



## Predictors of past-year e-cigarette use among young adults

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### ABSTRACT

Understanding the underpinnings of e-cigarette use among young adults is critical to addressing increasing uptake. We identified predictors of past-year e-cigarette use among young adults in Montreal, Canada. Data on potential predictors were available for 714 young adults participating in the ongoing Nicotine Dependence in Teens Study at age 20 in 2007–08. Past-year e-cigarette use was measured at age 30 in 2017–20. Each potential predictor was studied in a separate multivariable logistic regression model controlling for age, sex, and educational attainment. Male sex, friends who smoke, cigarette smoking, use of other tobacco products, alcohol use, use of marijuana, and impulsivity predicted past-year e-cigarette use. Higher educational attainment and very good/excellent self-rated health were protective. Program and policy makers will need to consider these predictors of e-cigarette use in the design of clinical and public health interventions targeting e-cigarette use in young adults.

### 1. Introduction

Preventing e-cigarette use among young adults in addition to adolescents is a public health imperative because of its relatively high prevalence in this age group (Canadian Tobacco and Nicotine Survey, 2019). In addition, there are concerns that e-cigarettes may be a gateway to smoking combustible cigarettes (Al-Hamdani and Davidson, 2021). Furthermore, there is growing evidence of the harmful effects of e-cigarettes on health, including lung damage and nicotine addiction (Jankowski et al., 2019; Hajek et al., 2017; Goniewicz et al., 2019; Jackler and Ramamurthi, 2019; Saji et al., 2020; Bhatta and Glantz, 2020).

Foundational to developing effective public health and clinical interventions is robust evidence on factors associated with e-cigarette use. Numerous cross-sectional studies identify a wide range of factors associated with e-cigarette use among young adults (Goniewicz and Zielinska-Danch, 2012; Hittner et al., 2020; Omoike and Johnson, 2021; Kenne et al., 2016; Lewek et al., 2019; Seabrook et al., 2021; Pericot-Valverde et al.; Melka et al., 2018; Trumbo and Harper, 2013; Hefner et al., 2019; Ramo et al., 2015; Leventhal et al., 2022; Lanza et al., 2020). However, these studies are limited by uncertainty about whether exposure preceded e-cigarette use. Longitudinal studies can address this

temporality issue, but only a few such studies have been published to date. These studies report that younger age (Agarwal et al., 2018; Spindle et al., 2017; Filippidis et al., 2017; Ahmad et al., 2022), male sex (Spindle et al., 2017; Ahmad et al., 2022; Jayakumar et al., 2020; Sompa et al., 2022), higher educational attainment (Filippidis et al., 2017), living in an urban area (Filippidis et al., 2017), past or current use of combustible cigarettes (Filippidis et al., 2017; Ahmad et al., 2022; Jayakumar et al., 2020; Sompa et al., 2022), use of other tobacco products (Spindle et al., 2017; Ahmad et al., 2022), cannabis use (Spindle et al., 2017; Ahmad et al., 2022; Jayakumar et al., 2020), peer networks that approve or use e-cigarettes (Agarwal et al., 2018; Ahmad et al., 2022; Jayakumar et al., 2020; Melka et al., 2019), and impulsivity and lower perseverance (Spindle et al., 2017) predict e-cigarette use.

Most of these longitudinal studies (Melka et al., 2019; Agarwal et al., 2018; Spindle et al., 2017; Filippidis et al., 2017; Ahmad et al., 2022; Jayakumar et al., 2020), however, had relatively short follow-up periods of 1–3 years, possibly limiting detection of risk factors to those that were more relevant in the short- versus the long-term. In addition, two were conducted among college students in the US (Agarwal et al., 2018; Spindle et al., 2017), one studied young women in Australia (Melka

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et al., 2019), one took place in Sweden (Sompa et al., 2022), and one covered 27 European countries (Filippidis et al., 2017), which may have limited their relevance in other jurisdictions with differing social or legislative contexts. Only two longitudinal studies have been conducted in Canada. One was limited by a small sample size (Jayakumar et al., 2020), and the other by its focus on pod-style e-cigarettes (Ahmad et al., 2022). In addition, except for one study which included persons over age 55 across 27 European countries, the samples in all studies were either solely or predominantly within the age range of 16–24 years. Young adulthood (i.e., age 20–29) (Chapter 3: *The Chief Public Health Officer's Report on the State of Public Health in Canada, 2011*) is characterized by numerous major life transitions, including leaving home, identity exploration and establishment, and decision-making about finances, work, relationships, education, and place of residence (Nelson and Padilla-Walker, 2013). Understanding whether predictors of e-cigarette use identified in youth age 16–24 are relevant in young adulthood is important to developing effective public health and clinical programing targeting this demographic.

In this study, we address these gaps using data from the Nicotine Dependence in Teens (NDIT) study (i.e., a 22-year follow-up of a population-based sample of adolescents in Montreal, Canada) to identify factors associated with past-year e-cigarette use among young adults. Factors potentially associated with e-cigarette use were drawn from among variables previously reported as associated with e-cigarette and/or combustible cigarette use. In this study, we used data from a 10-year follow-up of never e-cigarette users age 20 years in 2007–08 to identify risk and protective factors for past-year e-cigarette use at age 30.

