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Lockdown, bottoms up? Changes in adolescent substance use across the COVID-19 pandemic

Tara M. Dumas [a,*], Wendy E. Ellis [b], Stephen Van Hedger [a], Dana M. Litt [c], Madeleine MacDonald [a]

[a] Department of Psychology, Huron University College at Western University, London, ON, Canada
[b] Department of Psychology, King's University College at Western University, London, ON, Canada
[c] Department of Health Behavior and Health Systems, School of Public Health, University of North Texas Health Science Center, Fort Worth, TX, USA

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ABSTRACT

The COVID-19 pandemic notably altered adolescent substance use during the initial stage (Spring 2020) of the pandemic. The purpose of this longitudinal study is to examine trajectories of adolescent substance use across the pandemic and subsequent periods of stay-at-home orders and re-opening efforts. We further examined differences as a function of current high school student versus graduate status. Adolescents (n = 1068, 14–18 years, M_{age} = 16.95 years and 76.7% female at T1) completed 4 different self-report surveys, starting during the first stay-at-home order and ending approximately 14 months later. Negative binomial hurdle models predicted: (1) the likelihood of no substance use and (2) frequency of days of substance use. As hypothesized, results demonstrated significant increases in adolescents' likelihood of alcohol use, binge drinking, and cannabis use once initial stay-at-home orders were lifted, yet few changes occurred as a result of a second stay-at-home order, with rates never lowering again to that of the first lockdown. Further, graduates (and particularly those who transitioned out of high school during the study) demonstrated a greater likelihood and frequency of substance use and were more stable in their trajectories across periods of stay-at-home orders than current high school students. Unexpectedly, however, there was a strong increase in current high school students' likelihood of e-cigarette use and a significant linear increase in participants' frequency of e-cigarette use over the study. Results suggest adolescent substance use, and in particular, e-cigarette use among current high school students, may be of increasing concern as the pandemic evolves.

1. Introduction

Research demonstrates that the emergence of the COVID-19 pandemic notably altered young people's substance use patterns. Multiple studies revealed that, since the onset of the pandemic, adolescents and emerging adults now drink less heavily, but with more frequency (Dumas et al., 2020; Graupensperger, Fleming et al., 2021; White et al., 2020). E-cigarette use has also declined (Dumas et al., 2020; Gaiha et al., 2020), but results on cannabis use have been mixed (e.g., Dumas et al., 2020; Graupensperger, Fleming et al., 2021). The majority of these studies, however, were conducted in the early stage of the pandemic during initial emergency stay-at-home orders (Spring 2020). As such, it is unclear how adolescent substance use patterns have changed across the significant timespan of the pandemic.

On March 11th, 2020, the World Health Organization declared that the COVID-19 outbreak was a global pandemic (Ghebreyesus, 2020). What followed in many parts of the world were strict stay-at-home orders that spanned multiple weeks/months. Since then, periods of lower transmission rates have been accompanied by looser social restrictions scattered between periods of high transmission in which strict social restrictions were implemented. Ontario, Canada, where the present data were collected, has experienced multiple subsequent stay-at-home orders that span several months, with one beginning in December 2020 and another beginning in April 2021. During these times, the government restricted social gatherings and closed schools and non-essential businesses.

Across the pandemic, adolescent substance use patterns have likely changed. Given that most adolescents consume substances for social reasons (Kuntsche et al., 2005), stay-at-home orders likely have restrictive effects. For instance, the decrease in heavy drinking during

* Corresponding author at: Huron University College, 1349 Western Road, London, ON N6G 1H3, Canada.
E-mail address: tdumas2@uwo.ca (T.M. Dumas).

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initial stay-at-home orders has been explained as partly due to a lack of social opportunities (e.g., parties, gatherings with friends) and intoxication being more difficult to hide when adolescents are home under the watchful eyes of parents (Dumas et al., 2020). The decrease in e-cigarette use has been attributed partly to a lack of access, as adolescents usually procure supplies from peers (Pepper et al., 2018). Thus, we would expect that when stay-at-home orders are lifted, these substance use behaviors would increase and then decrease again with subsequent stay-at-home orders. However, longitudinal research demonstrates that worry about the COVID-19 virus, which is an important predictor of social distancing behavior (Smith et al., 2022), has declined since the initial stay-at-home order (Bendau et al., 2021). Thus, perhaps as a function of less adherence to stay-at-home orders, we might expect weaker declines in adolescent substance use during subsequent orders as compared to the first.

Finally, it is possible that substance use patterns differ as a function of adolescents' educational status. For instance, research suggests that adolescents who have graduated from high school, regardless of whether they attend post-secondary education or enter the workforce, tend to engage in more substance use than their same-aged high school peers (Kirst et al., 2014; White et al., 2005). This can be attributed to several factors including increased freedoms (e.g., independence from parents, more permissive parental attitudes about substance use), new social circles and stronger norms around substance use (particularly in college), increased feelings of maturity and new life stressors (e.g., adult responsibilities and increased academic/career-related demands) (Maggs, 1997; Neighbors et al., 2007; Schulenburg & Maggs, 2002; White et al., 2005). Thus, compared to current students, high school graduates may have engaged in more substance use across the pandemic. Furthermore, because graduates have fewer parental restrictions around substance use and greater access to peers, their substance use trajectories may be less impacted by subsequent periods of stay-at-home orders.

