

Indicators of dependence and efforts to quit vaping and smoking among youth in Canada, England and the USA

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ABSTRACT

Objective The current study examined indicators of dependence among youth cigarette smokers and e-cigarette users in Canada, England and the USA, including changes between 2017 and 2019.

Methods Data are from repeated cross-sectional online surveys conducted in 2017, 2018 and 2019 with national samples of youth aged 16–19 years, in Canada (n=12 018), England (n=11 362) and the USA (n=12 110). Measures included perceived addiction to cigarettes/e-cigarettes, frequency of experiencing strong urges to smoke/use an e-cigarette, plans to quit smoking/using e-cigarettes and past attempts to quit. Logistic regression models were fitted to examine differences between countries and changes over time.

Results The proportion of ever-users who vaped frequently was significantly higher in 2019 compared with 2017 for all outcomes in each country. Between 2017 and 2019, the proportion of past 30-day vapers reporting strong urges to vape on most days or more often increased in each country (Canada: 35.3%, adjusted OR (AOR) 1.69, 95% CI 1.20 to 2.38; England: 32.8%, AOR 1.55, 1.08 to 2.23; USA: 46.1%, AOR 1.88, 1.41 to 2.50), along with perceptions of being 'a little' or 'very addicted' to e-cigarettes (Canada: 48.3%, AOR 1.99, 1.44 to 2.75; England: 40.1%, AOR 1.44, 1.03 to 2.01; USA: 53.1%, AOR 1.99, 1.50 to 2.63). Indicators of dependence among smokers were consistently greater than e-cigarette users, although differences had narrowed by 2019, particularly in Canada and the USA.

Conclusions Prevalence of dependence symptoms among young e-cigarette users increased between 2017 and 2019, more so in Canada and the USA compared with England. Dependence symptom prevalence was lower for e-cigarettes than smoking; however, the gap has narrowed over time.

BACKGROUND

Nicotine is the primary constituent responsible for the reward, reinforcement and withdrawal effects of conventional cigarettes.¹ The pharmacological effects of nicotine can vary based on the mode of administration: smoke inhalation from conventional cigarettes delivers nicotine in a manner that maximises its bioavailability and consumer appeal, compared with other routes of administration, such as transdermal from patch or oral from gum, which have lower levels of abuse liability.^{2,3} Like combustible cigarettes, electronic cigarettes (e-cigarettes) can deliver nicotine to the lungs, although the rate of nicotine delivery varies across device design,

formulation (freebase vs salt, flavours), concentration of nicotine in the e-liquid and patterns of use.^{4–6}

The importance of dependence as a factor in promoting tobacco use is well established in existing literature.⁷ The measurement of e-cigarette dependence, however, is at an early stage.^{8,9} Several measures have been created or adapted from dependence measures designed for cigarette use, including many of the same 'core' indicators, such as frequency of use, urges, cravings and failure to control use, the latter of which is often operationalised in terms of intentions and efforts to quit.^{9–12} A 2018 review of the literature concluded that e-cigarettes can produce symptoms of dependence; however, the risk and severity of dependence are likely lower than for combustible tobacco cigarettes.¹³ Recent studies among adult e-cigarette users are generally consistent with the conclusion that e-cigarettes can produce withdrawal symptoms, negative affect and urges/craving, although to a lesser extent than conventional combustible cigarettes.^{12,14–19}

Dependence plays a fundamental role in the establishment of smoking among young people.^{7,20} The extent to which e-cigarettes promote and sustain dependence among youth and young adults remains an important research question, given the increase in vaping prevalence among these age groups.²¹ Although several measures have been developed to assess tobacco use dependence among young people,^{22,23} few studies have assessed e-cigarette dependence among young people, and all in the USA. A US school-based survey conducted in 2017 found youth e-cigarette users reported signs of dependence using the four item *E-Cigarette Dependence Scale*; however, dependence levels were generally low among past 30-day users.¹¹ A US prospective cohort study of 444 grade 12 students in 2016 and 2017 who reported any past-year e-cigarette use found that 12% of past-year e-cigarette users and 18% of past-month users reported at least one of 10 symptoms for e-cigarette dependence based on the *Hooked On Nicotine Checklist*.²⁴ Youth who reported one or more e-cigarette dependence symptoms at baseline was more likely to report continued vaping, as well as more frequent vaping patterns, at 6-month follow-up. The prevalence of reporting at least three of the 10 dependence symptoms was greater for combustible cigarettes than for e-cigarettes, while dependence was higher among 'dual' e-cigarette users and smokers compared



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with exclusive e-cigarette users.²⁵ Another US study examined levels of cotinine—the major nicotine metabolite—and three measures of dependence among 144 youth vapers.²⁶ Between 5% and 16% of youth vapers scored as ‘moderately to heavily addicted or dependent’ (depending on the scale), while all three scales were correlated with cotinine levels. In sum, the limited evidence to date suggests that e-cigarette use can result in the development of e-cigarette dependence; however, it is unclear to what degree and what impact such dependence may have on continuing usage, especially among youth and young adults.

The role of dependence as a barrier to stopping e-cigarette use has yet to be explored. Indeed, there are very little data on vaping cessation behaviours, including among adults. Among the few studies that have assessed intentions to stop vaping, estimates are highly variable, ranging from less than 10% who intend to stop in the near future to estimates of more than three-quarters who plan to stop vaping.^{18 25 27–29} Similarly, few studies have examined attempts to stop vaping or the success of such attempts. A survey of long-term vapers in Europe found that 10% had tried to quit vaping,³⁰ while a survey of university students in Central and Eastern Europe reported that 14% had ever tried to quit.³¹ Efforts to stop vaping are likely to be highly dependent on former and current smoking status, as well as reasons for vaping, and may also be related to e-cigarette dependence.³² To date, we are unaware of any studies that have examined vaping cessation behaviours among youth or non-users of tobacco.

