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IDENTIFYING BEHAVIOURAL CHARACTERISTICS OF TOBACCO PRODUCT AND E-CIGARETTE USE CLUSTERS: A REPEAT CROSS-SECTIONAL ANALYSIS

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ABSTRACT

Background: Youth may use a variety of tobacco products and e-cigarettes. However, there is a lack of evidence for the combinations of tobacco products and e-cigarettes commonly used by youth in Canada and whether youth from different usage classes share similar characteristics.

Methods: A cohort of 9th grade students from Ontario, Canada was identified at baseline (2013-14) of the COMPASS study (n=4651). Classes of youth that currently use similar combinations of tobacco products and e-cigarettes were identified at baseline, one (FY1) and two years later (FY2) using latent class analysis. Multinomial logistic regression models identified demographic and behavioural characteristics (e.g., environmental influences, substance use behaviours, etc.) of youth in current tobacco and e-cigarette use classes relative to youth in non-current use classes.

Results: At baseline, a three-class model was identified as best, while a four-class model was identified at FY1 and FY2. A non-current use group and an all-product use group were identified every year. Students that reported having friends that smoked cigarettes, binge drinking, and using marijuana were more likely to be classified into a current use class.

Conclusions: Tobacco cigarettes were more likely to be used with other products than on their own. An all-product use group was identified across all three survey waves and the prevalence of this group increased over time. Given that many youth in this study used more than one tobacco product or e-cigarette and commonly reported binge drinking and using marijuana, prevention and cessation activities should address the use of multiple products.

KEY WORDS: adolescence; latent class analysis; tobacco use; electronic cigarette

1. INTRODUCTION

A variety of tobacco and nicotine products are available in the Canada market, including tobacco cigarettes, pipe tobacco, cigarillos or little cigars (CLCs), cigars, smokeless tobacco, hookah, and more recently e-cigarettes. Although the sale of tobacco products and e-cigarettes is prohibited to those under the age of 19 years in Ontario, Canada, many youth still report accessing and using these products. Single product use is common, however there are some youth that use more than one product concurrently (i.e., polyproduct users). For example, evidence from one study in the USA identified that although 11.4% of 9th grade students reported currently using only one tobacco product or e-cigarette, 4.1% reported currently using two products and 4.0% reported currently using three or more products, and the prevalence of polyproduct use increased over time (Huh & Leventhal, 2016). Although tobacco products and e-cigarettes can be used in many different combinations, tobacco cigarettes are typically one of the products that are used among polyproduct users (Soneji, Sargent, & Tanski, 2014). Multiple USA studies have found that the dual use of tobacco cigarettes and cigars/cigarillos/little cigars is most common (Bombard, Rock, Pederson, & Asman, 2008; Everett, Malarcher, Sharp, Husten, & Giovino, 2000; Fix et al., 2014; Lee, Hebert, Nonnemaker, & Kim, 2015; Soneji et al., 2014); other popular combinations of products include tobacco cigarettes and smokeless tobacco (Bombard et al., 2008), tobacco cigarettes and hookah (Soneji et al., 2014), and more recently, tobacco cigarettes and e-cigarettes (Soneji et al., 2014).

Some studies have identified sociodemographic and behavioural factors associated with polyproduct use. Most of the research to date has focused on youth populations in the USA (Brooks, Gaier Larkin, Kishore, & Frank, 2008; Horn, Gao, Dino, & Kamal-Bahl, 2000; Mushtaq, Williams, & Beebe, 2012; Schuster, Hertel, & Mermelstein, 2013; Simon, Sussman, Dent, Burton, & Flay, 1993). However, variations in the number and types of products included in the analyses and contextual differences in

the popularity of different products between jurisdictions make it difficult to identify common themes across the research. Some studies have focused on identifying characteristics (e.g., age, gender, social influences) of dual users [e.g., dual tobacco cigarette and cigar users (Brooks et al., 2008), dual tobacco cigarette and smokeless tobacco users (Horn et al., 2000; Mushtaq et al., 2012; Simon et al., 1993)], while other studies have focused on identifying characteristics of polyproduct users without specifying particular combinations of products (e.g., Bombard et al., 2008; Fix et al., 2014; Lee et al., 2015; Soneji et al., 2014).