In the present study, Canadian adolescents (aged 14 to 18), completed batteries of self-report questionnaires across 4 waves: April 2020 (T1), August 2020 (T2), January 2021 (T3) and June 2021 (T4). This longitudinal design gives us a unique opportunity to compare adolescents' substance use patterns at the beginning of the pandemic with: (1) a subsequent time point in which the stay-at-home order was lifted (August 2020), businesses were open, and only gatherings over 10 people were banned (Reopening Ontario Act, 2020), (2) a second period of government mandated lockdown (January 2021) and, finally, (3) the end of a third lockdown (June 2021), as the province was rolling out vaccines and entering Step 1 of a re-opening plan, which slightly eased restrictions to outdoor gatherings, restaurants and retail (Ontario Roadmap to Reopen, 2021). We have multiple hypotheses. First, the likelihood and frequency of adolescent substance use will increase after initial stay-at-home orders have ended (H1a) and decrease during subsequent lockdown (H1b). Second, there will be a greater likelihood and frequency of substance use among graduates as opposed to current high school students (H2). Finally, high school graduates' trajectories of use will be less impacted by subsequent periods of stay-at-home orders (i.e., more stable across the pandemic) than high school students (H3).

2. Method

2.1. Recruitment procedure

Recruitment and completion of the T1 survey occurred from early- to mid-April 2020, approximately 3 weeks into the initial COVID-related stay-at-home orders. Participants were recruited via an advertisement on our research lab's Instagram page, which was shared with 16–18-year-old Ontarians via Instagram's promotion feature. We did not recruit adolescents under 16 years of age in this way because, according to Canada's research ethics policy, written parental consent is required for participants under the age of 16. Thus, we also e-mailed the advertisement and survey link to a group of 14–18-year-olds ($n = 155$) who were already completing a longitudinal study with us.

2.2. Participants

The total sample included 1068 participants. At T1, data was collected from 959 adolescents aged 14–18 years ($M_{age} = 16.95$, $SD = 0.84$; 76.7% Female, 21% Male, and 2.3% Other) who identified as White/European (65.2%), Asian (16.3%), Black North American/African (3.9%), Latino (3.1%), and Other (11.6%). The majority were high school students (83.8%) and 16.2% were graduates (14.4% enrolled in college/university). Of the high school students, there were 2.24% Grade 9′s, 12.58% Grade 10′s, 34.74% Grade 11′s and 50.44% Grade 12′s. Thus, the Grade 12 group, comprised of 405 participants, graduated high school during the study (between T1 and T2). Most participants were currently living with a parent/guardian (98.86%), while others lived with siblings, romantic partners, or roommates (1.14%). Data was collected from 345 participants at T2 ($M_{age} = 17.29$; 80.6% Female, 18.6% Male, and 0.9% Other), 512 participants at T3 ($M_{age} = 17.67$; 80.3% Female, 17.6% Male, and 1.6% Other) and 493 participants at T4 ($M_{age} = 17.96$; 79.1% Female, 17.6% Male, and 2.8% Other). These numbers do not include participants who did not correctly answer validation questions (e.g., "for this item, check the *strongly agree* box"). Across the 4 time points, data was removed for this reason from 512 adolescents.

2.3. Procedure

Ethics was obtained by the lead author's University Ethics Board. T1 data collection occurred from early-to-mid-April 2020, during initial stay-at-home orders. T2 occurred from late-August to early-September 2020, before the start of the academic school year, during which the state of emergency had been lifted and only gatherings larger than 10 were banned. T3 occurred mid-January to early-February 2021, during a second provincial stay-at-home order, similar to the first in that residents were permitted to leave home only for essential reasons and outdoor gatherings were restricted to 5 people. Finally, T4 occurred in the first 3 weeks of June 2021, as the third lockdown was coming to an end, vaccines had started to be distributed to the general public and the province entered Stage 1 of a 3-stage Re-opening plan, which allowed for indoor gatherings over 10 and some businesses to operate at decreased capacity.

At each time point, participants provided informed consent before completing a 20-minute self-reported survey. Study reimbursement included entry into a draw to win one of 20 $50 e-gift cards or AirPods (T1) and $15 e-gift cards (T2-T4).

2.4. Measures

Surveys included demographic questions and questions about substance use during the pandemic. Specifically, at each of the 4 time points, participants reported the number of days in the past 3 weeks (with a maximum of 21) on which they: (1) consumed any alcohol, (2) binge drank (i.e., consumed 4+/5 + standard drinks for females/males in one sitting; with one standard drink defined as 341-ml (12 oz) of beer, 142 ml (5 oz) of wine, 43 ml (1.5 oz) of liquor, or 341-ml (12 oz) of a premixed drink or "cooler"), (3) consumed any marijuana (e.g., joints, edibles), and (4) used e-cigarettes (i.e., vapes). Participants reported on their substance use at each of the study's 4 time points, which allowed us to examine use trajectories over time. Furthermore, at T1 (April 2020), participants reported on their frequency of substance use in the 3 weeks prior to the COVID-19 pandemic.