The current study examined indicators of dependence among youth in three countries: Canada, England and the USA. Using repeat cross-sectional national samples, the study also examined changes in selected indicators between 2017 and 2019, the period in which the prevalence of e-cigarette use has increased in North America, concurrent with the emergence of high-nicotine concentration salt-based products such as JUUL. To our knowledge, this is the first study to examine changes over multiple years in measures of dependence among youth, such as urges and self-reported addiction, and vaping cessation behaviours. Comparisons with cigarette smoking dependence are provided for the same measures.

METHODS

Repeated cross-sectional online surveys were conducted in 2017 (July/August), 2018 (August/September) and 2019 (August/September). National samples of 16- to 19-year-olds in Canada (n=12 018), England (n=11 362) and the USA (n=12 110) were recruited through the Nielsen Consumer Insights Global Panel. A full description of the study methods is available elsewhere.³³

Measures

Smoking and vaping frequency

Self-reported e-cigarette use and cigarette smoking measures included ever use, lifetime number of cigarettes/days vaped, last time smoked/vaped, and on how many of the past 30 days respondents smoked/vaped. Respondents were categorised for use within the past 30 days, the past week and on at least 20 of the past 30 days. Dual users were defined as respondents who reported vaping and smoking in the past 30 days.

Perceived addiction

Single-item measures of perceived addiction have been shown to predict frequency of use, cotinine levels and cessation behaviour, and are significantly associated with frequency of use and more established dependence scales among tobacco users^{34 35} and e-cigarette users.^{13 26} Past 30-day smokers and/or e-cigarette

users reported whether they considered themselves addicted to cigarettes/e-cigarettes: ‘Do you consider yourself addicted to [cigarettes/e-cigarettes/vaping]? (Not at all; Yes, a little addicted; Yes, very addicted; Don’t know; Refused)’. A binary variable was created for modelling which collapsed ‘Yes, very addicted’ and ‘Yes, a little addicted’ versus ‘Not at all’, excluding ‘Don’t know’ and ‘Refused’. Separate questions were asked for e-cigarettes and combustible cigarettes in all cases.

Urges

Self-reported urges are a common indicator for ‘craving’, which is a central concept in models of addiction and smoking cessation outcomes.³⁶ Past 30-day smokers and/or e-cigarette users were asked how often they experienced strong urges to use an e-cigarette/smoke a cigarette: ‘In the past 30 days, how often did you have a strong urge to [smoke a cigarette/use an e-cigarette/vape]? (Several times a day; Every day or most days; At least once a week; Less than once a week; Never; Don’t know; Refused)’. A binary variable was created for modelling which combined ‘Several times a day’ and ‘Every day or most days’ versus less often, excluding ‘Don’t know’ and ‘Refused’.

Intentions and attempts to quit

Past 30-day smokers and/or e-cigarette users were asked, ‘Are you planning to quit [smoking/using e-cigarettes/vaping]... Within the next month; Between 1–6 months from now; Sometime in the future, beyond 6 months; Not planning to quit; I don’t currently [smoke/use e-cigarettes]; Don’t know; Refused’. In addition, current smokers and/or past 30-day e-cigarette users were asked if they tried to ‘completely stop’ smoking/using e-cigarettes in the past 12 months.

Reasons for quitting or trying to quit

Former vapers (ie, vaped in the past 12 months but not in the past 30 days) were asked, ‘Which of the following are reasons you stopped using e-cigarettes/vaping in the LAST 12 MONTHS?’ (see list in table 4 for response options). Variations in wording were used for current (past 30-day) vapers who had tried to quit in the last 12 months (‘tried to stop’ rather than ‘stopped’) and ever-vapers who had not vaped in the past year (‘did not continue’).

Sociodemographic covariates included age group (16–17 vs 18–19), sex at birth (male vs female) and race/ethnicity (White (only) vs all other responses; derived from country-specific questions).

Analysis

Poststratification sample weights were calculated for each country, based on age, sex, geographical region and race/ethnicity (USA only). In addition, waves 2 and 3 were calibrated back to wave 1 for student status (student vs not) and grades (<70%, don’t know, or refused; 70%–79%; 80%–89%; 90%–100%) and used the National Youth Tobacco Survey in the USA and the Canadian Student Tobacco, Alcohol and Drugs Survey in Canada to calibrate to the trend over time for smoking in the last 30 days. A full description of the weighting procedures is available elsewhere.³³ Logistic regression models were fitted to examine changes between survey years and differences between countries, adjusting for sex, age group and race/ethnicity.

RESULTS

Sample

Table 1 shows characteristics of the samples in each country, by survey year.

Table 1 Sample characteristics, youth aged 16–19 years, by country and survey year, weighted % (n)