Latent class analysis is a relatively new technique that identifies mutually exclusive groups of individuals that respond in similar ways to given variables within a large population (Lanza, Collins, Lemmon, & Schafer, 2007; Quek et al., 2013). Multiple studies have begun to use this technique to identify common groups of tobacco product and e-cigarette use (e.g., Gilreath et al., 2016; Harrell, Naqvi, Plunk, Ji, & Martins, 2017; Huh & Leventhal, 2016; Morean et al., 2016; Nasim, Blank, Cobb, & Eissenberg, 2012; Simon et al., 2017). To date, all of the studies have identified groups of product users among youth populations in the USA (Gilreath et al., 2016; Harrell et al., 2017; Huh & Leventhal, 2016; Morean et al., 2016; Nasim et al., 2012; Simon et al., 2017); there is currently an absence of similar work about polyproduct use data from other jurisdictions. Additionally, to our knowledge, few of these studies have examined the association between class membership and other risk (e.g., alcohol or marijuana use) or protective behaviours (e.g., breakfast consumption or physical activity). Given that historically youth concurrently used more than one tobacco product and products such as e-cigarettes are increasing in reported use (e.g., Gilreath et al., 2016; Huh & Leventhal, 2016), it is important to identify whether there are certain groups of youth that use certain combinations of products and the sociodemographic and behavioural characteristics of these groups. Given these gaps in the literature, this study identified

the tobacco product and e-cigarette clusters for three data collection years among a sample of Canadian secondary school students.

2. MATERIALS AND METHODS

COMPASS is a prospective cohort study (2012-2021) that collects hierarchical longitudinal data from a convenience sample of Canadian 9th to 12th grade students (Leatherdale et al., 2014). The current study reports longitudinal student-level linked data from Year 2 (2013-14), Year 3 (2014-15), and Year 4 (2015-16) of the COMPASS host study. Consistent with our previous analysis (Cole, Kennedy, Chaurasia, & Leatherdale, 2017), "baseline" for the present study included data from Year 2 when students were in 9th grade, "Follow-up Year 1" (FY1) included data from Year 3 when students were in 10th grade, and "Follow-up Year 2" (FY2) included data from Year 4 when students were in 11th grade. Due to the substantially smaller sample size during initial rollout of the study and the fact that e-cigarette use data were not initially collected in the questionnaire, Year 1 data (2012-13) are not included. A full description of the COMPASS study and its methods is available online (www.compass.uwaterloo.ca) and in print (Leatherdale et al., 2014). The COMPASS study received ethics approval from the University of Waterloo Research Ethics Board, as well as participating school board review panels.

2.1. Sample selection

Student data were linked over time using a unique code generated by each student (Bredin & Leatherdale, 2013). Only students that identified being in 9th grade at Baseline and that had data for each follow-up year were included, leaving a sample of 4651 students from 70 secondary schools in Ontario, Canada (linked sample; 41.3% of participating students); 6602 students did not have data for each follow-up year (unlinked sample).

2.2. Measures

The COMPASS questionnaire (Cq) items have demonstrated reliability and validity for current smoking among youth (Wong, Shields, Leatherdale, Malaison, & Hammond, 2012). Current tobacco cigarette use was measured with a single question: "On how many of the last 30 days did you smoke one or more cigarettes?" Students that reported using cigarettes on at least one of the last 30 days were identified as "current users", while students that did not report using cigarettes on at least one of the last 30 days (including never users) were identified as "non-current users". Similarly, experimentation with alternative tobacco products and e-cigarettes was measured with a single multi-item question that measured past 30-day use of each product (e.g., e-cigarettes, cigarillos or little cigars, cigars, pipe tobacco, smokeless tobacco, and hookah) among respondents. For each alternative tobacco product or e-cigarette, those that reported using a product within the last 30 days were identified as "current users", while students that did not report using the product within the last 30 days were identified as "non-current users". For our analyses, respondents that indicated using hookah to smoke tobacco or to smoke herbal sheesha/shisha were combined and identified as "hookah users".

The Cq also collects student-level sociodemographic and behavioural data consistent with national tobacco surveillance tools (Elton-Marshall et al., 2011). We controlled for baseline gender and race and explored the influence of current spending money (i.e., amount of spending money reported at each year) on class membership at each year. Social environmental factors can influence the availability of tobacco/nicotine products for youth. Measures of interest included the number of friends that smoke tobacco cigarettes reported at each year and the school connectedness score at each year [continuous score between 6 and 24, with higher scores indicating greater school connectedness (Azagba & Asbridge, 2013)]. Behavioural factors of interest included both substance use measures and non-substance use measures. It is well-established that youth commonly use multiple substances, including tobacco/nicotine products, alcohol, and marijuana (Costello, Leatherdale, Ahmed, Church, &

Cunningham, 2012; Leatherdale & Burkhalter, 2012). Therefore, we included self-reported binge drinking and marijuana use at each year. We also included the number of classes skipped in the last 4 weeks reported at each year. Finally, we included the number of school days breakfast was eaten reported at each year and the amount of time spent doing moderate and/or vigorous physical activity over the past week at each year as possible protective factors.