2.5. Analytic plan

Our 4 outcome variables of interest – days of use for alcohol, binge

drinking, cannabis and e-cigarettes – are all positively skewed count variables. Thus, we adopted negative binomial hurdle models, which account for zero-inflation and provide two sets of results. First, they utilize data from the full sample in a logistic model which predicts the *likelihood* that participants scored a 0 on a given outcome variable (i.e., did not consume a given substance, e.g., alcohol). Second, they utilize a zero-truncated negative binomial distribution (truncated because scores of "0″ are not included) to predict the *frequency* of the outcome variable (i.e., number of days on which participants used substances, e.g., alcohol). We ran 4 different negative binomial hurdle models using the "glmmTMB" package (Brooks et al., 2017) performed in R Version 4.1.1. Participants were modeled with random intercepts. Time-point, pre-COVID substance use, high school status, and gender were included as fixed effects. Two variables were included to measure high school status with high school student as the reference group (*High School Status 1*: 0 = high school student and 1 = adolescents transitioning out of high school (i.e., between T1 and T2) and *High School Status 2*: 0 = high school student and 1 = prior graduate (i.e., those who graduated prior to our study). For gender, 1 = female and 0 = non-female. For the pre-COVID substance use variable, the type of use (e.g., alcohol use, binge drinking) matched that of the outcome variable. Because pre-pandemic use was not measured in the same way as T1-T4 substance use (i.e., participants were required to recall their behavior before the pandemic began as opposed to their behavior in the last 3 weeks) and because recent research suggests this type of cross-sectional, retrospective reporting of pre-COVID substance use produces differing results than that of longitudinal studies (Romm et al., 2021), we included this measure as a covariate in our analyses rather than as an initial time point in participants' substance use trajectories. Time was treated as an ordered factor, allowing us to examine linear, quadratic, and cubit trends over the 4 time-points. We tested the effects of high school status on the slope of time to examine potential differences in substance use trajectories. Significant effects of time or time X high school status were followed-up with a series of contrasts with false discovery rate (FDR) adjusted *p*-values using the Benjamini-Hochberg procedure to account for multiple comparisons (Benjamini & Hochberg, 1995).

2.6. Missing data

Of the total 1068 participants, we received valid data from 89.79%, 32.30%, 47.94% and 46.16% at T1, T2, T3 and T4, respectively. Results of a 2x2x2 Analysis of Variance (ANOVA) demonstrated no significant age differences, and a series of Chi-Square tests revealed no significant gender differences in participants who did and who did not complete surveys at T1($F(1,1063) = 0.80$, $p = .37$ and $\chi^2(1) = 3.29$, $p = .07$) or T2 ($F(1,1063) = 2.78$, $p = .10$ and $\chi^2((1) = 1.05$, $p = .31$). There were no age differences at T3 ($F(1,1063) = 2.32$, $p = .13$) or T4 ($F(1,1063) = 0.02$, $p = .89$), but significant gender differences, with more non-female participants completing the surveys than expected ($\chi^2(1) = 4.26$, $p = .04$ and $\chi^2(1) = 5.39$, $p = .02$). This is likely because at T3 and T4 we sent out additional reminder e-mails/texts to non-female participants given their lower representation in the previous surveys. Further, results of an ANOVA revealed no significant differences on T1 substance use between participants who did and did not complete T2 (Wilk's $\Lambda = 0.99$, $F(4, 926) = 2.32$, $p = .06$), T3 (Wilk's $\Lambda = 1.00$, $F(4, 926) = 0.55$, $p = .69$), or T4 surveys (Wilk's $\Lambda = 1.00$, $F(4, 926) = 0.55$, $p = .70$). Thus, missing data was accounted for using restricted maximum likelihood estimation. This technique produces more plausible parameter estimates and thus is preferred to listwise deletion (Calvin, 1993).

3. Results

Results of negative binomial hurdle modelling can be found in Tables 1 and 2. There were no significant gender differences in our models, so we do not discuss them further. Pre-pandemic prevalence rates, which were used as covariates in our models were as follows: 32.2% for alcohol use, 19.4% for binge drinking, 18.2% for cannabis use and 13.7% for e-cigarette use. Additionally, and not surprisingly, pre-pandemic use was a significant predictor in all models. Prevalence rates for substance use during the study can be found in Table 3.

Results of the negative binomial hurdle modelling revealed that for likelihood of no alcohol use, there were significant linear, quadratic and cubic trends. The quadratic trend differed significantly between current high school students and those who transitioned out of high school during the study. Contrasts revealed that all participant groups decreased in their likelihood of no alcohol use (i.e., increased in their likelihood of use) from T1 to T2 (i.e., after the first lockdown), but only high school students increased in their likelihood of no alcohol use (i.e., decreased in their likelihood of use) from T2 to T3 (i.e., when entering the second lockdown). Finally, those transitioning out of high school decreased again in their likelihood of no use from T3 to T4 (i.e., at the end of the third lockdown) (see Table 4 for contrasts examining change over time). Contrasts also revealed a greater likelihood of no alcohol use for current high school students as compared to participants transitioning out of high school at T1 and T4 and graduates at T2 (see Table 5 for all contrasts examining student status).