	Canada			England			USA		
	2017 (n=4038)	2018 (n=3845)	2019 (n=4135)	2017 (n=3995)	2018 (n=3874)	2019 (n=3493)	2017 (n=4095)	2018 (n=4034)	2019 (n=3981)
Age (mean; SD)	17.6; 1.1	17.5; 1.1	17.5; 1.1	17.5; 1.0	17.6; 1.0	17.5; 0.9	17.5; 1.1	17.5; 1.1	17.5; 1.1
Sex*									
Male	51.4 (2077)	51.5 (1979)	51.3 (2121)	51.3 (2050)	51.3 (1989)	51.3 (1793)	51.1 (2094)	51.1 (2061)	51.1 (2034)
Female	48.6 (1961)	48.5 (1866)	48.7 (2014)	48.7 (1945)	48.7 (1885)	48.7 (1700)	48.9 (2001)	48.9 (1973)	48.9 (1947)
Race/ethnicity†									
White (only)	58.4 (2358)	47.0 (1807)	53.8 (2225)	79.4 (3172)	77.0 (2985)	76.0 (2654)	73.4 (3006)	73.3 (2959)	73.6 (2931)
Mixed/other/not stated	41.6 (1680)	53.0 (2038)	46.2 (1910)	20.6 (823)	23.0 (889)	24.0 (839)	26.6 (1089)	26.7 (1075)	26.4 (1050)
E-cigarette use									
Ever	29.3 (1182)	33.2 (1275)	40.6 (1680)	33.7 (1348)	33.1 (1283)	36.1 (1260)	31.3 (1283)	33.1 (1336)	43.6 (1734)
In the past 30 days	8.4 (340)	12.1 (463)	17.8 (738)	8.7 (347)	9.0 (351)	12.6 (439)	11.1 (454)	15.7 (635)	18.5 (736)
≥20 days in past 30 days	1.8 (74)	2.4 (92)	5.7 (236)	1.5 (59)	2.0 (76)	2.7 (94)	2.2 (89)	3.8 (154)	6.7 (267)
Cigarette smoking									
Ever	31.9 (1288)	31.0 (1193)	31.1 (1287)	40.4 (1615)	40.1 (1554)	38.2 (1334)	32.3 (1322)	32.4 (1306)	33.5 (1334)
In the past 30 days	10.7 (431)	10.0 (383)	9.3 (384)	15.6 (622)	16.7 (645)	14.8 (519)	11.0 (451)	11.7 (470)	7.9 (315)
≥20 days in past 30 days	4.3 (173)	4.1 (158)	2.9 (118)	4.3 (173)	5.8 (226)	4.7 (165)	3.7 (151)	3.9 (156)	2.5 (100)
Dual use (e-cigarettes and cigarette smoking)									
Ever	20.0 (809)	20.2 (776)	23.8 (983)	26.6 (1064)	26.0 (1006)	26.4 (924)	22.4 (919)	22.4 (902)	26.7 (1062)
In the past 30 days	4.0 (162)	4.7 (181)	5.5 (228)	5.0 (201)	5.5 (214)	6.5 (226)	6.0 (245)	6.5 (263)	5.1 (204)
≥20 days in past 30 days	0.5 (20)	0.5 (18)	0.6 (24)	0.3 (13)	0.7 (28)	0.7 (26)	0.4 (15)	0.6 (23)	0.5 (21)

*Determined by response to 'sex at birth' survey item; where sex at birth was missing, inferred from gender if 'man' or 'woman' selected.

†Determined by response(s) to a survey item with multiple categories, categorised into those who specified only White/European, or any other response; wording of the Canadian source question changed slightly, from response option 'White' in 2017 to 'European' in 2018 to 'White or European' in 2019.

Frequency of vaping and smoking among ever-users

Table 2 shows the frequency of vaping among all youth who had ever tried vaping. In 2019, the proportion who vaped in the past 30 days, past week and on ≥20 of the past 30 days was substantially higher among ever-vapers in the USA and Canada compared with England ($p<0.001$). In addition to the 2018–2019 contrasts shown in table 2, the frequency of vaping was significantly greater in 2019 compared with 2017 for all outcomes in all countries ($p<0.01$ for all).

Among ever-smokers in the USA, the proportion who smoked in the past 30 days, past week and on ≥20 of the past 30 days decreased for all outcomes between 2017 and 2019 and between 2018 and 2019 ($p<0.001$ for all). In England, the proportion of ever-smokers who smoked in the past week and on ≥20 of the past 30 days increased between 2017 and 2018 ($p<0.01$ for both). In Canada, the proportion of ever-smokers who reported smoking on ≥20 of the past 30 days decreased between 2017 and 2019 and between 2018 and 2019 ($p<0.01$ for both).

Dependence indicators

Urges to vape

Figure 1 presents indicators of vaping and cigarette smoking dependence among past 30-day vapers and smokers (see online supplemental table 1 for full data including responses of 'Don't know'). In 2019, strong urges to vape on most days or more often were reported by 46.1% of past 30-day vapers in the USA, 35.3% in Canada and 32.8% in England. In country-stratified models to examine changes over time within each country, the proportion of vapers who reported strong urges to vape on most days or more often did not change significantly between 2017 and 2018 within any of the countries. However, strong urges to vape increased between 2018 and 2019 in Canada (adjusted OR (AOR) 1.74, 95% CI 1.34 to 2.26; $p<0.0001$) and the USA

(AOR 1.42, 95% CI 1.09 to 1.85; $p=0.008$) and between 2017 and 2019 in all countries (Canada: AOR 1.69, 95% CI 1.20 to 2.38, $p=0.003$; England: AOR 1.55, 95% CI 1.08 to 2.23, $p<0.02$; USA: AOR 1.88, 95% CI 1.41 to 2.50, $p<0.0001$).

Urges to smoke

In 2019, strong urges to smoke on most days or more often were reported by 59.3% of past 30-day smokers in the USA, 42.1% in Canada and 39.2% in England. The proportion who reported strong urges to smoke on most days or more often did not change significantly between 2017 and 2019 within any of the countries, but increased between 2017 and 2018 in England (AOR 1.38, 95% CI 1.08 to 1.77; $p=0.01$), and decreased between 2018 and 2019 in Canada (AOR 0.73, 95% CI 0.56 to 0.94; $p=0.02$); no other between-year differences were significant.