2.3. Analysis

Self-reported tobacco product and e-cigarette use was identified at each year. Simple descriptive statistics identified the prevalence of use of each product at each year and the number of products used in the last 30 days at each year. We used latent class analyses (LCA) to identify mutually exclusive groups of individuals based on similar responses to a measured variable (Lanza et al., 2007; Quek et al., 2013). LCA uses maximum likelihood to estimate parameters (Lanza et al., 2007). We used a step-wise process that compared the fit of a model with k classes to a model with k-1 classes to identify the best fitting model. Consistent with previous research (Lanza et al., 2007; Quek et al., 2013), we used the Bayesian Information Criterion (BIC) and the model-adjusted BIC (adj-BIC) to identify the best fitting model, while considering the values of the average posterior probabilities and model interpretability. Consistent with previous research, probabilities between 0.50 and 1.00 were considered "high", those between 0.10 and 0.49 were "moderate", and those between 0.00 and 0.09 were considered "near-zero" (Harrell et al., 2017). At each year, we identified the number of latent classes that best described the data using PROC LCA in SAS. We controlled for student-level clustering within schools during model selection.

Each student was assigned to a single class at each year based on the latent class with the highest posterior probability. Descriptive statistics examined the characteristics of students within each class at each year. We tested for differences in the characteristics of members of each class using chi-square tests. Due to low response numbers across many measures, responses within explanatory variables

were collapsed across categories. Multinomial logistic regression models for nominal outcomes (using PROC GLIMMIX) identified the sociodemographic and behavioural characteristics of students in classes, using the non-current use class as a reference group at each data collection year. All regression models controlled for student-level clustering within schools. SAS version 9.4 was used for all analyses.

3. RESULTS

Overall, 25.1% of students reported currently using a tobacco product or e-cigarette at some point during the study period. Figure 1 presents the prevalence of current tobacco product and e-cigarette use at each data collection year. The most frequently used products throughout the study period were tobacco cigarettes, e-cigarettes, and CLCs. The prevalence of current use of most products almost doubled between baseline and FY1, and almost tripled between baseline and FY2. By FY2, 18.8% of students reported currently using a tobacco product or e-cigarette. Most notably, the prevalence of current use of e-cigarettes surpassed that of tobacco cigarettes at baseline and in FY1 before matching that of tobacco cigarettes in FY2.
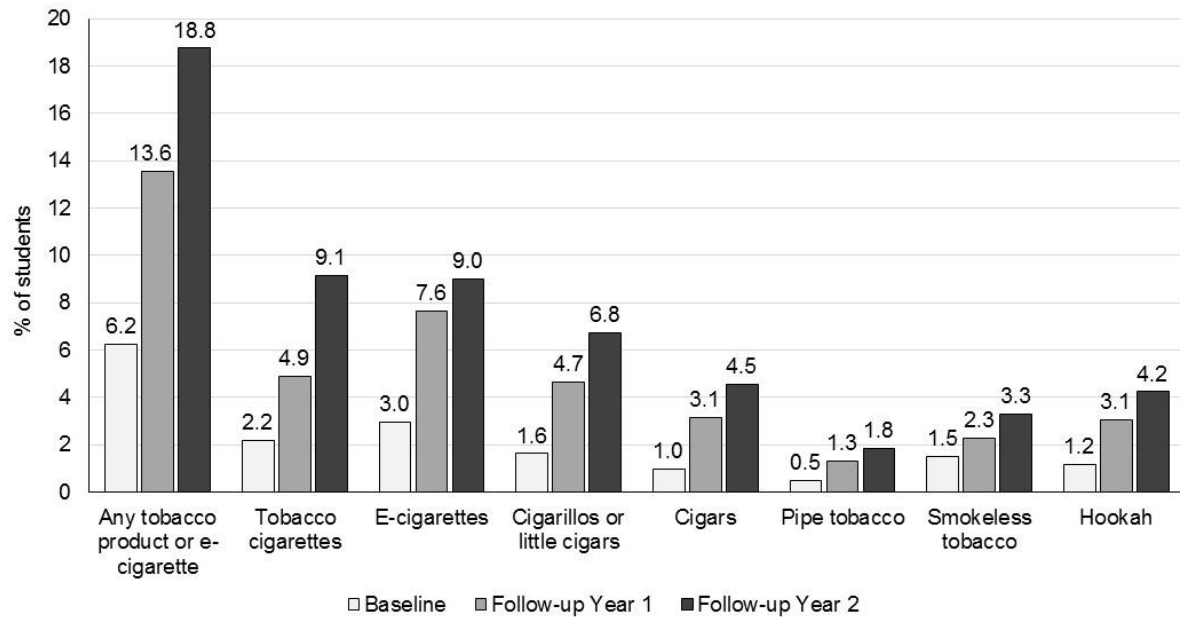
Figure 1. Self-reported tobacco product and e-cigarette use in the last 30 days at baseline, Follow-up Year 1, Follow-up Year 2, 2013-16 COMPASS study

Table 1 presents the proportion of students that reported using one or more products within the last 30 days at baseline, FY1, and FY2, overall and by gender. Over time, fewer students reported using zero products within the last 30 days and more students reported using multiple products within the last 30 days; this was particularly true for male students relative to female students.