For frequency of alcohol use, there was a significant cubic trend that differed significantly between high school students and graduates (see Fig. 1). Contrasts revealed that only for current high school students did frequency of alcohol use increase from T1 to T2 (see Table 4). Furthermore, adolescents transitioning from high school engaged in a significantly greater frequency of alcohol use than high school students at T1 (see Table 5).

For likelihood of no binge drinking, there were significant linear, quadratic and cubic trends, which did not differ as a function of high school status (see Table 1). Contrasts revealed that participants were significantly more likely to not binge drink at T1 than at T2, T3 or T4. Further, participants' likelihood of not binge drinking increased significantly from T2 to T4 (see Table 4). Finally, a significant between-subjects effect revealed that current high school students were significantly more likely to not binge drink than adolescents who transitioned out of high school. For frequency of binge drinking, no significant time or student status effects emerged.

For likelihood of no cannabis use, a significant linear trend emerged that did not differ by school status (see Table 1). Participants were significantly more likely to not use cannabis at T1 as compared to T2, T3 and T4 (see Table 4). For frequency of use, only a between-subjects effect emerged with participants transitioning out of high school engaging in a greater frequency of cannabis use as compared to current high school students.

For likelihood of no e-cigarette use, there were significant linear and quadratic trends. The linear trend differed significantly by student status (see Table 1). For current high school students, their likelihood of no e-cigarette use was significantly lower at T3 and T4 than T1. At T1, current high school students were 26.52 times more likely to engage in no e-cigarette use than at T4. For those transitioning out of high school and graduates, their likelihood of no e-cigarette use stayed stable across the study. For frequency of use, there was a significant linear trend that did not differ by student status (see Fig. 2). The frequency of e-cigarette use was significantly higher at T4 as compared to T1 (see Table 5). A between-subjects effect also demonstrated it was significantly higher for participants who transitioned out of high school as compared to current high school students.[1]

[1] Because of the significant overlap between student-status and age, we re-ran all negative binomial hurdle models with age as a predictor instead of student-status. Older age had a significant main effect on the likelihood and frequency of alcohol use and the likelihood of binge drinking.

Table 1
Likelihood of No Substance Use (Scoring a "0" for Number of Days Used) Based on Negative Binomial Hurdle Models.

	Alcohol Use			Binge Drinking			Cannabis Use			E-Cigarette Use		
	B	*p*	*OR*	*B*	*p*	*OR*	*B*	*p*	*OR*	*B*	*p*	*OR*
Linear Time	**−0.4**	**0.04**	**0.67**	**−0.85**	**0.02**	**0.43**	**−0.86**	**0.03**	**0.42**	**−2.42**	**<0.001**	**0.09**
Quadratic Time	**0.57**	**0.01**	**1.77**	**1.54**	**<0.001**	**4.66**	0.37	0.38	1.45	**1.08**	**0.02**	**2.94**
Cubic Time	**−0.68**	**<0.001**	**0.51**	**−1.11**	**<0.001**	**0.33**	−0.54	0.21	0.58	−0.06	0.90	0.94
High School Status 1	**−0.46**	**0.02**	**0.63**	**−1.15**	**0.01**	**0.32**	−0.74	0.20	0.48	0.3	0.63	1.35
High School Status 2	**−0.59**	**0.04**	**0.55**	−0.26	0.67	0.77	−0.47	0.57	0.63	1.04	0.30	2.83
Gender	−0.01	0.98	0.99	−0.28	0.56	0.76	0.42	0.52	1.52	0.22	0.75	1.25
Pre-Pandemic Use	**−0.89**	**<0.001**	**0.41**	**−1.32**	**<0.001**	**0.27**	**−1.88**	**<0.001**	**0.15**	**−0.89**	**<0.001**	**0.41**
HS Status 1 X Linear Time	−0.41	0.13	0.66	−0.56	0.24	0.57	−0.81	0.16	0.44	**2.32**	**<0.001**	**10.18**
HS Status 2 X Linear Time	−0.69	0.06	0.50	−0.16	0.80	0.85	−0.85	0.20	0.43	**1.76**	**0.04**	**5.81**
HS Status 1 X Quadratic Time	**−0.67**	**0.02**	**0.51**	−0.76	0.11	0.47	1.01	0.08	2.75	0.25	0.70	1.28
HS Status 2 X Quadratic Time	0.47	0.23	1.60	0.48	0.43	1.62	0.16	0.81	1.17	−1.57	0.09	0.21
HS Status 1 X Cubic Time	0.08	0.79	1.08	0.2	0.68	1.22	−0.22	0.71	0.80	−0.16	0.80	0.85
HS Status 2 X Cubic Time	0.15	0.72	1.16	1.03	0.07	2.80	−0.62	0.37	0.54	−1.28	0.18	0.28

Note. Bold = $p < .05$. *High School Status 1*: 0 = high school student and 1 = teens transitioning out of high school (i.e., between T1 and T2). *High School Status 2*: 0 = high school student and 1 = prior graduate (i.e., those who graduated prior to our study). Gender: 1 = female and 0 = non-female.