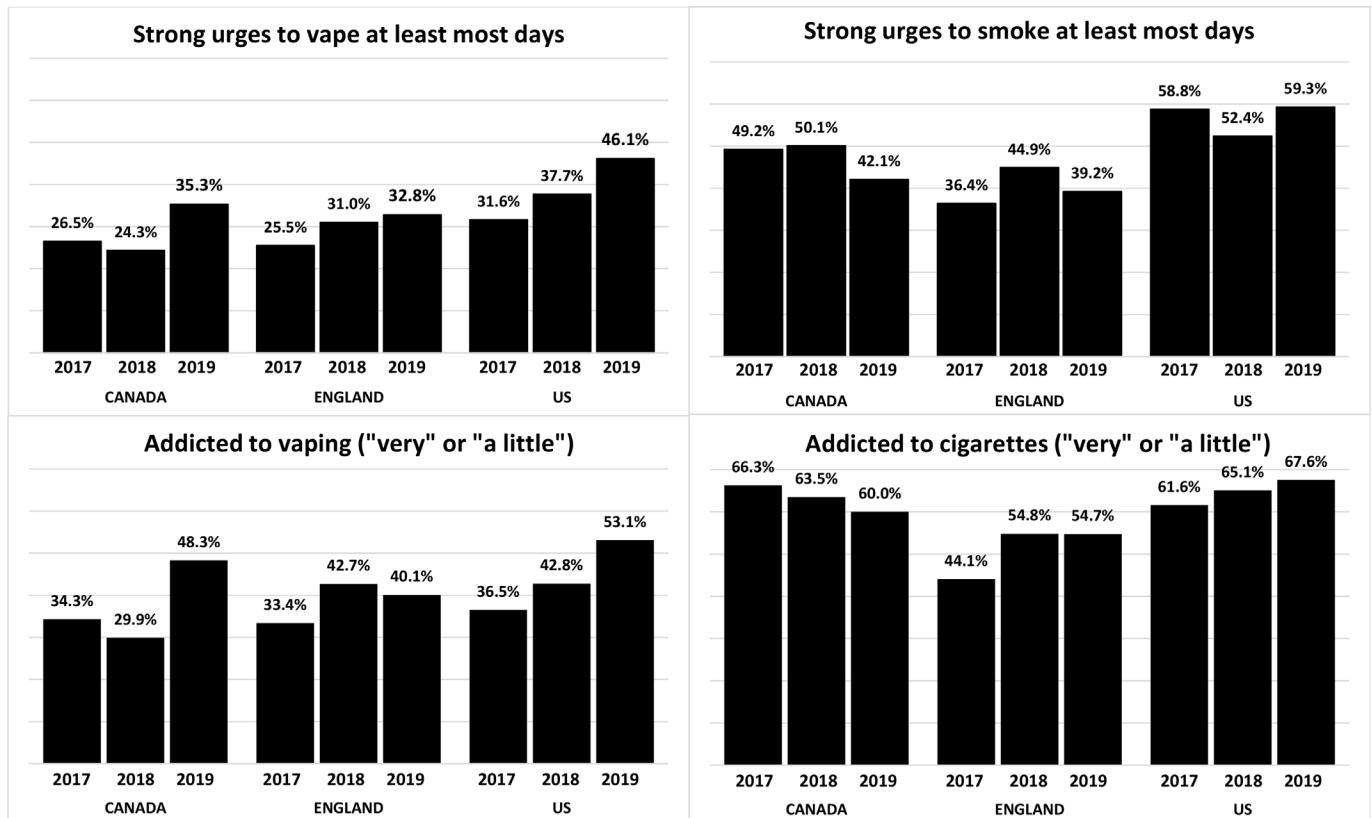
Perceived addiction to vaping

In 2019, 53.1% of past 30-day vapers in the USA reported they were either 'a little' or 'very addicted' to e-cigarettes, compared with 48.3% in Canada, and 40.1% in England. In country-stratified models to examine changes over time within each country, the proportion of past 30-day vapers who reported that they were either a little or very addicted to e-cigarettes increased between 2017 and 2019 in all countries (Canada: AOR 1.99, 95% CI 1.44 to 2.75, $p<0.0001$; England: AOR 1.44, 95% CI 1.03 to 2.01, $p=0.03$; USA: AOR 1.99, 95% CI 1.50 to 2.63, $p<0.0001$); in Canada and the USA, there were no differences between 2017 and 2018, but significant increases between 2018 and 2019 (Canada: AOR 2.30, 95% CI 1.79 to 2.95, $p<0.0001$; USA: AOR 1.52, 95% CI 1.17 to 1.97, $p=0.002$), while in England there was an increase between 2017 and 2018 (AOR

Table 2 Proportions of ever-users who vaped/smoked in the past 30 days, past week, and on ≥ 20 days in the past month, by country, 2017–2019

	Canada					England					USA				
	2017	2018	2019	Difference 2019 vs 2018		2017	2018	2019	Difference 2019 vs 2018		2017	2018	2019	Difference 2019 vs 2018	
Vaping (among ever-vapers)	n=1182	n=1275	n=1680			n=1348	n=1283	n=1260			n=1283	n=1336	n=1734		
Past 30-day vaping	28.8% (340)	36.3% (463)	43.9% (738)	1.36 (1.17 to 1.59); p<0.0001		25.8% (347)	27.3% (351)	34.8% (439)	1.44 (1.19 to 1.75); p=0.0002		35.4% (454)	47.5% (635)	42.5% (736)	0.81 (0.68 to 0.97); p=0.02	
Past-week vaping	17.6% (208)	22.7% (290)	30.2% (508)	1.48 (1.24 to 1.75); p<0.0001		13.7% (184)	14.0% (179)	19.2% (241)	1.49 (1.17 to 1.91); p=0.001		20.4% (262)	31.1% (416)	29.0% (503)	0.91 (0.75 to 1.09); p=0.31	
Vaping ≥ 20 days of past 30	6.3% (74)	7.2% (92)	14.0% (236)	2.11 (1.63 to 2.73); p<0.0001		4.4% (59)	5.9% (76)	7.5% (94)	1.33 (0.92 to 1.94); p=0.13		6.9% (89)	11.5% (154)	15.4% (267)	1.42 (1.10 to 1.85); p=0.008	
Cigarette smoking (among ever-smokers)	n=1288	n=1193	n=1287			n=1615	n=1554	n=1334			n=1322	n=1306	n=1334		
Past 30-day smoking	33.4% (431)	32.1% (383)	29.8% (384)	0.91 (0.77 to 1.07); p=0.24		38.5% (622)	41.5% (645)	38.9% (519)	0.90 (0.76 to 1.06); p=0.19		34.1% (451)	36.0% (470)	23.6% (315)	0.56 (0.46 to 0.67); p<0.0001	
Past-week smoking	23.9% (308)	24.4% (291)	22.4% (288)	0.90 (0.76 to 1.07); p=0.23		24.2% (391)	28.6% (444)	26.7% (356)	0.91 (0.76 to 1.09); p=0.29		26.3% (347)	25.7% (336)	17.3% (231)	0.61 (0.50 to 0.76); p<0.0001	
Smoking ≥ 20 days of past 30	13.4% (173)	13.3% (158)	9.2% (118)	0.66 (0.53 to 0.83); p=0.0004		10.7% (173)	14.5% (226)	12.3% (165)	0.83 (0.65 to 1.05); p=0.11		11.4% (151)	11.9% (156)	7.5% (100)	0.61 (0.46 to 0.80); p=0.0004	

Data are weighted %(n) or adjusted OR (AOR) with 95% CI and associated p values, adjusted for sex, age group and race/ethnicity.