Table 1. Number of products used in the last 30 days at baseline, Follow-up Year 1, and Follow-up Year 2, 2013-2016 COMPASS study

Number of products used*	Baseline (%)			Follow-up Year 1 (%)			Follow-up Year 2 (%)		
	Overall	Female	Male	Overall	Female	Male	Overall	Female	Male
0	93.8	94.37	93.09	86.4	89.54	83.06	81.3	85.58	76.64
1	3.7	3.33	4.15	7.1	6.34	7.85	9.6	8.59	10.61
2	1.6	1.58	1.56	3.2	2.58	3.79	4.0	3.50	4.64
3	0.5	0.33	0.58	1.6	0.96	2.27	2.3	1.42	3.25
4+	0.5	0.38	0.62	1.8	0.58	3.03	2.8	0.92	4.86

*possible products included: tobacco cigarettes, e-cigarettes, CLCs, cigars, pipe tobacco, smokeless tobacco, or hookah

Fit statistics for the class models at baseline, FY1, and FY2 can be found in Supplementary Table 1. Based on the low BIC, low adj-BIC, the average posterior probabilities, and the ease of model interpretability, a 3-class model was selected as the best fitting model at baseline, a 4-class model was selected in FY1, and a 4-class model was selected in FY2. Figure 2 presents the probabilities of currently using each tobacco product or e-cigarette for the 3-class (baseline) and 4-class models (FY1, FY2). Notably, there was a difference in the number and types of classes that were identified at each year. At baseline, the identified classes were (1) non-current users (94.9%) who reported a low probability of using all products; (2) current tobacco cigarette, CLC, and e-cigarette users (4.7%) who reported a moderate probability of using these products; and (3) current all-product users (0.3%) who reported a high probability of using all products. At FY1, identified classes were (1) non-current users (89.7%) who reported a low probability of using all products; (2) current e-cigarette users (5.2%) who reported a high probability of using only e-cigarettes; (3) current dual tobacco cigarette and CLC users (4.3%) who reported a high probability of using these two products; and (4) current all-product users (0.8%) who reported a high probability of using all products. At FY2, identified classes were (1) non-current users (86.6%) who reported a low probability of using all products; (2) current dual tobacco cigarette and e-cigarette users (9.7%) who reported a moderate-high probability of using these two products; (3) current tobacco cigarette, CLC, cigar, and e-cigarette users (2.7%) who reported a high probability of using these products; and (4) current all-product users (1.0%) who reported a high probability of using all products. A non-current user and an all-product user class were consistently identified across all three years. While an exclusive tobacco cigarette use class was not apparent in these analyses, an exclusive e-cigarette use class was first apparent in FY1 but did not remain in FY2.
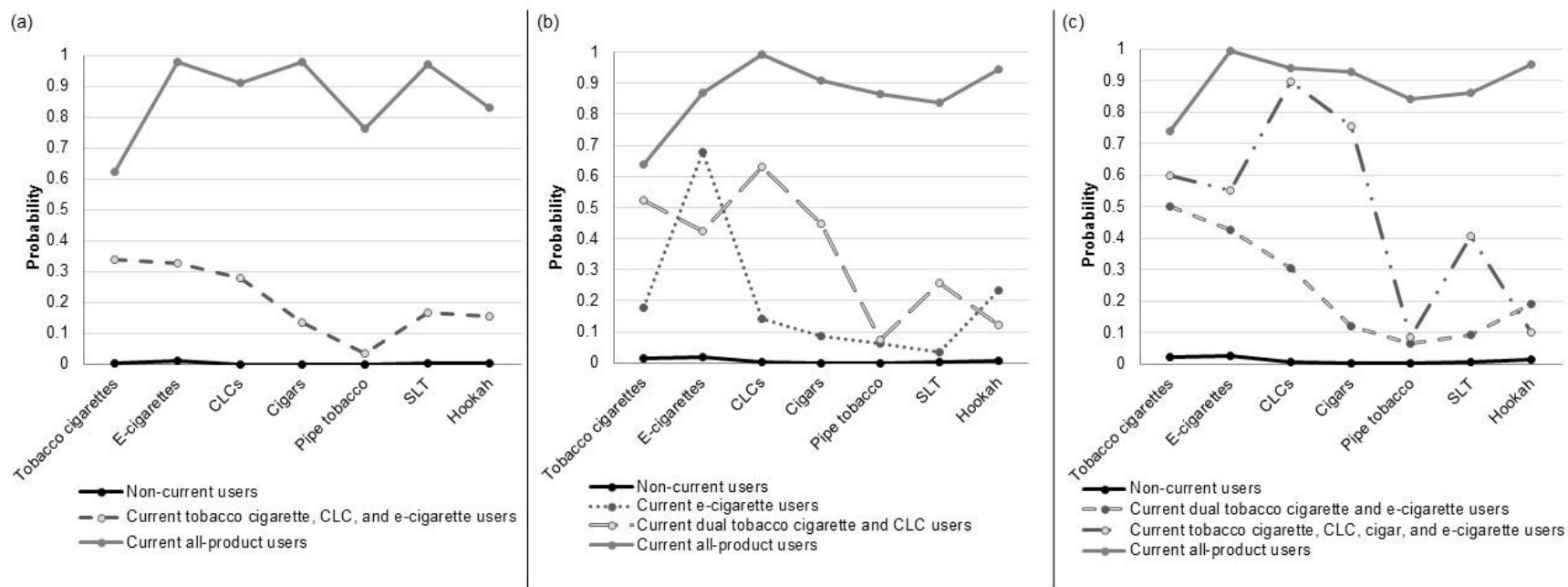
Figure 2a-c. Probabilities of using each tobacco product or e-cigarette (in the last 30 days) (a) for the 3-class model at baseline, (b) for the 4 class model at Follow-up Year 1, and (c) for the 4 class model at Follow-up Year 2, 2013-16 COMPASS study