## 2. Methods

We drew data from the Nicotine Dependence in Teens (NDIT) study (O'Loughlin et al., 2015). NDIT recruited 1294 participants ages 12–13 years in 7th grade (1999–2000) in a non-probability sample of 10 Montreal-area high schools selected to include schools located in urban, suburban and rural neighbourhoods, schools serving students of high, moderate and low socioeconomic status and schools serving French and English-speaking students. Data were collected from participants four times during the 10-month school year from 7th to 11th grade, for a total of 20 data collection cycles over 5 years throughout high school. After high school, data were collected in four cycles: 2007–08 (cycle 21), 2010–12 (cycle 22), 2017–20 (cycle 23) and 2020–21 (cycle 24), when the participants were ages 20.4 (0.8), 24.0 (0.7), 30.5 (1.0) and 33.6 (0.6) years, on average. At cohort inception in 7th grade, participant characteristics were comparable to those reported in the 1999 provincially representative Québec Child and Adolescent Health and Social Survey (QCAHHS) (O'Loughlin et al., 2015; Paradis et al.). For this study, we used data from cycles 21 and 23 for the main analyses.

Data on most potential risk or protective factors were drawn from cycle 21 (i.e., at age 20.4 years on average) which took place before enactment of the 2018 Tobacco and Vaping Products Act, after which enticing flavoured products catapulted sales of e-cigarette products in the Canadian market. Past-year e-cigarette use was measured in cycle 23 at age 30.5 (i.e., 10 years after the potential predictors studied herein were measured). In addition to exposures measured in cycle 21, we also studied four time-invariant exposures (i.e., age, sex, Caucasian, born in Canada). The association between these time-invariant exposures and past-year e-cigarette use in cycle 23 will remain stable regardless of when they were measured. Of 880 participants who completed cycle 21, 714 (80 %) reported data on e-cigarette use in cycle 23 and were retained for analysis.

NDIT was approved by the Ethics Committee of the Centre de Recherche du Centre Hospitalier de l'Université de Montréal (ND 06.087). Parental consent was obtained in cycle 1, and participants provided consent in post-high school data collections.

### 2.1. Study variables

Participants were asked in cycle 23 how often (never; less than once a month; 1–3 times per month; 1–6 times per week; every day) in the past 12 months they had used: (i) e-cigarettes with nicotine; (ii) e-cigarettes without nicotine; and (iii) e-cigarettes to vape marijuana, hash oil, liquid or wax. For analyses, responses were recoded as no if participants responded never to (i), (ii) and (iii), and yes if any other response was endorsed for (i), (ii) or (iii) (Dugas et al., 2020).

Factors investigated as potentially associated with e-cigarette use were selected based on previous reports that the variable was associated with e-cigarette and/or combustible cigarette use, and that data for the variable were available in NDIT. These included seven *sociodemographic characteristics* (i.e., age, sex, Caucasian status, born in Canada, educational attainment, household income, employed), four indicators of *smoking in the social environment* (i.e., parental smoking status, sibling smoking status, number of friends who smoke, partner's smoking status); seven *lifestyle-related* indicators (i.e., past-year cigarette smoking, use of other tobacco products, alcohol use, and marijuana use, meets moderate-to-vigorous physical activity (MVPA) guidelines, sleep quality, body mass index (BMI)); eight *psychological indicators* (i.e., depressive symptoms, anxiety symptoms, ability to handle unexpected/difficult problems, self-esteem, impulsivity, novelty-seeking, number of life events in past year, daily stress), and five *health-related variables* (i.e., self-rated health, self-rated mental health, diagnosed anxiety disorder, mood disorder and/or learning disability). Because NDIT did not measure self-esteem, impulsivity or novelty-seeking in cycle 21, data for these variables were drawn from cycle 22, 18 and 18, respectively. [Supplementary File 1](#) describes questionnaire item(s), response options, recoding for analysis and references if applicable, for each study variable.

### 2.2. Data analysis

We conducted descriptive analyses to check distributions, identify missing data and outliers, and compute means (SD) for continuous variables and proportions for categorical variables.

To avoid issues of multiple testing, we investigated each potential predictor as an independent study that addressed a single hypothesis (Bender and Lange, 2001). We first examined the associations between each potential predictor and past-year e-cigarette use in cross-tabulations. Continuous variables were categorized for these analyses. Then only two models were estimated for each variable – an unadjusted logistic regression model and a multivariable model adjusting for age, sex, and educational attainment (i.e., a minimal sufficient adjustment set for estimating the total effect of the potential predictor on past-year e-cigarette use). Note that continuous variables were retained as continuous in the logistic regression modeling.

We did not estimate a model including all predictors because adjustment by variables that are not confounders of the association between the variable and the outcome (but rather colliders or mediators) could bias the estimated coefficient (Schisterman et al., 2009; Westreich and Greenland, 2013). We concluded that a variable was associated with past-year e-cigarette use if the confidence interval for the estimate excluded the null value.

Finally, we conducted a sensitivity analysis in which we used past-month (rather than past-year) e-cigarette use as the outcome. Data were analyzed using SPSS version 20.0 (released 2011, SPSS Statistics for Windows; IBM Corp).

## 3. Results

Of 880 participants who completed cycle 21 at age 20.4 (i.e., considered to be baseline in this current study), 714 (81 %) with data on past-year e-cigarette use at age 30.5 in cycle 23 were retained for analysis. There were few important differences between groups in most

study variables, although relatively fewer participants retained for analysis were male; relatively more had university-educated mothers; and relatively fewer had parents who smoke (Table 1).

Of the 714 participants retained for analysis, 18.5 % reported past-year e-cigarette use including 23.6 % of males and 14.5 % of females. Among these 132 e-cigarette users, 55.3 % used e-cigarettes less than once a month; 19.7 % used them 1–3 times per month; 15.9 % used them 1–6 times per week, and 9.1 % were daily users.

