study design and helped to draft the manuscript. All authors have read and approved the final manuscript.

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Supplemental Materials

Results for 3-Class Solution

Latent class analysis for substance use disorder symptom trajectory.

Results of latent class analysis also supported the 3-class solution. Specifically, the 3-class solution had lower BIC, SABIC, CAIC, and AWE values, as well as a significant VLMR-LRT value compared to the 4-class solution (see Table 2).

Based on visual inspection of the line graph of the 3-class solution (see Figure 2), which was based on GAIN-SS means and standard errors, the three class groups identified were labeled as: (i) Low Stable, characterized by minimal substance use symptoms across all three waves ($n = 534$, 69.8%); (ii) Relapse, characterized by mild symptom score at Wave 1 that decreased to a low score at Wave 2, that then increased to moderate score at Wave 3 ($n = 191$, 25.0%); and (iii) Deteriorating, characterized by low substance use symptom score at Wave 1 that increased to a moderate score at Wave 2 and Wave 3 ($n = 40$, 5.2%). The average probabilities of class membership are 72.5%, 82.1%, and 93.8%, respectively, for Classes 1, 2, and 3.

Demographic variables and substance use classes.

Results of the chi-square tests and multinomial logistic regressions revealed that participants in the different substance use classes (low stable, relapse, and deteriorating) differed significantly on ethnicity and whether both parents were born in Canada. In particular, non-White ethnicity and having both parents born outside of Canada were associated with a less severe substance use class. In addition, substance use classes were not significantly associated with age, sex, family SES, or parents' post-secondary education level (see Table 4).

Discussion for 3-Class Solution

Results of the present study additionally supported a three-class solution as a fitting model for adolescence substance use trajectories; these are labelled as low stable, relapse, and deteriorating. The substance use classes are aligned with the others commonly found in the literature, specifically a no/minimal symptom class (low stable) and an escalating problem class (deteriorating) (10-17). Similar to other findings, results of the present study revealed that the majority