Descriptive statistics for characteristics of students in the identified classes at each year can be found in Supplementary Tables 2-4. Tables 2-4 present the multinomial logistic regression model results comparing the characteristics at baseline of students in the current use classes against those in the non-current use classes at each data collection year. Results from these repeated cross-sectional analyses suggest that having friends that smoked cigarettes was associated with higher odds of being classified into a current use class [Odds Ratio (OR) 1.61-5.68]. Students that reported ever binge drinking and ever using marijuana also had higher odds of being classified into a current use class (OR 3.29-7.67 and OR 4.05-32.11, respectively). Finally, students that reported skipping classes in the last 4 weeks had higher odds of being classified into a current use class (OR 1.57-3.95). Neither breakfast consumption nor physical activity level were significantly associated with the odds of being classified into a current use class.

Table 2. Student-level sociodemographic and behavioural characteristics associated with membership in current use classes relative to the non-current use class (reference) at baseline, 2013-14 COMPASS study

		CLASS 2 Current cigarette, CLC, and e-cigarette users	CLASS 3 Current all-product users
		OR (95%CI)	OR (95%CI)
Environmental variables			
Number of friends that smoke cigarettes	None	1.00	1.00
	Any	3.06 (2.04, 4.59)***	3.76 (0.89, 15.79)
School connectedness score (each unit increase)		0.92 (0.86, 0.98)**	0.90 (0.73, 1.11)
Behavioural factors (substance use)			
Binge drinking status	Never binged	1.00	1.00
	Ever binged	3.44 (2.23, 5.32)***	1.79 (0.44, 7.20)
Marijuana use status	Never used marijuana	1.00	1.00
	Ever used marijuana	9.97 (6.54, 15.21)***	8.17 (1.79, 37.32)**
Behavioural factors (non-substance use)			
Number of classes skipped in the last 4 weeks	None	1.00	1.00
	Any	1.94 (1.24, 3.02)**	3.95 (1.02, 15.27)*
Number of school days ate breakfast	Less than 5 days	1.00	1.00
	Everyday (5 days)	0.78 (0.51, 1.20)	0.98 (0.25, 3.92)
Meets Canadian physical activity recommendations	No	1.00	1.00
	Yes	1.00 (0.68, 1.48)	0.67 (0.18, 2.49)
Sociodemographic characteristics			
Gender	Female	1.00	1.00
	Male	1.37 (0.91, 2.05)	1.73 (0.45, 6.69)

Ethnicity	White	1.00	1.00
	Other	1.56 (1.01, 2.41)*	3.98 (0.99, 15.99)
Spending money	Zero / I Don't Know	1.00	1.00
	$1-$20	0.99 (0.61, 1.59)	2.15 (0.40, 11.47)
	More than $20	1.46 (0.88, 2.42)	1.33 (0.18, 9.69)

* p<0.05 ** p<0.01 *** p<0.001

Model: Class 2 (n=155) versus Class 1 (n=4147)

Model: Class 3 (n=12) versus Class 1 (n=4147)

All models controlled for student-level clustering within schools (n=70)

Table 3. Student-level sociodemographic and behavioural characteristics associated with membership in

current use classes relative to the non-current use class (reference) at Follow-up Year 1, 2014-15