Table 2 shows the proportion of participants who reported past-year e-cigarette use in each category of each potential predictor. Note that continuous variables were categorized for these analyses but were retained as continuous in the unadjusted and adjusted logistic regression models. The unadjusted logistic regression models which estimate the OR for each association before any adjustment, substantiate the findings in the simple cross-tabulation analyses.

In multivariable analyses, two of the seven sociodemographic variables investigated were associated with e-cigarette use. Male sex was associated with a higher odds of past-year e-cigarette use, and higher

**Table 1**

Baseline characteristics\* of NDIIT participants retained and not retained for analysis (n = 880), Nicotine Dependence in Teens Study, Montreal, Canada, 1999–2020.

Characteristics of participants	Retained for analysis (n = 714)	Not retained for analysis (n = 166)
<i>Sociodemographic indicators</i>		
Age, mean (sd)	20.3 (0.7)	20.7 (0.9)
Male, %	44.0	54.2
Participant attended/graduated university, %	19.8	17.5
Mother university-educated, %	46.5	37.7
Household income, CAN < 30,000\$, %	39.3	45.2
Employed, %	77.7	75.9
French-speaking, %	30.5	32.5
Caucasian, %	79.1	77.7
Born in Canada, %	93.8	91.6
<i>Smoking in social environment</i>		
Parent(s) smoke, %	34.0	44.6
Sibling(s) smoke, %	20.9	27.7
Friends smoke, %	64.1	65.7
Partner smokes, %	11.8	10.2
<i>Lifestyle indicators</i>		
Ever smoked, %	67.4	73.5
Past-year use of other tobacco products, %	45.2	51.2
Past-year alcohol use, %	90.8	91.0
Past-year marijuana use, %	44.1	44.6
Meets MVPA guidelines, %	46.1	53.1
Past-month sleep quality poor/fair, %	28.3	32.1
Overweight/obese, %	20.3	27.0
<i>Psychological indicators</i>		
Depressive symptoms, mean (sd)	9.8 (7.7)	9.5 (8.3)
Self-esteem <sup>†</sup> , mean (sd)	2.6 (0.3)	2.6 (0.3)
Lifetime anxiety symptoms, mean (sd)	3.6 (3.4)	3.6 (3.4)
Poor/fair ability to handle unexpected/difficult problems %	18.5	10.9
Impulsivity <sup>‡</sup> , mean (sd)	2.3 (0.9)	2.5 (1.0)
Novelty-seeking <sup>‡</sup> , mean (sd)	2.9 (0.8)	3.1 (0.8)
No. life events in past year, mean (sd)	3.0 (2.7)	3.1 (3.1)
Daily stress, quite/extremely stressful, %	14.6	16.9
<i>Health-related indicators</i>		
Poor/fair self-rated health, %	12.8	11.5
Poor/fair self-rated mental health, %	12.7	8.5
Diagnosed anxiety disorder, %	7.3	4.2
Diagnosed mood disorder, %	6.3	4.2
Diagnosed learning disability, %	4.8	7.3

\*In cycle 21 †Self-esteem was measured in cycle 22; impulsivity and novelty-seeking were measured in cycle 18.

**Table 2**

Odds Ratios (ORs) (95 % confidence intervals (Cis)) for factors potentially associated with past-year e-cigarette use among young adults (n = 714), Nicotine Dependence in Teens Study, Montreal, Canada, 1999–2020.

	n	Past-year e-cigarette use %	OR <sub>crude</sub> (95 % CI)	OR <sub>adj</sub> (95 % CI) *
<i>Sociodemographic indicators</i>				
Age (in cycle 23), y <sup>†</sup>				
< 30.1	261	19.2	1.1 (0.9, 1.3)	1.1 (0.9, 1.3)
30.1 < 30.8	223	17.0		
≥ 30.8	230	19.1		
Sex				
Female	400	14.5	ref	ref
Male	314	23.6	1.8 (1.2, 2.7)	1.7 (1.2, 2.6)
Caucasian				
No	149	12.8	ref1.7	ref1.6
Yes	565	20.0	(1.0, 2.9)	(0.9, 2.7)
Born in Canada				
No	44	9.1	ref2.4	ref2.3
Yes	670	19.1	(0.8, 6.7)	(0.8, 6.5)
Educational attainment				
High school or less	147	27.9	ref	ref
Some post-high school	431	16.9	0.5 (0.3, 0.8)	0.6 (0.4, 0.9)
Attended or graduated university	133	13.5	0.4 (0.2, 0.8)	0.4 (0.2, 0.8)
Household income, CAD <sup>‡</sup>				
≥ 100,000	144	16.7	ref	ref
30,000 < 99,000	194	20.1	1.3 (0.7, 2.2)	1.2 (0.7, 2.2)
< 30,000	219	21.5	1.4 (0.8, 2.4)	1.3 (0.7, 2.3)
Employed				
Yes	554	19.5	ref1.1	ref1.0
No	159	18.2	(0.7, 1.7)	(0.7, 1.6)
<i>Smoking in social environment</i>				
Parent(s) smoke				
No	471	17.0	ref1.3	ref1.3
Yes	243	21.4	(0.9, 2.0)	(0.9, 2.0)
Sibling(s) smoke(s)				
No	565	18.1	ref1.1	ref1.1
Yes	149	20.1	(0.7, 1.8)	(0.7, 1.8)
Number of friends who smoke <sup>‡</sup>				
0	250	9.0	1.2 (1.1, 1.3)	1.2 (1.1, 1.3)
1	154	14.9		
≥2	302	27.2		
Partner smokes				
No	630	17.5	ref1.7	ref1.7
Yes	84	26.2	(1.0, 2.8)	(1.0, 3.0)
<i>Lifestyle indicators</i>				
Past-year cigarette smoking				
No	378	9.5	ref	ref
Yes	335	28.7	3.8 (2.5, 5.8)	3.9 (2.5, 6.1)
Past-year use of other tobacco products				
No	390	10.5	ref	ref
Yes	323	28.2	3.3 (2.2, 5.0)	3.1 (2.1, 4.7)
Past-year alcohol use <sup>‡</sup>				
Never	66	12.1	1.5 (1.2, 1.9)	1.5 (1.2, 1.9)
Monthly	377	14.0		
Weekly	269	26.0		
Past-year marijuana use <sup>‡</sup>				
Never	399	9.3	1.7 (1.5, 2.0)	1.7 (1.5, 1.9)
Monthly	177	20.9		
Weekly	136	42.6		
Meets MVPA guidelines				
No	387	17.8	ref1.1	ref0.9
Yes	327	19.3	(0.8, 1.6)	(0.6, 1.4)
Past-month sleep quality <sup>‡</sup>				
Poor/fair	201	21.4	1.1 (0.9, 1.3)	1.0 (0.9, 1.3)