Note: "Refused" and "Don't know" responses excluded from denominators

Figure 1 Indicators of perceived vaping and cigarette smoking dependence among past 30-day users, 2017–2019, by country, weighted % (n).

1.48, 95% CI 1.02 to 2.13; $p=0.04$) but no difference between 2018 and 2019.

Perceived addiction to smoking

In 2019, 67.6% of past 30-day smokers in the USA reported they were either 'a little' or 'very addicted' to cigarettes, compared with 60.0% in Canada and 54.7% in England. The proportion of past 30-day smokers who reported that they were either 'a little' or 'very addicted' to cigarettes did not vary significantly by year in Canada or the USA, but increased between 2017 and 2018 (AOR 1.49, 95% CI 1.17 to 1.90; $p=0.001$) and from 2017 to 2019 (AOR 1.53, 95% CI 1.19 to 1.97; $p=0.0009$), though not between 2018 and 2019, in England.

Changes in dependence indicators among exclusive users versus dual users

Online supplemental table 2 shows data on urges to use and perceived addiction by exclusive users versus dual users. Dual users reported higher levels of dependence symptoms than exclusive vapers in all cases and exclusive smokers in most cases. There was a significant interaction between dual/exclusive use and year in Canada and the USA: exclusive vapers reported greater increases in vaping urges between 2017 and 2019 compared with dual users in Canada ($p=0.047$) and the USA ($p=0.021$), with no difference in England ($p=0.751$). Exclusive vapers also reported greater increases in perceived addiction than dual users between 2017 and 2019 in Canada ($p=0.013$) and the USA (0.006), but not England ($p=0.968$). No differences were observed between exclusive and dual users in changes over time for urges to smoke or perceived addiction to smoking.

Quit intentions and attempts

Table 3 shows plans and attempts to quit vaping and/or smoking cigarettes, among past 30-day e-cigarette users and smokers in each country. The proportion of past 30-day vapers planning to quit within the next 6 months relative to those planning to quit sometime in the future or not planning to quit did not change significantly by survey year in England or the USA. In Canada, the proportion planning to quit in the next 6 months increased between 2018 and 2019 (AOR 1.69, 95% CI 1.25 to 2.29; $p=0.0007$) and between 2017 and 2019 (AOR 1.53, 95% CI 1.04 to 2.26; $p=0.03$). The proportion of past 30-day smokers planning to quit within the next 6 months did not change significantly by survey year in any country.

The proportion of past 30-day vapers who reported trying to quit in the last 12 months relative to those who reported they had not tried to quit increased between 2018 and 2019 only in Canada (AOR 1.40, 95% CI 1.04 to 1.90; $p=0.03$), but increased between 2017 and 2019 in all three countries (Canada: AOR 1.89, 95% CI 1.23 to 2.92, $p=0.004$; England: AOR 1.56, 95% CI 1.00 to 2.42, $p=0.048$; USA: AOR 1.45, 95% CI 1.01 to 2.08, $p=0.04$). Among smokers, few changes within countries were observed in quit attempts: the proportion of past 30-day smokers who tried to quit in the past 12 months decreased between 2017 and 2018 in the USA (AOR 0.57, 95% CI 0.34 to 0.95, $p=0.03$), and increased between 2018 and 2019 in Canada (AOR 1.53, 95% CI 1.03 to 2.28; $p=0.04$).

Reasons for quitting

Reasons for stopping/trying to stop/discontinuing use of e-cigarettes among ever-vapers are shown in table 4. The most common

Table 3 Quit intentions and attempts among past 30-day e-cigarette users and past 30-day smokers, 2017–2019, by country, weighted %(n)