COMPASS study

		CLASS 2 Current e-cigarette users	CLASS 3 Current dual tobacco cigarette and CLC users	CLASS 4 Current all-product users
		OR (95%CI)	OR (95%CI)	OR (95%CI)
Environmental variables				
Number of friends that smoke cigarettes	None	1.00	1.00	1.00
	Any	1.61 (1.20, 2.17)**	5.02 (3.32, 7.57)***	5.68 (2.25, 14.36)***
School connectedness score (each unit increase)		0.94 (0.90, 0.99)*	0.96 (0.90, 1.02)	0.86 (0.77, 0.97)*
Behavioural factors (substance use)				
Binge drinking status	Never binged	1.00	1.00	1.00
	Ever binged	3.29 (2.33, 4.64)***	7.67 (4.12, 14.28)***	4.64 (1.24, 17.36)*
Marijuana use status	Never used marijuana	1.00	1.00	1.00
	Ever used marijuana	4.05 (2.96, 5.55)***	5.87 (3.79, 9.07)***	32.11 (7.09, 145.41)***
Behavioural factors (non-substance use)				
Number of classes skipped in the last 4 weeks	None	1.00	1.00	1.00
	Any	1.57 (1.14, 2.17)**	1.76, 1.17, 2.66)**	1.89, 0.81, 4.44)
Number of school days ate breakfast	Less than 5 days	1.00	1.00	1.00
	Everyday (5 days)	0.95, 0.71, 1.28)	1.20 (0.80, 1.79)	1.25 (0.54, 2.91)
Meets Canadian physical activity recommendations	No	1.00	1.00	1.00
	Yes	0.99 (0.75, 1.32)	1.49 (0.99, 2.24)	1.53 (0.61, 3.83)
Sociodemographic characteristics				
Gender	Female	1.00	1.00	1.00
	Male	2.11 (1.57, 2.83)***	6.95 (4.40, 10.99)***	23.35 (6.49, 84.07)***
Ethnicity	White	1.00	1.00	1.00
	Other	1.11 (0.80, 1.55)	0.53 (0.31, 0.92)*	0.30 (0.08, 1.07)
Spending money	Zero / I Don't Know	1.00	1.00	1.00
	$1-$20	1.63 (1.12, 2.36)*	1.18 (0.66, 2.09)	0.87 (0.22, 3.44)
	More than $20	1.44 (0.98, 2.10)	1.97 (1.17, 3.34)*	3.20 (1.04, 9.85)*

* p<0.05 ** p<0.01 *** p<0.001

Model 1: Class 2 (n=252) versus Class 1 (n=3911)

Model 2: Class 3 (n=151) versus Class 1 (n=3911)

Model 3: Class 4 (n=31) versus Class 1 (n=3911)

All models controlled for student-level clustering within schools (n=70)

Table 4. Student-level sociodemographic and behavioural characteristics associated with membership in

current use classes relative to the non-current use class (reference) at Follow-up Year 2, 2015-16

COMPASS study

		CLASS 2 Current dual cigarette and e-cigarette users	**CLASS 3** Current cigarette, CLC cigar, and e-cigarette users	**CLASS 4** Current all-product users
		OR (95%CI)	OR (95%CI)	OR (95%CI)
Environmental variables				
Number of friends that smoke cigarettes	None	1.00	1.00	1.00
	Any	3.36 (2.51, 4.51)***	4.30 (2.73, 6.78)***	4.22 (1.92, 9.28)***
School connectedness score (each unit increase)		0.96 (0.92, 1.00)	1.03 (0.97, 1.10)	0.94 (0.86, 1.03)
Behavioural factors (substance use)				
Binge drinking status	Never binged	1.00	1.00	1.00
	Ever binged	4.91 (2.95, 8.19)***	4.97 (2.21, 11.18)***	1.60 (0.61, 4.18)
Marijuana use status	Never used marijuana	1.00	1.00	1.00
	Ever used marijuana	6.04 (4.21, 8.66)***	8.03 (4.54, 14.19)***	10.67 (3.53, 32.21)***
Behavioural factors (non-substance use)				
Number of classes skipped in the last 4 weeks	None	1.00	1.00	1.00
	Any	2.47 (1.85, 3.30)***	1.46 (0.96, 2.24)	3.41 (1.57, 7.37)**
Number of school days ate breakfast	Less than 5 days	1.00	1.00	1.00
	Everyday (5 days)	0.77 (0.57, 1.05)	1.22 (0.97, 1.89)	0.98 (0.47, 2.05)
Meets Canadian physical activity recommendations	No	1.00	1.00	1.00
	Yes	1.20 (0.91, 1.58)	1.45 (0.94, 2.24)	0.96 (0.47, 1.93)
Sociodemographic characteristics				
Gender	Female	1.00	1.00	1.00
	Male	2.17 (1.63, 2.89)***	7.85 (4.57, 13.50)***	13.36 (4.58, 38.98)***
Ethnicity	White	1.00	1.00	1.00
	Other	1.24 (0.88, 1.75)	0.79 (0.44, 1.41)	1.62 (0.74, 3.52)
Spending money	Zero / I Don't Know	1.00	1.00	1.00
	$1-$20	1.18 (0.74, 1.89)	1.03 (0.43, 2.50)	0.88 (0.23, 3.41)
	More than $20	1.42 (0.97, 2.08)	2.54 (1.30, 4.96)**	2.02 (0.75, 5.47)