(continued on next page)

Table 2 (continued)

	n	Past-year e-cigarette use %	OR <sub>crude</sub> (95 % CI)	OR <sub>adj</sub> (95 % CI) *
Good	184	15.2		
Very good/excellent	326	18.1		
<b>Body mass index</b> <sup>†</sup>				
Normal (<25.0)	566	17.8	ref1.1	ref0.9
Overweight (25–29.9)	107	18.7	(0.6, 1.8)	(0.5, 1.6)
Obese (>30)	37	27.0	1.7 (0.8, 3.6)	1.4 (0.6, 3.0)
<b>Psychological indicators</b>				
<b>Depressive symptoms in past 2 weeks</b> <sup>†</sup>				
0–10	468	16.9	1.0 (1.0, 1.0)	1.0 (0.9, 1.0)
11–50	245	18.4		
<b>Self-esteem</b> <sup>†</sup>				
≤ 2.4	197	16.7	1.5 (0.7, 3.3)	1.3 (0.6, 2.9)
2.5 < 2.6	239	14.6		
≥ 2.7	229	22.3		
<b>Lifetime anxiety symptoms</b> <sup>†</sup>				
0–2	444	16.0	1.1 (1.0, 1.2)	<b>1.1 (1.0, 1.2)</b>
3–10	270	22.6		
<b>Ability to handle unexpected/difficult problems</b> <sup>†</sup>				
Poor/fair	132	19.7	1.0 (0.9, 1.2)	1.1 (0.9, 1.3)
Good	179	15.1		
Very good/excellent	401	19.5		
<b>Impulsivity</b> <sup>†</sup>				
1.00–1.71	183	10.9	<b>1.4 (1.1, 1.8)</b>	<b>1.4 (1.1, 1.8)</b>
1.86–2.67	184	15.2		
2.71–5.00	188	22.9		
<b>Novelty-seeking</b> <sup>†</sup>				
1.00–2.50	179	13.4	1.2 (0.9, 1.6)	1.3 (1.0, 1.7)
2.56–3.11	178	15.7		
3.22–5.00	201	19.9		
<b>No. life events in past year</b> <sup>†</sup>				
0–1	217	13.8	<b>1.1 (1.0, 1.2)</b>	<b>1.1 (1.0, 1.2)</b>
2–4	347	16.7		
5–18	150	29.3		
<b>Daily stress</b> <sup>†</sup>				
Not at all/not very stressful	336	18.2	1.1 (0.9, 1.3)	1.2 (0.9, 1.4)
A bit stressful	273	16.1		
Quite/extremely stressful	104	25.0		
<b>Health-related indicators</b>				
<b>Self-rated health</b> <sup>†</sup>				
Poor/fair	91	23.1	0.8 (0.7, 1.0)	<b>0.8 (0.6, 0.9)</b>
Good	259	22.8		
Very good/excellent	361	14.1		
<b>Self-rated mental health</b> <sup>†</sup>				
Poor/fair	90	22.2	1.0 (0.8, 1.2)	0.9 (0.8, 1.1)
Good	162	17.9		
Very good/excellent	459	17.7		
<b>Diagnosed anxiety disorder</b>				
No	660	17.7	ref1.7	ref1.9
Yes	52	26.9	(0.9, 3.3)	(1.0, 3.7)
<b>Diagnosed mood disorder</b>				
No	667	18.0	ref1.5	ref1.5
Yes	45	24.4	(0.7, 3.0)	(0.7, 3.1)
<b>Diagnosed learning disability</b>				
No	678	18.4	ref0.9	ref0.8
Yes	34	17.6	(0.7, 1.1)	(0.3, 2.1)

\*Models were adjusted for age, sex and educational attainment except for the model for age (which was adjusted for sex and educational attainment only); for sex (which was adjusted for age and educational attainment only); and for educational attainment (which was adjusted for age and sex only).

OR indicates the increase in the probability of the outcome per one-unit change in the exposure variable.

Self-esteem was measured in cycle 22; impulsivity and novelty-seeking were measured in cycle 18.

Totals differ because of missing values.