Figure 2. Three-Class Solution for Substance Use Trajectories

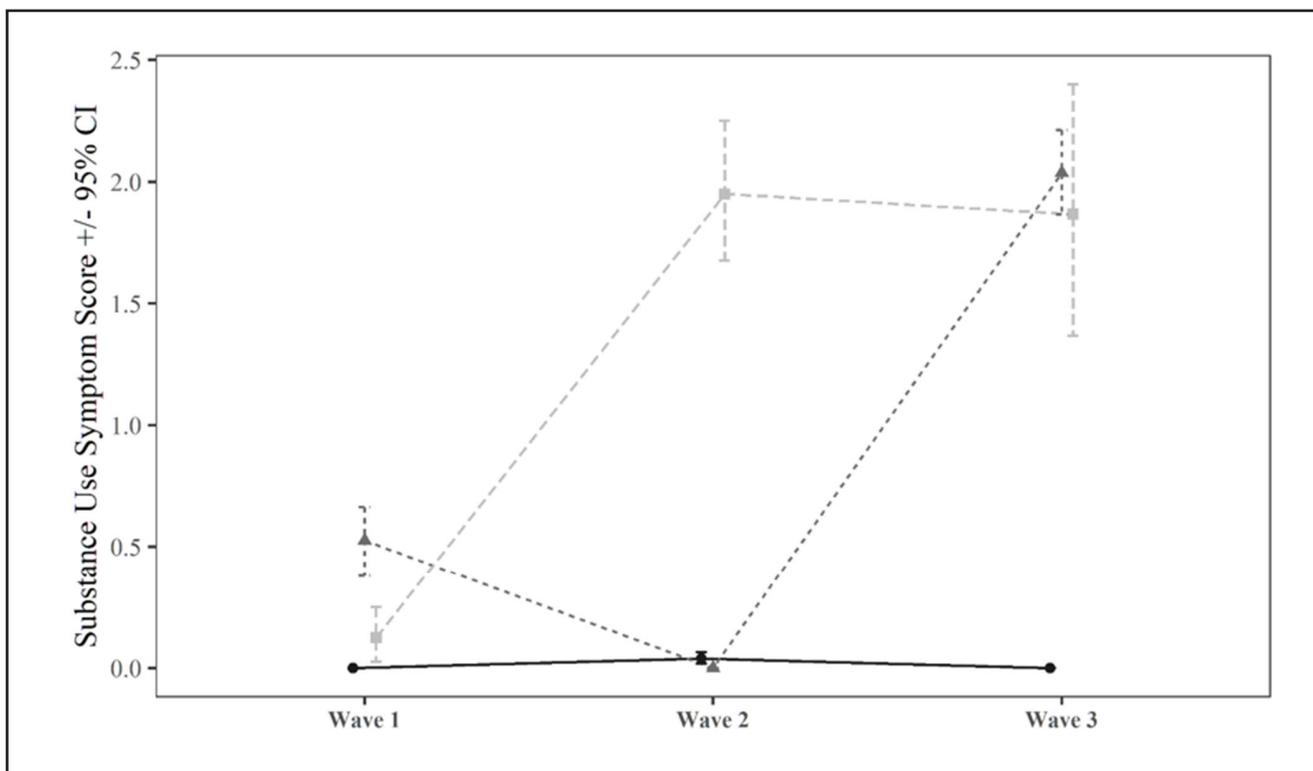


Table 4. Demographic Characteristics across the Three Classes (Wave 1)

	Low Stable (n = 534)	Deteriorating (n = 191)	Relapse (n = 40)	χ^2	p	Effect size ^b
	M (SD)	M (SD)	M (SD)			
Age	12.71 (.66)	12.78 (.69)	12.70 (.61)	5.47	.706	.055
Family socio-economic status	7.04 (1.53)	7.10 (1.47)	6.81 (1.72)	19.95	.794	.145
	% (n)	% (n)	% (n)	F	p	Effect size ^b
Sex				.15	.860	.024
Male	70.6 (272)	23.9 (92)	5.5 (21)			
Female	69.0 (261)	25.9 (98)	5.0 (19)			
Ethnicity ^a				5.87	.009	.137
Caucasian/White	65.8 (290)*	27.7 (122)	6.6 (29)			
Asian/Pacific Islander	81.3 (104)	17.2 (22)	1.6 (2)			
Black	79.5 (35)	13.6 (6)	6.8 (3)			
Indigenous	60.0 (6)	40.0 (4)	0.0 (0)			
Hispanic/ Latinx	73.3 (11)	26.7 (4)	0.0 (0)			
Multiple	72.7 (48)	25.8 (17)	1.5 (1)			
Parents born in Canada				7.06	.004	.149
Neither	80.2 (178)*	16.2 (36)*	3.6 (8)			
One or more	65.2 (343)*	28.9 (152)*	5.9 (31)			
Mother's post-secondary education				1.41	.256	.066
Graduated	70.2 (259)	26.0 (96)	3.8 (14)			
Did not graduate	67.3 (109)	25.9 (42)	6.8 (11)			
Father's post-secondary education				0.78	.458	.052
Graduated	70.1 (223)	24.8 (79)	5.0 (16)			
Did not graduate	65.0 (106)	29.4 (48)	5.5 (9)			

^aSignificance test conducted on Caucasian/White versus other ethnic groups due to sample sizes; ^bEffect size: Cramer's V;

*Post-hoc tests show significant differences at $p < .01$.

of adolescents do not experience substance use problems, as well as that some adolescents develop more significant substance use problems later in their adolescent years (50).

The present study revealed a small percentage of adolescents who are early initiators of substance use (relapse); these adolescents demonstrated some symptoms at around age 12-13 that decreased to a low level at age 14-15, which then escalated to a moderate level at around age 17-18. While the trajectory is not linear, such that there is an improvement at age 14-15, this group may reflect a high-risk group, given the evidence that early initiation of substance

use is associated with worse outcomes (29, 30, 50, 51). It is possible that this group of adolescents would demonstrate more severity of symptoms at a later age or have other comorbid conditions. Possible explanations for the association between early initiation of substance use and later escalating substance use problem and other psychosocial problems have been put forth in the main article. Results of the study contribute to the limited literature on the trajectory of substance use problems beginning in early adolescence (25, 26) and within a Canadian context. Results also highlight the importance of prevention and intervention measures aimed at problematic substance use.