	Canada			England			USA		
	2017	2018	2019	2017	2018	2019	2017	2018	2019
Vaping	(n=340)	(n=463)	(n=738)	(n=347)	(n=351)	(n=439)	(n=454)	(n=635)	(n=736)
Are you planning to quit using e-cigarettes/vaping...									
Within the next month	9.8 (33)	11.6 (54)	15.0 (109)	9.7 (33)	11.9 (42)	10.6 (46)	9.1 (41)	10.0 (63)	12.1 (89)
Between 1 and 6 months from now	10.3 (35)	8.5 (39)	15.0 (110)	12.7 (44)	12.1 (42)	9.8 (43)	11.5 (52)	16.7 (106)	12.3 (90)
Sometime in the future, beyond 6 months	15.7 (53)	18.6 (86)	19.3 (141)	16.8 (58)	19.3 (68)	16.7 (73)	19.2 (87)	20.9 (133)	24.4 (180)
Not planning to quit	26.4 (90)	26.2 (121)	21.3 (156)	25.6 (88)	26.9 (94)	30.3 (133)	32.0 (145)	30.2 (192)	24.7 (182)
I don't currently use e-cigarettes	18.7 (64)	25.5 (118)	17.0 (124)	19.9 (69)	22.5 (79)	21.2 (93)	12.2 (55)	12.2 (77)	10.9 (81)
Don't know	19.1 (65)	9.7 (45)	12.5 (91)	15.4 (53)	7.2 (25)	11.5 (51)	15.8 (72)	10.0 (63)	15.6 (115)
Have you tried to completely stop using e-cigarettes/vaping in the LAST 12 MONTHS?									
Yes	12.2 (41)	18.7 (86)	26.8 (196)	12.7 (44)	16.5 (58)	21.0 (92)	15.3 (69)	21.9 (138)	25.0 (184)
No*	46.7 (159)	51.4 (236)	52.6 (384)	49.6 (170)	57.7 (202)	53.0 (231)	55.1 (249)	63.3 (398)	62.6 (461)
Not applicable†	37.8 (128)	25.6 (118)	17.1 (124)	35.7 (122)	22.5 (79)	21.3 (93)	28.1 (127)	12.3 (77)	10.9 (81)
Don't know‡	3.3 (11)§	4.4 (20)	3.5 (25)	1.9 (7)§	3.3 (11)§	4.6 (20)	1.5 (7)§	2.5 (15)	1.5 (11)§
Cigarette smoking	(n=431)	(n=383)	(n=384)	(n=622)	(n=645)	(n=519)	(n=451)	(n=470)	(n=315)
Are you planning to quit smoking...									
Within the next month	12.2 (52)	12.8 (49)	15.6 (60)	9.7 (60)	10.7 (69)	11.7 (60)	17.2 (78)	17.7 (83)	15.3 (48)
Between 1 and 6 months from now	13.2 (57)	16.6 (63)	15.3 (59)	12.2 (75)	13.0 (84)	10.8 (56)	15.7 (71)	18.2 (86)	16.5 (52)
Sometime in the future, beyond 6 months	25.3 (108)	23.7 (90)	23.7 (91)	22.7 (140)	30.9 (199)	21.5 (111)	24.3 (110)	25.5 (120)	25.1 (79)
Not planning to quit	15.0 (64)	23.9 (91)	16.7 (64)¶	17.0 (105)	18.8 (122)	20.4 (106)	16.0 (72)	16.9 (80)	18.1 (57)
I don't currently smoke	19.1 (82)	14.2 (54)	14.2 (54)	27.4 (170)	20.3 (131)	21.6 (112)	9.8 (44)	11.0 (52)	10.0 (31)
Don't know	15.1 (65)	8.8 (33)	14.6 (56)	11.2 (69)	6.3 (41)	14.1 (73)	17.0 (77)	10.6 (50)	15.0 (47)
Have you tried to completely stop smoking in the LAST 12 MONTHS?									
Yes	19.6 (85)	14.6 (56)	22.7 (87)	14.8 (92)	15.3 (99)	18.8 (97)	20.5 (93)	12.6 (59)	16.7 (53)
No*	25.8 (111)	23.5 (90)	21.0 (81)	22.7 (141)	26.2 (169)	22.5 (117)	19.5 (88)	21.6 (100)	21.5 (68)
Not applicable¶	54.6 (235)	60.8 (232)	55.5 (213)	61.7 (384)	58.4 (377)	58.2 (302)	59.8 (270)	65.4 (304)	61.2 (193)
Don't know‡	0.0 (0)	1.0 (4)§	0.8 (3)§	0.8 (5)§	0.1 (0)	0.5 (2)§	0.2 (1)§	0.4 (2)§	0.7 (2)§

Respondents who refused (missing values) are excluded (removed from the denominator).

*Includes those who said 'No' to ever trying to stop in a previous (not shown) item.

†Responded to previous item (plans to quit) with 'Don't currently use' (or, in 2017, with 'Don't know').

‡Includes those who said 'Don't know' to ever trying to stop in a previous (not shown) item.

§High variability (coefficient of variation >33.3%); interpret with caution.

¶Respondents who were not asked because they were not classified as current smoker (ie, had not smoked at least 100 cigarettes) but did smoke in the last 30 days.

reasons for stopping across all three countries were, 'Only tried e-cigarettes/vaping to see what it was like' and 'Lost interest/didn't enjoy it.' Relatively few changes were observed in reasons for stopping e-cigarette use between 2018 and 2019, with the exception that the proportions of ever-vapers in Canada and the USA who reported stopping out of concern about health risks and addiction increased, and in Canada, fewer youth reported that they only tried e-cigarette/vaping to see what it was like, and more reported that friends/partner wanted them to stop. There were no significant changes in England.

DISCUSSION

The findings from the current study suggest that among young people who try e-cigarettes, frequent use became more common between 2017 and 2019, and this has occurred to a greater extent in the USA and Canada, compared with England. Frequent use is an important indicator of dependence.^{9 13 14 37 38} By contrast, among ever-smokers, more frequent smoking decreased between 2017 and 2019, particularly in the USA. Among past 30-day vapers, strong urges to vape also increased significantly between 2017 and 2019 in all three countries; strong urges to smoke among past 30-day-smokers were more common (eg, 59.3% for smoking vs 46.1% for vaping in 2019, USA), but with no

consistent changes over the years. Similarly, among past 30-day vapers, feeling very or a little addicted to vaping increased between 2017 and 2019 in the three countries; feeling very little or a little addicted to smoking was more common among past 30-day smokers (eg, 67.6% for smoking vs 53.1% for vaping in 2019, USA) but with no consistent changes across countries (although England increased). In Canada and the USA, increases between 2017 and 2019 in urges to vape and perceived addiction to vaping were greater among exclusive vapers compared with dual users.