<sup>†</sup> Continuous variables were categorized for descriptive purposes but included as continuous in the logistic regression models.

participant educational attainment was associated with a lower odds (Table 2). Of the four variables measuring smoking in the social environment, only number of friends who smoke was associated with an increased odds of e-cigarette use. The adjusted OR for partner smokes was 1.7, but the 95 % confidence interval for the estimate included the null value of 1.0. All variables related to substance use were associated with e-cigarette use, but none of meets moderate-to-vigorous physical activity (MVPA) guidelines, sleep quality or BMI were associated with the outcome. Among the eight psychological indicators, only impulsivity was associated with e-cigarette use. Finally, very good/excellent self-rated health was protective. The adjusted OR for diagnosed anxiety disorder was 1.9, but the 95 % confidence interval included the null value of 1.0.

### 3.1. Sensitivity analyses

In sensitivity analyses (see Supplementary File 2), we repeated the analyses to identify predictors of past-month (rather than past-year) e-cigarette use. The level of precision in the past-month analysis was lower in the past-month analysis (due to the lower number of past-month e-cigarette users). However, the adjusted estimates in the past-month analysis were similar to those in the past-year analysis with one possible exception. Diagnosed mood disorder was not associated with past-year e-cigarette use (1.5 (0.7, 3.1)) but was strongly associated with past-month e-cigarette use (i.e., adjusted OR (95 % CI) = 2.9 (1.1, 6.5)).

### 3.2. Interpretation

In this paper, we address gaps in knowledge on factors associated with e-cigarette use among young adults, the age group with the highest prevalence of e-cigarette use in Canada (Tobacco and Survey, 2019). Most of our findings align with those of previous longitudinal studies which show that factors associated with e-cigarette use include male sex (Spindle et al., 2017; Ahmad et al., 2022; Jayakumar et al., 2020; Sompa et al., 2022), past or current use of combustible cigarettes (Filippidis et al., 2017; Ahmad et al., 2022; Jayakumar et al., 2020; Sompa et al., 2022), cannabis use (Spindle et al., 2017; Ahmad et al., 2022; Jayakumar et al., 2020), having peer networks that approve of or use e-cigarettes (Agarwal et al., 2018; Ahmad et al., 2022; Jayakumar et al., 2020; Melka et al., 2019), and impulsivity (Spindle et al., 2017). This alignment suggests that predictors commonly found among youth ages 16–24 also predict e-cigarette use among young adults over age 24.

Our findings also align with established predictors of combustible cigarette smoking. According to a systematic review of longitudinal predictors of smoking in youth, lower socioeconomic status, poor academic performance, smoking among family members and other social networks, and sensation-seeking were among the most consistent predictors of cigarette smoking (Wellman et al., 2016). Researchers who examined predictors of smoking uptake among young adults specifically found that alcohol use, higher impulsivity, and poor academic performance were associated with smoking uptake between adolescence and young adulthood (O'Loughlin et al., 2014). This alignment suggests that the underpinnings of any tobacco-related product use may be similar, and possibly that the choice of a specific product may depend more on access and availability than on individual characteristics.

Higher educational attainment was protective of e-cigarette use in our study. This contradicts earlier reports that higher education (Filippidis et al., 2017) and higher socioeconomic status (Brown et al., 2014) are associated with e-cigarette use among adults, and in particular with use of e-cigarettes as a cessation aid to quit smoking (Pokhrel et al., 2014). Such differences across studies could reflect increased understanding of the benefits and harms of e-cigarettes as knowledge accumulates over time. Assari et al. (Assari et al., 2020) cautioned, though, that the role of educational attainment in e-cigarette use is complex. In their work, higher education attainment was generally protective in a large sample of US adults. However, in race-stratified analyses, high

educational attainment was inversely associated with the risk of e-cigarette use in Whites but not Blacks, prompting attention to population disparities. In a recent scoping review on disparities in exposure to advertising for e-cigarettes and heated tobacco products, Grilo et al. (Grilo et al., 2021) advised that e-cigarette research should apply a health equity lens from inception to inform interventions that aim to eliminate disparities.

Our findings support previous reports that co-use of different psychoactive substances, including tobacco, cannabis, and alcohol is common in young adults who use e-cigarettes (Fix et al., 2014; Conway et al., 2017; Cohn et al., 2015). Because co-use has been associated with poor mental health and substance use problems (Fix et al., 2014), screening in clinical settings for tobacco, cannabis, and alcohol use among e-cigarette users could help identify those with more vulnerable mental health. Promoting quitting or reducing e-cigarette use in young adults who co-use may require more complex and/or tailored interventions focused on positive coping strategies rather than, or in addition to, interventions that promote e-cigarette reduction or cessation.

That very good/excellent self-rated health was protective of e-cigarette use is also noteworthy. Similar to co-use of multiple psychoactive substances, health-promoting behaviors may also cluster within individuals. A person who values their health may avoid any or all behaviors perceived as possibly unhealthy, including e-cigarette use, in order to maintain their good health. Alternatively, individuals who perceive themselves to be in excellent health may be better able to cope with life challenges without relying on psychoactive substances. Public health messaging that leverages factors that help individuals maintain and improve their health (e.g., regular exercise, healthy nutrition, positive coping strategies) may be a productive route to reducing perceived need for psychoactive substances.

Smoking cessation is consistently the number one reason for e-cigarette uptake among young adults, especially among those over age 25 (Tobacco and Survey, 2020). In fact, 65% of e-cigarette users in Canada are current smokers, and 20 % are former smokers (Vaping in Canada). However, data on reasons for e-cigarette use were not collected in NDIT. More work is needed to better understand reasons for uptake and continued use of e-cigarettes, especially given that past or current smoking predicted e-cigarette uptake in this study. Public health messaging for young adult e-cigarette users will need to carefully balance messaging related to harm reduction, while also promoting prevention and cessation.