Table 2
Frequency of Substance Use Based on Negative Binomial Hurdle Models.

	Alcohol Use			Binge Drinking			Cannabis Use			E-Cigarette Use		
	B	*p*	*RR*	*B*	*p*	*RR*	*B*	*p*	*RR*	*B*	*p*	*RR*
Linear Time	**0.27**	**0.05**	**1.31**	−0.64	0.09	0.53	0.38	0.08	1.46	**0.39**	**0.02**	**1.48**
Quadratic Time	−0.14	0.32	0.87	−0.13	0.69	0.88	−0.09	0.71	0.91	0.21	0.29	1.23
Cubic Time	**0.39**	**0.01**	**1.48**	−0.36	0.25	0.70	−0.42	0.16	0.66	−0.25	0.25	0.78
High School Status 1	**0.31**	**0.01**	**1.36**	0.22	0.37	1.25	**0.33**	**0.046**	**1.39**	**0.3**	**0.049**	**1.35**
High School Status 2	0.06	0.72	1.06	−0.30	0.40	0.74	−0.16	0.43	0.85	0.11	0.60	1.12
Gender	0.05	0.69	1.05	0.26	0.33	1.30	0.03	0.84	1.03	0.13	0.36	1.14
Pre-Pandemic Use	**0.13**	**<0.001**	**1.14**	**0.12**	**<0.001**	**1.13**	**0.10**	**<0.001**	**1.11**	**0.07**	**<0.001**	**1.07**
HS Status 1 X Linear Time	−0.18	0.31	0.84	0.26	0.52	1.30	−0.10	0.69	0.90	−0.02	0.93	0.98
HS Status 2 X Linear Time	−0.42	0.06	0.66	0.97	0.15	2.64	−0.09	0.78	0.91	−0.18	0.51	0.84
HS Status 1 X Quadratic Time	0.11	0.56	1.12	0.23	0.53	1.26	−0.02	0.94	0.98	−0.25	0.29	0.78
HS Status 2 X Quadratic Time	0.00	1.00	1.00	−0.22	0.71	0.80	0.11	0.76	1.12	−0.27	0.37	0.76
HS Status 1 X Cubic Time	−0.32	0.09	0.73	0.36	0.32	1.43	0.53	0.11	1.70	0.41	0.12	1.51
HS Status 2 X Cubic Time	**−0.47**	**0.04**	**0.63**	0.06	0.91	1.06	0.28	0.49	1.32	0.13	0.70	1.14

Note. Bold = $p \leq 0.05$. *High School Status 1*: 0 = high school student and 1 = teens transitioning out of high school (i.e., between T1 and T2). *High School Status 2*: 0 = high school student and 1 = prior graduate (i.e., those who graduated prior to our study). Gender: 1 = female and 0 = non-female.

Table 3
Prevalence Rates of Substance Use in the Past 3 Weeks.

	%(*f*)			
	Time 1	Time 2	Time 3	Time 4
Alcohol Use				
Total Sample	31.1(293)	44.2(152)	38.9(199)	45.4(221)
High School Students	25.1(99)	42.4(61)	30.5(67)	36.1(78)
Transitioners	34.3(136)	41.3(59)	37.0(61)	50.6(81)
Graduates	37.7(57)	56.1(32)	56.5(48)	55.4(46)
Binge Drinking				
Total Sample	9.4(88)	20.8(71)	17.8(91)	18.6(91)
High School Students	6.1(24)	18.8(27)	10.5(23)	11.0(24)
Transitioners	12.2(48)	22.4(32)	20.6(34)	24.8(40)
Graduates	10.7(16)	21.8(12)	29.4(25)	22.9(19)
Cannabis Use				
Total Sample	14.1(132)	18.0(62)	17.4(89)	20.4(100)
High School Students	11.2(44)	11.8(17)	11.3(25)	16.1(35)
Transitioners	14.9(59)	19.6(28)	23.0(38)	22.5(36)
Graduates	19.2(29)	29.8(17)	20.0(17)	27.7(23)
E-Cigarette Use				
Total Sample	9.6(90)	11.4(39)	14.3(73)	14.5(70)
High School Students	8.4(33)	9.0(13)	15.8(35)	16.8(36)
Transitioners	10.5(41)	13.4(19)	14.0(23)	10.6(17)
Graduates	10.7(16)	12.3(7)	10.6(9)	12.2(10)