* p<0.05 ** p<0.01 *** p<0.001
Model 1: Class 2 (n=288) versus Class 1 (n=3943)
Model 2: Class 3 (n=116) versus Class 1 (n=3943)
Model 3: Class 4 (n=36) versus Class 1 (n=3943)
All models controlled for student-level clustering within schools (n=70)

4. DISCUSSION

Tobacco product and e-cigarette use continues to be prevalent among youth populations in Ontario,

Canada. The data in this study indicate that 1 in 4 youth reported currently using a tobacco product

and/or e-cigarette at some point during the study period, and almost 1 in 10 youth reported currently using multiple products when they were in 11th grade. Additionally, the prevalence of use of each product significantly increased over time; between 9th and 10th grade the prevalence of use of many products doubled, and between 9th and 11th grade the prevalence of use of many products tripled. The current study took a novel approach to detecting cross-sectional latent classes of tobacco product and e-cigarette use across three waves of a large longitudinal study. By identifying classes of product use for a cohort of students over time, we discovered different classes of products used by students at each data collection year, suggesting that tailored tobacco prevention messaging may be necessary for students in different grades to address the use of popular products. Furthermore, given the dramatic increases in current use as students progress through secondary school, consistent prevention messaging may be important throughout adolescence to discourage the initiation and escalation of tobacco product and e-cigarette use.

Interestingly, consistent with results from the USA (e.g., Gilreath et al., 2016; Huh & Leventhal, 2016; Morean et al., 2016; Simon et al., 2017) an exclusive tobacco cigarette group was not apparent in these analyses, and tobacco cigarette smoking was more often grouped with the use of other tobacco products and e-cigarettes. There are a variety of possible reasons for polyproduct use being common in these data, including personality factors such as increased risk taking or rebelliousness (Fix et al., 2014), increased experimentation with various products in this age group, policies that restrict access to tobacco cigarettes [including tobacco taxes, clean-air policies, and age restrictions (Levy, Chaloupka, & Gitchell, 2004)], and perceptions of reduced harm for other tobacco products and e-cigarettes (Choi, Fabian, Mottey, Corbett, & Forster, 2012; Smith et al., 2011; Wray, Jupka, Berman, Zellin, & Vijaykumar, 2012). It is clear that school-based prevention and cessation programs should address the use of other tobacco products and e-cigarettes in addition to tobacco cigarettes; additional approaches are needed

to prevent youth from experimenting with various products during secondary school given the negative effects of nicotine on the developing brain (Smith, McDonald, Bergstrom, Ehlinger, & Brielmaier, 2015; Yuan, Cross, Loughlin, & Leslie, 2015) and the risk of long-term addiction.

Consistent with previous research (Gilreath et al., 2016; Huh & Leventhal, 2016; Morean et al., 2016; Simon et al., 2017), the current analysis identified a group of non-current users at each year, and this class had the largest membership at each year. However, the data also indicate that membership in this class decreased over time as students progressed through secondary school and tried various tobacco products and/or e-cigarettes. Given that many youth did not report using a tobacco product or e-cigarette in the last 30 days, additional research should identify protective factors among this group of students and novel school-based prevention approaches that could prevent future use of products. Furthermore, given the fluid nature of tobacco product and e-cigarette use in this age group, additional research is needed to identify the various products and trajectories of use to differentiate between experimental users (that try a product but do not continue using it) and regular users (that try a product and become addicted). Understanding those who transition into new product use, or even more importantly, out of using products, would be valuable insight for informing future prevention initiatives.

Similarly, the current analysis identified polyproduct users every year, which also supports previous findings (Gilreath et al., 2016; Harrell et al., 2017; Huh & Leventhal, 2016; Morean et al., 2016; Simon et al., 2017). Polyproduct use was common in this age group, and there was always a subgroup of youth that were at highest risk of using all products of interest (i.e., all-product users). These youth might be at higher risk of nicotine dependence given their use of other tobacco products or e-cigarettes in addition to tobacco cigarettes (Timberlake, 2008). Previous evidence indicates that polyproduct users are more likely to report tobacco cravings within the first five minutes of waking up in the morning, one sign of

nicotine dependence (Harrell et al., 2017). Membership in the all-product use class also increased over time as students progressed through secondary school and tried additional products. Prevention programs should draw awareness to the risks of using any tobacco product or e-cigarette, while cessation activities should address and discourage the use of other tobacco products and e-cigarettes in addition to tobacco cigarettes.

In addition to identifying clusters of product use, this study identified behavioural characteristics associated with membership in each class. These data indicate that peer influences are important for using tobacco products and e-cigarettes. Students that reported having friends that smoked cigarettes were consistently more likely to be classified into a current use class and particularly into the all-product use class. Friend groups may influence the decision to use tobacco products or e-cigarettes by providing access to novel products and opportunities to experiment with various products, particularly in social situations (Hammal et al., 2016; Richter, Caraballo, Gupta, & Pederson, 2008). Additional research is needed to identify both where various tobacco products and e-cigarettes are obtained and when these products are commonly used by youth. This knowledge could then inform policies that restrict access to these products by youth and programs that discourage the use of these products by youth.