In our sensitivity analyses, mood disorders was a risk factor for past-month e-cigarette use (in contrast to the past-year analyses in which mood disorders was not detected). Removing e-cigarette users who used less than monthly from the pool of all past-year e-cigarette users may have rendered the group more homogeneous, such that the signal for mood disorders was stronger and therefore detectable. Further research is needed to understand the relationship between mood disorders and e-cigarette use.

#### 4. Limitations

Although the characteristics of NDIT participants at inception resembled those of same-age young persons participating in the provincially-representative QCAHSS (Ahmad et al., 2022), loss-to-follow-up since inception may have affected generalizability of the findings. Loss-to-follow-up since baseline in this current study (i.e., cycle 21) could have resulted in selection bias. Because of the relatively small sample size of e-cigarette users, we collapsed all types of e-cigarette users into a single grouping, precluding identification of predictors in specific sub-groups. Use of self-report data may have contributed to misclassification bias. Residual confounding may have affected the estimates due to misclassification in the measurement of the (potential) confounding factors included in the modeling or to unmeasured confounding factors. Given that 31 separate associations were examined, some statistically significant findings may be attributable to chance.

However, this seems unlikely since our findings align with those of previous studies. The relatively small sample sizes could have limited our ability to detect some associations. Finally, although this study covers a 10-year timespan from age 20.4 to 30.5, past-year and current e-cigarette use were captured in cycle 23 only and we did not ask about age first tried. However, data for most potential predictors were collected 10 years earlier in 2007–08 and e-cigarettes were not easily available in the Canadian market until 2018.

#### 5. Implications

That numerous risk factors for e-cigarette use mirror those for cigarette smoking (and other substances) is likely a cornerstone for moving forward. Reasons for co-use of these products must be identified, as well as factors distinguishing unique use of specific products. If replicated, the underpinnings of higher e-cigarette use among persons with lower education need to be better understood. It is not known whether this simply reflects the well-established social gradient in cigarette smoking, or if the underpinnings are unique to e-cigarette use. Regardless, an equity lens may be appropriate in e-cigarette research, as well as in the conceptualization of e-cigarette programs and policy. Further, co-use of tobacco, cannabis, alcohol, and e-cigarette use warrant consideration when developing interventions and making recommendations for young adults who use e-cigarettes. That social influences (i.e., friends smoking status) is a possible underpinning of e-cigarette use speaks to the need for programs and policy that address social norms about e-cigarette use. Self-rated health is another important factor that warrants focus in prevention interventions. Finally, ongoing monitoring of the prevalence and risk factors for e-cigarette use is critical as e-cigarette technology evolves and as new nicotine-delivery products are marketed.

#### 6. Conclusions

Among young adults in Canada, male sex, friends smoking, impulsivity, and substance use were identified as risk factors for e-cigarette use. Higher educational attainment and very good/excellent self-rated health were protective. Program and policy makers will need to consider these factors in the design of clinical and public health interventions targeting e-cigarette use in young adults.

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#### CRediT authorship contribution statement

All authors contributed to conceptualizing the study and the analytic plan, interpreted the results, and reviewed and revised the manuscript. LLS reviewed the literature and drafted a first version of the manuscript. EKO conducted the analyses and wrote sections of the manuscript. TR assisted with data analysis. JOL oversaw data collection, funding, and analysis, and assisted in writing the manuscript. All authors approved the final manuscript as submitted and agree to be accountable for all aspects of the work.

#### 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.

## Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.pmedr.2022.101965>.