4. Discussion

Study results provide unique insights into the trajectories of multiple types of substance use across the first 14 months of the COVID-19 pandemic. In line with H1a, adolescents were less likely to refrain from alcohol use, binge drinking, and cannabis use once initial stay-at-home orders were lifted (April to August 2020); however, inconsistent with H1b, adolescents' likelihood of abstaining from substance use, for the most part, did not increase after entering a second stay-at-home order period (January 2021) (except for current high school students' alcohol use). Thus, adolescent substance use rates do not seem as affected by subsequent stay-at-home orders as compared to the first. As mentioned previously, worry about the COVID-19 virus - a major predictor of social distancing behavior (Smith et al., 2022) - has declined significantly since the beginning of the pandemic (Bendau et al., 2021). Thus, it is possible that a greater proportion of adolescents may take advantage of social substance use opportunities than during the first stay-at-home order, regardless of government restrictions (Dumas et al., 2020). It is important to note, however, that as opposed to our findings regarding likelihood of use, few increases in frequency of use over time were found among the substance-using adolescents in our study (increases only for e-cigarette use and current high school students' alcohol use). Thus, the pandemic appears to have had a more salient effect on whether or not adolescents are willing and able to use substances, perhaps, for example, by affecting social substance-using opportunities, acquiring of supplies, and opportunities to be away from the watchful eyes of their parents/guardians.

A second aim of this study was to examine differences in substance use trajectories across the COVID-19 pandemic as a function of high school status. In line with H2 and previous research (Kirst et al., 2014; White et al., 2005), there were some significant differences in likelihood and frequency, with more engagement in alcohol, binge drinking and cannabis use among high school graduates and those who graduated

Table 4
Contrasts Examining Change Over Time for Significant Main Effects and Interactions.

	T1 → T2			T2 → T3			T3 → T4			T1 → T3			T1 → T4			T2 → T4		
	Est.	*Ratio*	*p*	*Est.*	*Ratio*	*p*	*Est.*	*Ratio*	*p*	*Est.*	*Ratio*	*p*	*Est.*	*Ratio*	*p*	*Est.*	*Ratio*	*p*
Contrasts for Significant Main Effects of Time																		
Likelihood of Binge Drinking	**6.88**	**12.96**	**<0.001**	−1.47	0.64	0.17	−1.09	0.72	0.28	**6.09**	**8.26**	**<0.001**	**5.13**	**5.91**	**<0.001**	**−2.44**	**0.46**	**0.02**
Likelihood of Cannabis Use	**5.16**	**8.34**	**<0.001**	−1.24	0.63	0.25	1.71	1.84	0.13	**4.23**	**5.25**	**<0.001**	**5.80**	**9.64**	**<0.001**	0.40	1.16	0.69
Frequency of E-Cigarette Use	−0.28	0.95	0.78	−1.33	0.79	0.28	−0.72	0.89	0.57	−1.88	0.75	0.12	**−2.72**	**0.67**	**0.04**	−1.99	0.70	0.12
Contrasts for Significant Time X High School Status Interactions																		
Likelihood of Alcohol Use																		
High School Students	**4.63**	**3.85**	**<0.001**	**−2.31**	**0.48**	**0.05**	0.72	1.24	0.57	**2.27**	**1.86**	**0.05**	**3.09**	**2.31**	**0.01**	−1.64	0.60	0.16
Transitioners	**2.83**	**2.20**	**0.02**	−1.38	0.65	0.24	**3.23**	**2.70**	**0.01**	1.32	1.43	0.27	**4.90**	**3.84**	**<0.001**	1.80	1.75	0.12
Graduates	**4.24**	**7.35**	**<0.001**	−0.43	0.81	0.75	−0.16	0.92	0.90	**3.86**	**5.92**	**<0.001**	**3.77**	**5.47**	**0.001**	−0.60	0.74	0.65
Frequency of Alcohol Use																		
High School Students	**−3.01**	**0.54**	**0.04**	1.97	1.50	0.25	−1.69	0.72	0.35	−0.96	0.82	0.65	−2.72	0.59	0.07	0.40	1.08	0.85
Transitioners	−0.88	0.87	0.65	0.35	1.06	0.85	−0.47	0.93	0.84	−0.51	0.92	0.83	−1.09	0.85	0.65	−0.10	0.98	0.95
Graduates	−0.02	0.99	0.99	−0.12	0.97	0.95	1.06	1.31	0.65	−0.17	0.97	0.95	0.94	1.27	0.65	0.89	1.27	0.65
Likelihood of E-Cigarette Use																		
High School Students	2.95	9.12	0.06	1.64	2.74	0.31	0.12	1.06	0.93	**4.73**	**24.97**	**<0.001**	**4.82**	**26.52**	**<0.001**	1.72	2.91	0.31
Transitioners	2.42	4.79	0.13	−0.37	0.78	0.79	−1.48	0.34	0.38	2.05	3.74	0.18	0.33	1.26	0.81	−1.82	0.26	0.28
Graduates	0.93	2.72	0.57	−1.24	0.22	0.42	1.63	7.30	0.31	−0.44	0.61	0.78	1.41	4.42	0.39	0.44	1.63	0.78

Note. Bold = $p \leq 0.05$. *Ratio* = odds ratio for likelihood outcomes and risk ratio for frequency outcomes.