It is well established that risk behaviours tend to cluster together, and in addition to tobacco products and e-cigarettes, many youth experiment with alcohol and marijuana. In the current study, students that reported binge drinking and using marijuana were consistently more likely to be classified into a current use class and particularly into the all-product use class. This association was stronger for marijuana use rather than binge drinking. By inhibiting decision-making, both alcohol and marijuana may encourage the use of tobacco products and e-cigarettes. Tobacco may also be mixed with marijuana when it is smoked, aiding in the development of nicotine addiction (Humfleet & Haas, 2004). It is clear that multi-

substance use school and community programming is important. Additional data are needed to identify the pathways between tobacco product and e-cigarette use and marijuana use, particularly given the pending legalization of marijuana in Canada (Canada & Health Canada, 2016).

Of note, the only modifiable protective factor that was significantly associated with the likelihood a student was classified into a current use class was school connectedness. Students with higher school connectedness scores were less likely to be in some current use clusters. The association between school connectedness and cigarette smoking has been previously shown (Kaai, Leatherdale, Manske, & Brown, 2013; Sabiston et al., 2009), and prevention interventions could continue to encourage feelings of connection to the school community to prevent tobacco product and e-cigarette use. Although there were significant differences in the prevalence of breakfast consumption and physical activity across product clusters (Supplementary Tables 2-4), where fewer youth in product youth clusters ate breakfast every day and more youth in product use clusters met Canadian physical activity recommendations, no significant association with product use cluster was identified in the regression analyses. It is possible that due to the small sample size of some clusters, we had insufficient power to identify a significant association. Alternatively, it is possible that risk behaviours (e.g., binge drinking, marijuana use) are more important predictors of cluster membership or there are other important protective factors that were not measured in the current study. Future research should continue to investigate factors that protect against tobacco product and e-cigarette use among youth populations.

4.1. Strengths and Limitations

This study fills a much needed research gap with respect to the use of tobacco products and e-cigarettes among youth in Canada, particularly given the recent popularity of e-cigarette use. To our knowledge, this study represents the first in Canada to identify latent classes of tobacco product and e-cigarette use among secondary school students. The use of a longitudinal sample in this study is a unique approach to

identifying latent classes of product use over time in a cohort of youth. The Cq collects data on a range of health behaviours and the use of multiple products, which allowed us to include a variety of tobacco products when identifying latent classes. Furthermore, we were able to investigate the association between latent class membership and other health behaviours, which has largely been absent in the literature.

Although there are many strengths with this study, there are some limitations. We were limited in our measure of alternative tobacco product and e-cigarette use (i.e., use within the last 30 days), which may not represent usual use of these products. Furthermore, this measure does not provide any indication of frequency of use or whether products are used individually or in combination. Future research should explore how and when these products are used. The use of a longitudinal sample may have influenced the latent classes that we found, particularly given that tobacco users tend to drop out of longitudinal studies (Siddiqui, Flay, & Hu, 1996) and risk behaviours tend to cluster together (Fix et al., 2014; Morean et al., 2016). LCA is a relatively new analysis technique and there are no standard criteria for model selection, meaning that a different approach and interpretation could identify other classes of product use. However, our approach was consistent with previous studies that have used LCA. Although this study relied on self-reported smoking behaviours, these measures have been shown to be reliable and valid (Fendrich, Mackesy-Amiti, Johnson, Hubbell, & Wislar, 2005; Wong et al., 2012) and students were ensured that their responses were confidential. Data collections only occurred yearly and may have missed critical developmental periods or life events that lead to smoking experimentation. Finally, the results may not be generalizable to all youth in Ontario or Canada given that the COMPASS study used a convenience sample of students. Future analyses should verify these findings using additional Canadian data sources.

4.2. Conclusions

The prevalence of use of various tobacco products and e-cigarettes increased significantly among youth populations during secondary school, and an increasing number of youth reported using more than one tobacco product or e-cigarette over time. Tobacco cigarette use was more often grouped with other tobacco product and e-cigarette use than on its own. As a result, additional prevention and cessation programs may be necessary to discourage polyproduct use. Some differences in class profiles were identified over three consecutive years, suggesting there may be differences in product preferences as students age. Multi-substance use school and community programming continues to be important given the classes identified and that alcohol and marijuana use were important factors associated with class membership.

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HIGHLIGHTS:

- Cigarettes were more likely to be used with other products than on their own

- The prevalence of polyproduct use increased over time

- Different classes were identified over three consecutive years

- Members of product use classes shared many characteristics in common

- Binge drinking and marijuana use were common across classes