## References

- Agarwal, D., Loukas, A., Perry, C.L. 2018. Examining college students' social environment, normative beliefs, and attitudes in subsequent initiation of electronic nicotine delivery systems. *Health education and behavior* [Internet]. 2018 Aug 1 [cited 2021 May 30];45(4), 532–539. Available from: <https://doi.org/10.1177/1090198117739672>.
- Ahmad, S., Wang, T., Schwartz, R., Bondy, S.J. 2022. Predictors of pod-type e-cigarette device use among Canadian youth and young adults. *Health Promotion and Chronic Disease Prevention in Canada: Research, Policy and Practice*. 42(1), 12.
- Al-Hamdani, Hopkins, M., Davidson, D.B. 2021. The 2020-2021 Youth and Young Adult Vaping Project EXECUTIVE SUMMARY.
- Assari, S., Mistry, R., Bazargan, M., 2020. Race, educational attainment, and e-cigarette use. *J. Med. Res. Innov.* 4 (1).
- Bender, R., Lange, S., 2001. Adjusting for multiple testing - when and how? *J. Clin. Epidemiol.* 54 (4), 343–349.
- Bhatta, D.N., Glantz, S.A. 2020. Association of E-cigarette use with respiratory disease among adults: a longitudinal analysis. *Am. J. Prevent. Med.* [Internet]. [cited 2022 Feb 1];58(2):182–190. Available from: <http://www.ajpmonline.org/article/S0749379719303915/fulltext>.
- Brown, J., West, R., Beard, E., Michie, S., Shahab, L., McNeill, A., 2014. Prevalence and characteristics of e-cigarette users in Great Britain: findings from a general population survey of smokers. *Addict. Behav.* 39 (6), 1120–1125.
- Canadian Tobacco and Nicotine Survey (CTNS): summary of results for 2019 - Canada.ca [Internet]. [cited 2022 Feb 1]. Available from: <https://www.canada.ca/en/health-canada/services/canadian-tobacco-nicotine-survey/2019-summary.html>.
- Chapter 3: The Chief Public Health Officer's Report on the State of Public Health in Canada 2011 – The health and well-being of Canadian youth and young adults - Canada.ca [Internet]. [cited 2022 Feb 1]. Available from: <https://www.canada.ca/en/public-health/corporate/publications/chief-public-health-officer-reports-state-public-health-canada/chief-public-health-officer-report-on-state-public-health-canada-2011/chapter-3.html>.
- Cohn, A., Villanti, A., Richardson, A., Rath, J.M., Williams, V., Stanton, C., Mermelstein, R., 2015. The association between alcohol, marijuana use, and new and emerging tobacco products in a young adult population. *Addict. Behav.* 1 (48), 79–88.
- Conway, K.P., Green, V.R., Kasza, K.A., Silveira, M.L., Borek, N., Kimmel, H.L., Sargent, J.D., Stanton, C., Lambert, E., Hilmi, N., Reissig, C.J., 2017. Co-occurrence of tobacco product use, substance use, and mental health problems among adults: findings from Wave 1 (2013–2014) of the Population Assessment of Tobacco and Health (PATH) Study. *Drug Alcohol Dependence* 1 (177), 104–111.
- Dugas, E.N., Sylvestre, M.P., Sylvestre, M.P., O'Loughlin, J., O'Loughlin, J., 2020. Type of e-liquid vaped, poly-nicotine use and nicotine dependence symptoms in young adult e-cigarette users: a descriptive study. *BMC Public Health* 20 (1), 1–8.
- Filippidis, F.T., Laverty, A.A., Gerovasili, V., Vardavas, C.L., 2017. Two-year trends and predictors of e-cigarette use in 27 European Union member states. *Tobacco Control*. 26 (1), 98–104.
- Fix, B.V., O'Connor, R.J., Vogl, L., Smith, D., Bansal-Travers, M., Conway, K.P., Ambrose, B., Yang, L., Hyland, A., 2014. Patterns and correlates of polytobacco use in the United States over a decade: NSDUH 2002–2011. *Addict. Behav.* 39 (4), 768–781.
- Goniewicz, M.L., Boykan, R., Messina, C.R., Elisca, A., Tolentino, J., 2019. High exposure to nicotine among adolescents who use Juul and other vape pod systems ('pods'). *Tob. Control*. 28 (6), 676–677.
- Goniewicz, M.L., Zielinska-Danch, W., 2012. Electronic cigarette use among teenagers and young adults in Poland [cited 2022 Feb 1];130(4). Available from: <https://pubmed.ncbi.nlm.nih.gov/22987874/>.
- Grilo, G., Crespi, E., Cohen, J.E., 2021. A scoping review on disparities in exposure to advertising for e-cigarettes and heated tobacco products and implications for advancing a health equity research agenda. *Int. J. Equity Health* 20 (1), 1–3.
- Hajek, P., Przulj, D., Phillips, A., Anderson, R., McRobbie, H., 2017. Nicotine delivery to users from cigarettes and from different types of e-cigarettes. *Psychopharmacology*. 234 (5), 773–779.
- Hefner, K.R., Sollazzo, A., Mullaney, S., Coker, K.L., Sofuoglu, M., 2019. E-cigarettes, alcohol use, and mental health: use and perceptions of e-cigarettes among college students, by alcohol use and mental health status. *Addict. Behav.* 1 (91), 12–20.
- Hittner, J.B., Penmetsa, N., Bianculli, V., Swickert, R., 2020. Personality and substance use correlates of e-cigarette use in college students. *Personal. Ind. Differ.* 1 (152), 109605.
- Jackler RK, Ramamurthi D. Nicotine arms race: JUUL and the high-nicotine product market. *Tobacco Control* [Internet]. 2019 Nov 1 [cited 2022 Feb 1];28(6):623–8. Available from: <https://tobaccocontrol.bmj.com/content/28/6/623>.
- Jankowski, M., Krzystanek, M., Zejda, J.E., Majek, P., Lubanski, J., Lawson, J.A., et al., 2019. E-cigarettes are more addictive than traditional cigarettes—A study in highly educated young people. *Int. J. Environ. Res. Public Health* [Internet]. Jul 1 [cited 2022 Feb 1];16(13). Available from: <https://pmc/articles/PMC6651627/>.
- Jayakumar, N., O'Connor, S., Diemert, L., Schwartz, R. 2020. Predictors of E-Cigarette Initiation: Findings From the Youth and Young Adult Panel Study. *Tobacco Use Insights*. 13:1179173X2097748.