high school during our study as opposed to current high school students. It is possible that these findings are partly a function of age, as older adolescents tend to engage in more substance use (Johnson et al., 2021) and have greater opportunities for substance use than younger adolescents (e.g., via having friends who are of legal age to buy alcohol – 19 years in Ontario, Canada). However, only student status was a significant predictor of substance use trajectories over the study. In general, high school students' substance use appeared to be more affected by the pandemic's restrictions, given that they were the only group who increased in their frequency of substance use after the first stay-at-home order (from T1 to T2) and increased in their likelihood of abstaining from alcohol use during the second stay-at-home order (from T2 to T3). This could be due to greater parental restrictions and supervision during times of stay-at-home orders as compared to those graduating or who have graduated, who tend to be granted more autonomy to make their own choices (Schulenburg & Maggs, 2002).

Furthermore, it is important to acknowledge that participants who transitioned out of high school during the study appear particularly high risk for substance use. According to Fig. 1, these individuals experienced the highest frequency of alcohol use at each time point. Additionally, other student-status effects were largely due to significant differences between those who transitioned out of high school and current high school students, with the former group demonstrating a decreased likelihood of no binge drinking, and greater frequency of cannabis and e-cigarette use. These results are consistent with past findings suggesting that periods of transition during the emergence into adulthood, including the transition from high school to college, are times of heightened substance use (e.g., Fromme et al., 2008; Patrick et al., 2020; Schulenberg et al., 2018). They may further be explained by the *transitions overload model* (Schulenburg & Maggs, 2002), which suggests that when significant or multiple transitions occur, as is typical during the adolescent-to-emerging-adulthood period, individuals may turn to less adaptive coping mechanisms, such as substance use, to deal with the accompanying feelings of stress and instability. Given that the COVID-19 pandemic has added an additional stressor to adolescents' lives, resulting in increases in coping-related substance use (Dumas et al., 2020; Graupensperger, Fleming et al., 2021), it will be especially important to continue to monitor adolescents who face additional stressors in the way of life transitions.

It is also noteworthy that current high school students decreased quite dramatically in their likelihood of abstaining from e-cigarette use and also increased in their frequency of use across the study. Interestingly, national research from the United States suggests that the upward trend in adolescent e-cigarette use from 2017 to 2019 leveled off in 2020 (Miech et al., 2021). However, this 2020 data was collected towards the beginning of the pandemic, when rates, at least in our study, were relatively low and opportunities to procure e-cigarette supplies were limited due to lockdown-related store closures and decreased access to friends. Further, some youth quit e-cigarette use at the beginning of the pandemic for fear the damage to their lungs would make them more susceptible to COVID-19 (Gaiha et al., 2020). Thus, our research suggests it is important to closely monitor future trends in adolescents' e-cigarette use, especially among high school students. This is of particular importance as fears about susceptibility to the COVID-19 virus decrease (e.g., with vaccine availability) (Bendau et al., 2021) and opportunities for face-to-face socialization with peers, who are a main source of e-cigarette supplies (Pepper et al., 2018) and whose norms play a significant role in shaping adolescents' use (Trucco et al., 2021), increase.

Related to clinical implications, our results suggest that although there was some fluctuation of substance use between time points, substance use never returned to levels observed at the beginning at the pandemic. It is possible that the sharp increase after the first stay-at-home order was a reaction to stress or new-found freedom and social interactions. As such, it is possible that some adolescents who would not normally engage in substance use became more susceptible to initiating use during this unique period. Importantly, the prevalence rates for

Table 5
Contrasts Examining Differences in Student Status for Significant Time X Student Status Interactions.

	T1			T2			T3			T4		
	Est.	*Ratio*	*p*	*Est.*	*Ratio*	*p*	*Est.*	*Ratio*	*p*	*Est.*	*Ratio*	*p*
Likelihood of Alcohol Use												
High School Students vs. Transitioners	**2.24**	**1.71**	**0.05**	−0.05	0.98	0.96	0.79	1.31	0.55	**3.05**	**2.86**	**0.01**
High School Students vs. Graduates	−0.24	0.92	0.86	1.16	1.76	0.33	**2.27**	**2.94**	**0.05**	1.69	2.19	0.15
Frequency of Alcohol Use												
High School Students vs. Transitioners	**−3.05**	**0.58**	**0.04**	−0.41	0.92	0.85	−1.97	0.65	0.25	−0.91	0.84	0.65
High School Students vs. Graduates	−2.06	0.64	0.25	0.62	1.18	0.79	−1.10	0.76	0.65	1.23	1.39	0.65
Likelihood of E-Cigarette Use												
High School Students vs. Transitioners	1.22	2.99	0.42	0.52	1.57	0.77	−1.03	0.45	0.54	−2.24	0.14	0.14
High School Students vs. Graduates	0.51	1.90	0.77	−0.43	0.57	0.78	−2.21	0.05	0.14	−0.99	0.32	0.56

Note. Bold = $p \leq 0.05$. *Ratio* = odds ratio for likelihood outcomes and risk ratio for frequency outcomes.