In 2017, the ratio of frequent to ever use was substantially higher for smoking than vaping. However, by 2019, this pattern was inverted in Canada and the USA: ever-vapers were more likely to report frequent use, compared with ever-smokers. In the USA, twice as many ever-vapers reported vaping at least 20 days in the past month, compared with the corresponding measure for ever-smokers. Data from ever-vapers in England showed a similar pattern, although to a lesser extent than in Canada and the USA. No consistent trends were observed for smoking in Canada or England, although fewer ever-smokers in the USA reported regular smoking between 2017 and 2019, which is consistent with longerterm trends, in which prevalence of daily smoking has declined at a greater rate than ever smoking

Table 4 Reasons for stopping or trying to stop using e-cigarettes among ever-vapers*, 2017–2019, weighted % (n)

Reasons	Canada				England				USA			
	2017	2018	2019	Difference	2017	2018	2019	Difference	2017	2018	2019	Difference
	n=883	n=898	n=1138	2019 vs 2018†	n=1044	n=990	n=913	2019 vs 2018†	n=898	n=839	n=1181	2019 vs 2018†
Only tried e-cigarette/vaping to see what it was like	74.3 (656)	59.5 (534)	52.2 (594)	0.73 (p=0.001)	72.3 (755)	62.9 (623)	59.7 (545)	0.86 (p=0.17)	67.6 (607)	51.3 (430)	50.5 (596)	0.96 (p=0.69)
Lost interest/did not enjoy it†	–	35.3 (317)	35.0 (398)	0.98 (p=0.84)	–	31.1 (308)	33.0 (302)	1.09 (p=0.43)	–	35.2 (296)	35.3 (417)	1.01 (p=0.94)
Concerned about addiction	16.0 (142)	20.9 (187)	29.3 (333)	1.59 (p<0.0001)	15.6 (163)	16.1 (159)	19.3 (176)	1.25 (p=0.10)	18.7 (168)	21.0 (176)	28.5 (337)	1.52 (p=0.001)
Cost too much	25.3 (224)	21.0 (189)	20.7 (236)	0.99 (p=0.95)	17.6 (184)	15.8 (156)	12.4 (113)	0.76 (p=0.06)	24.6 (221)	21.3 (178)	20.0 (236)	0.94 (p=0.62)
Concerned about possible health risks or side-effects	30.5 (269)	29.7 (267)	41.0 (466)	1.65 (p<0.0001)	23.4 (244)	23.2 (230)	25.2 (230)	1.12 (p=0.36)	31.3 (281)	31.4 (264)	41.9 (495)	1.58 (p<0.0001)
Uncomfortable using in public	14.7 (130)	12.9 (116)	12.2 (139)	0.95 (p=0.71)	9.8 (102)	8.4 (83)	8.6 (78)	1.03 (p=0.88)	11.3 (102)	8.9 (74)	8.2 (97)	0.93 (p=0.70)
Did not like the taste	14.3 (127)	8.0 (72)	9.3 (106)	1.17 (p=0.36)	10.7 (111)	8.0 (79)	8.0 (73)	1.00 (p=0.99)	16.4 (147)	9.7 (81)	9.1 (108)	0.92 (p=0.63)
Did not help me quit smoking§	2.5 (22)	0.7 (6)	1.3 (14)	1.81 (p=0.12)	2.5 (26)	2.9 (28)	2.0 (18)	0.69 (p=0.22)	2.2 (20)	1.7 (14)¶	1.0 (12)	0.62 (p=0.28)
Did not help me cut back on cigarettes§	2.1 (18)	0.9 (8)	1.0 (11)	1.14 (p=0.73)	2.6 (27)	2.6 (26)	2.2 (20)	0.85 (p=0.61)	2.5 (23)	1.5 (12)	0.8 (9)	0.54 (p=0.17)
No longer needed e-cigarettes to keep from smoking§	1.2 (10)¶	0.4 (4)¶	0.8 (9)	2.02 (p=0.20)	0.6 (6)¶	0.8 (8)¶	0.6 (6)¶	0.77 (p=0.65)	0.3 (3)¶	0.5 (4)¶	0.9 (11)¶	1.87 (p=0.30)
Parents/family wanted me to stop†	–	11.6 (104)	14.9 (170)	1.32 (p=0.053)	–	7.9 (78)	8.6 (78)	1.09 (p=0.64)	–	14.8 (124)	18.5 (218)	1.27 (p=0.12)
Friends/partner wanted me to stop†	–	6.3 (56)	8.7 (99)	1.44 (p=0.04)	–	3.2 (31)	4.1 (38)	1.32 (p=0.30)	–	9.8 (82)	8.2 (96)	0.82 (p=0.27)
Did not have an e-cigarette/ vape or cartridges/e-liquidst	–	18.9 (170)	16.2 (184)	0.81 (p=0.08)	–	14.0 (138)	11.0 (101)	0.75 (p=0.06)	–	14.9 (125)	14.3 (169)	0.96 (p=0.81)
Other	9.7 (59)	1.3 (11)	0.6 (6)¶	0.45 (p=0.09)	6.1 (63)	0.9 (9)¶	0.5 (5)¶	0.55 (p=0.35)	9.4 (57)	0.7 (6)¶	0.9 (11)¶	1.22 (p=0.71)
Don't know	2.1 (18)	2.2 (20)	2.3 (26)	1.02 (p=0.96)	2.3 (24)	2.5 (25)	2.2 (20)	0.86 (p=0.66)	2.1 (18)	2.1 (18)	1.7 (20)	0.84 (p=0.70)

* Different versions of the question were asked for current (past 30-day) vapers who had tried to quit in the past year, former vapers (ever vaped but not in the past year), and experimental vapers (vaped in the past year but not in the past 30 days), and combined here. Respondents could select all options that applied; percentages do not add to 100.

† AORs and p values from within-country logistic regression models adjusting for sex, age group (16–17, 18–19), and race/ethnicity ('White', other).

‡ Response option added in wave 2.

§ Asked only of respondents who were smokers.

¶ High variability (coefficient of variation >33.3%); interpret with caution.

in Canada and the USA.^{39 40} Future research is needed to assess the relationship between the increase in e-cigarette use and dependence symptoms and the decrease in combustible cigarette use and dependence.