- Kenne, D.R., Mix, D., Banks, M., Fischbein, R. 2016. Electronic cigarette initiation and correlates of use among never, former, and current tobacco cigarette smoking college students. <https://doi.org/103109/1465989120151068387> [Internet]. [cited 2022 Feb 1];21(5):491–494. Available from: <https://www.tandfonline.com/doi/abs/10.3109/14659891.2015.1068387>.
- Lanza, H.L., Motlagh, G., Orozco, M., 2020. E-cigarette use among young adults: a latent class analysis examining co-use and correlates of nicotine vaping. *Addict. Behav.* 1 (110), 106528.
- Leventhal, A.M., Dai, H., Barrington-Trimis, J.L., Tackett, A.P., Pedersen, E.R., Tran, D. D., 2022. Disposable e-cigarette use prevalence, correlates, and associations with previous tobacco product use in young adults. *Nicotine Tobacco Res.* 24 (3), 372–379.
- Lewek, P., Woźniak, B., Maludzinska, P., Smigielski, J., Kardas, P., 2019. E-cigarette use and its predictors: Results from an online cross-sectional survey in Poland. *Tobacco Induced Diseases* [Internet]. [cited 2022 Feb 1];17(November). Available from: <https://pmc/articles/PMC6856825/>.
- Melka, X.S., Xmpth, X., Chojenta, X.L., Xphd, X., Holliday, X.G., Loxton, X.J. 2018. Predictors of E-cigarette use among young Australian women. *Am. J. Prevent. Med.* [Internet]. 56(2):293–9. Available from: <https://doi.org/10.1016/j.amepre.2018.09.019>.
- Melka, A.S., Chojenta, C.L., Holliday, E.G., Loxton, D.J. 2019. Predictors of E-cigarette use among young Australian women. *Am. J. Prevent. Med.* [Internet]. [cited 2020 Nov 10];56(2), 293–299. Available from: <https://pubmed.ncbi.nlm.nih.gov/30554978/>.
- Nelson, L.J., Padilla-Walker, L.M., 2013. Flourishing and floundering in emerging adult college students. *Emerg. Adulthood*. 1 (1), 67–78.
- O'Loughlin, J., Dugas, E.N., Brunet, J., DiFranza, J., Engert, J.C., Gervais, A., et al. 2015. Cohort profile: the nicotine dependence in teens (NDIT) study. *Int. J. Epidemiol.* [Internet]. [cited 2021 May 30];44(5), 1537–1546.
- O'Loughlin, J.L., Dugas, E.N., O'Loughlin, E.K., Karp, I., Sylvestre, M.P., 2014. Incidence and determinants of cigarette smoking initiation in young adults. *J. Adolescent Health* 54 (1), 26–32.
- Omoike, O.E., Johnson, K.R. 2021. Prevalence of Vaping and Behavioral Associations of Vaping Among a Community of College Students in the United States. *Journal of Community Health* [Internet]. 1234;46:190–194. Available from: <https://doi.org/10.1007/s10900-020-00868-y>.
- Paradis, G., Lambert, M., O'loughlin, J., Lavallee, C., Msc~ J.A., Berthiaume, P., et al. The Quebec Child and Adolescent Health and Social Survey: design and methods of a cardiovascular risk factor survey for youth.
- Pericot-Valverde, I., Gaalema, D.E., Priest, J.S., Higgins, S.T. E-cigarette Awareness, Perceived Harmfulness, and Ever Use among U.S. Adults HHS Public Access.
- Pokhrel, P., Little, M.A., Fagan, P., Kawamoto, C.T., Herzog, T.A., 2014. Correlates of use of electronic cigarettes versus Nicotine Replacement Therapy for help with smoking cessation. *Addict. Behav.* 39, 1869–1873.
- Ramo, D.E., Young-Wolff, K.C., Prochaska, J.J., 2015. Prevalence and correlates of electronic-cigarette use in young adults: findings from three studies over five years. *Addict. Behav.* 1 (41), 142–147.
- Saji, S., Patil, S.S., Alleyn, M., Lockey, R., Kolliputi, N., 2020. Nicotine in E-cigarette smoke: cancer culprit? *J. Cell Commun. Signal.* [Internet]. Mar 1 [cited 2022 Feb 1]; 14(1):127. Available from: <https://pmc/articles/PMC7176775/>.
- Schisterman, E.F., Cole, S.R., Platt, R.W., 2009. Overadjustment bias and unnecessary adjustment in epidemiologic studies. *Epidemiology*. 20 (4), 488–495.
- Seabrook, J.A., Twynstra, J., Gilliland, J.A. 2021. Correlates of Lifetime and Past Month Vape Use in a Sample of Canadian University Students: <https://doi.org/10.1177/11782218211052059> [Internet]. [cited 2022 Feb 1];15. Available from: <https://journals.sagepub.com/doi/full/10.1177/11782218211052059>.
- Sompa, S.I., Zettergren, A., Ekström, S., Upadhyay, S., Ganguly, K., Georgelis, A., Ljungman, P., Pershagen, G., Kull, I., Melén, E., Palmberg, L., 2022. Predictors of electronic cigarette use and its association with respiratory health and obesity in young adulthood in Sweden: findings from the population-based birth cohort BAMSE. *Environ. Res.* 15 (208), 112760.
- Spindle, T.R., Hiler, M.M., Cooke, M.E., Eissenberg, T., Kendler, K.S., Dick, D.M., 2017. Electronic cigarette use and uptake of cigarette smoking: a longitudinal examination of U.S. college students. *Addict. Behav.* 1 (67), 66–72.
- Canadian Tobacco and Nicotine Survey – Summary of results for 2020. [Internet]. [cited 2022 June 1]. Available from: <https://www150.statcan.gc.ca/n1/daily-quotidien/210317/dq210317b-eng.htm>.
- Trumbo, C.W., Harper, R. 2013. Use and Perception of Electronic Cigarettes Among College Students. 2013 [cited 2022 Feb 1]; Available from: <https://www.tandfonline.com/action/journalInformation?journalCode=vach20>.
- Vaping in Canada: What We Know. [Internet]. [cited 2022 June 1]. Available from: <https://www.canada.ca/en/health-canada/services/smoking-tobacco/vaping/canada.html>.
- Wellman, R.J., Dugas, E.N., Dutczak, H., O'Loughlin, E.K., Datta, G.D., Lauzon, B., O'Loughlin, J., 2016. Predictors of the onset of cigarette smoking: a systematic review of longitudinal population-based studies in youth. *Am. J. Prevent. Med.* 51 (5), 767–778.
- Westreich, D., Greenland, S. 2013. Commentary the table 2 fallacy: presenting and interpreting confounder and modifier coefficients. *Am. J. Epidemiol.* [Internet]. [cited 2022 Feb 1];177(4), 292–298. Available from: <https://academic.oup.com/aje/article/177/4/292/147738>.