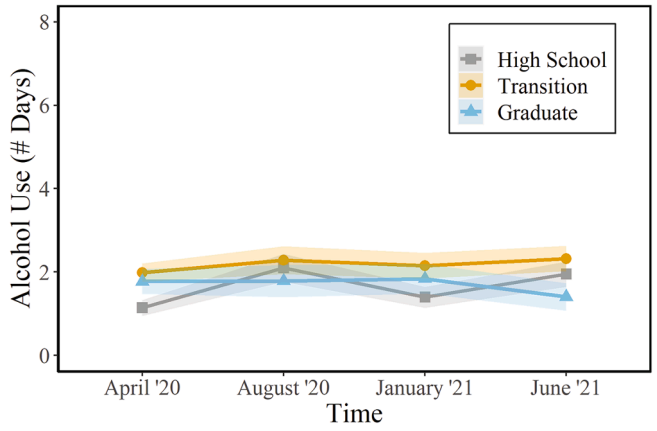

Fig. 1. Frequency of Alcohol Use Trajectories as a Function of High School Status.

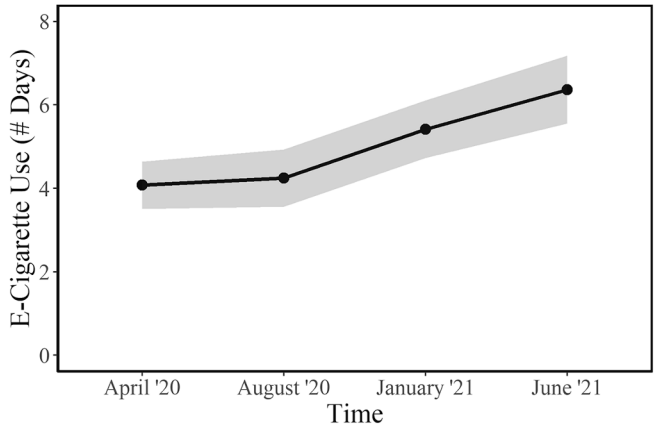

Fig. 2. Trajectory of the Frequency of E-Cigarette Use.

alcohol use were notably higher at the end of our study (45.4%) as compared to our pre-pandemic data (32.2%) and the pre-pandemic national Canadian average among adolescents (27.4%; Health Canada, 2019). Rates for other substances were closer to previously reported averages and thus, upward trends may reflect movement back towards typical pre-pandemic use. Regardless, it is possible that the pandemic may have altered substance use rates, particularly for alcohol, in a unique way that clinicians and researchers alike should continue to monitor. Given that COVID-19 may become endemic, it will be important to determine if new strategies to address adolescent substance use are warranted that take into account the potentially unique contexts and motivations for substance use during this era.

Despite the important insights this study provides, this work should be considered in light of potential limitations. First, given that data were collected from a primarily Caucasian, female, Canadian sample, it is unclear how results may generalize to different cultures and populations or countries that had less restrictive lockdown and social distancing policies. It is also important that results be replicated with a greater number of non-female-identifying participants to test potential gender differences in substance use trajectories. Further concerns of sample representation may stem from our convenience sampling via the social media site, Instagram. However, participants' pre-pandemic substance use prevalence rates were similar to that of National pre-pandemic averages (Health Canada, 2019). Next, as noted in the methods, there was considerable attrition from T1 to T2. However, this attrition was not related to participants' substance use. One potential reason why T2 had the lowest response rate is because data was collected during summer break, a time during which adolescents are less likely to check e-mail and may have been more preoccupied with social activities given that it was the time point with the fewest pandemic-related restrictions. Also, it would be worthwhile for future researchers to measure quantity of substance use rather than frequency of use, as was done in the current study. This would provide a more nuanced understanding of fluctuations in the amount of substances adolescents used across the pandemic. Finally, future research should focus on developing a more comprehensive understanding of variables that predict differences in adolescents' substance use trajectories across the pandemic beyond that of demographic variables such as student status. For instance, recent cross-sectional research suggests that perceived changes in peer drinking norms since the pandemic is an important predictor of changes in youths' own use (Graupensperger, Jaffe et al., 2021).

Overall, this study sheds important light on adolescents' substance use trajectories during the COVID-19 pandemic and provides evidence that adolescent substance use, and in particular, use among those transitioning from high school, as well as e-cigarette use among current high school students, may be of particular concern. As the pandemic continues to evolve and people settle into a "new normal", it will remain important to monitor these trajectories to determine if there are long-term impacts on adolescent substance use.

5. Author Agreement

The final version of the manuscript has been read and approved by all authors. None of the original material contained in the manuscript has been submitted for consideration elsewhere and we will not submit it to other journals while our manuscript is under consideration by Addictive Behaviors.

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CRediT authorship contribution statement

Tara M. Dumas: Conceptualization, Methodology, Formal analysis, Writing – original draft. **Wendy E. Ellis:** Conceptualization, Methodology. **Stephen Van Hedger:** Formal analysis, Writing – review & editing. **Dana M. Litt:** Writing – original draft. **Madeleine MacDonald:** Methodology, Writing – review & editing.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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