Substantial proportions of past 30-day vapers reported other symptoms of dependence. In 2019, between one-third and just over half of past 30-day vapers reported frequent strong urges to vape or feeling at least 'a little' addicted to e-cigarettes. Urges to vape and perceived addiction increased over time in all countries, but to a greater extent in Canada and the USA, compared with England. The prevalence of frequent strong urges and perceived addiction were lower for vaping than for smoking, consistent with previous studies.^{14 15 18 24 25 41–43} However, differences between the two diminished over time. Compared with previous studies, the prevalence estimates of dependence indicators in the current study are somewhat higher. This is most likely because the current study reported data for past 30-day vapers, whereas other studies have included ever and less than monthly vapers.

The increase in prevalence of dependence symptoms among e-cigarette users is consistent with the increasing popularity of high nicotine salt-based products among youth.⁴⁴ Two studies have examined whether newer 'pod' devices, such as JUUL, were associated with greater levels of dependence. The first study found no differences between pod and non-pod users on scores of the *Hooked On Nicotine Checklist*, among a sample of youth and young adults in California.⁴⁵ The second study found that 27% of past-week e-cigarette users attending outpatient clinics endorsed at least one of five dependence statements drawn from different scales, and users of pods were more likely to endorse statements such as the 'need to vape' after waking, and had greater urges to vape than non-pod users.⁴⁶

The use of high nicotine concentration salt-based products would also help to explain the relatively larger increase in dependence symptoms in Canada and the USA. In England, e-cigarettes cannot exceed nicotine concentrations of 20 mg/mL; therefore, while brands such as JUUL are available for sale in England, they have approximately one-third the nicotine concentration of the most popular version of JUUL sold in Canada and the USA.⁴⁷ Overall, the use of e-cigarettes with nicotine content above 20 mg/mL is substantially more prevalent among youth vapers in Canada and the USA than England.⁴⁸ Notably, the market-wide shift towards nicotine salt products in North America occurred between 2017 and 2019, the period during which we observed increases in the frequency of youth vaping and dependence.^{49–51}

Another key index of dependence is inability to quit using the product. Between 2017 and 2019, there was a significant increase in all three countries in the proportion of vapers who tried to quit and were unable to do so. In 2019, approximately 50% of past 30-day vapers reported that they planned to quit vaping in Canada and the USA, while 25%–27% reported trying unsuccessfully to quit in the past year—similar to levels reported by past 30-day smokers. Youth reported a wide variety of reasons for trying to stop vaping. Relatively few changes were observed over time in reasons for quitting, with the two notable exceptions of increased concerns about addiction and health effects. This may also reflect increasingly negative media portrayals of the risks of vaping, particularly in response to the outbreak of e-cigarette or vaping product use-associated lung injury in the USA, which was erroneously attributed to vaping nicotine products rather than illicit cannabis contaminated with vitamin E (the predominant cause of the outbreak).^{52 53} Future research should examine likelihood of stopping e-cigarette use among youth, as well as factors such as dependence that may moderate cessation success.

Limitations

Measurement of dependence for e-cigarettes is at an early stage. To date, most measures have been adapted from those used to measure tobacco dependence; however, e-cigarette dependence may require more tailored approaches to account for the unique patterns of vaping, such as the ability to vape more consistently throughout the day, compared with smoking, which is typically characterised in terms of the number of cigarettes.^{54 55} The current study used single-item indicators of dependence, which do not capture the complexity of dependence for e-cigarettes, including those features that may be unique to e-cigarettes.⁴² However, compared with more elaborate scales, single-item measures have been shown to have comparably strong associations with cotinine, frequency of use and future outcomes.^{12 26 34 35} The current study is also subject to limitations common to survey research, including social desirability bias; however, we would expect this to be relatively consistent over time and across countries. Participants were not recruited using probability-based sampling; therefore, the findings do not provide representative estimates within each country. However, the same methodology was used across survey years, samples were weighted to match country demographics and smoking prevalence trends (in Canada and USA), and the prevalence estimates are consistent with those from other national benchmark studies.²¹ As described in the Methods section, the weighting procedures were revised in Canada and the USA, which resulted in slightly different estimates compared with earlier publications.⁴⁹ The current study did not examine factors related to socioeconomic status, such as household income or parental education. Finally, the study used a repeat cross-sectional design, with different participants recruited at each wave, rather than a prospective cohort design, in which the same participants are followed up over time.

CONCLUSIONS

Symptoms of dependence among young e-cigarette users are increasing, including frequency of use, experiencing frequent

What this paper adds

- ▶ The role of dependence in tobacco smoking is well established, and a recent review concluded that e-cigarettes can produce symptoms of dependence. However, the extent to which e-cigarettes promote and sustain dependence remains an important research question, and few studies have assessed e-cigarette dependence among young people.
- ▶ Few studies have assessed intentions or attempts to stop vaping; none have examined vaping cessation behaviours among youth or non-users of tobacco.
- ▶ The current study examined indicators of dependence and vaping cessation behaviours among youth in Canada, England, and the USA, between 2017 and 2019—the first to examine changes over multiple years in measures of dependence—and found an increase in frequent use, urges to vape and perceived addiction among users, particularly in Canada and the USA.
- ▶ There was a significant increase from 2017 to 2019 in all three countries in the number of vapers who tried to quit and were unable to do so.
- ▶ While indicators of dependence remain less prevalent than for cigarette smoking, the gap narrowed considerably, particularly among US and Canadian youth.

strong urges to vape, feelings of addiction and unsuccessful quit attempts. Indicators of dependence remain less prevalent than for cigarette smoking; however, the gap has narrowed considerably in the past 2 years, particularly among youth in Canada and the USA. The findings highlight the importance of understanding whether the increased dependence symptoms among vapers represent a natural evolution of the vaping market and development of products with higher dependence potential, or whether other policy differences between countries, such as product standards or marketing regulations, account for country-level differences. The extent to which the frequency of vaping and symptoms of dependence persist into young adulthood represents an important question for assessing the public health impact of vaping among young people.

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Competing interests DH has served as a paid expert witness in legal challenges against tobacco companies.

Patient consent for publication Not required.

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Data availability statement Data are available upon reasonable request. Deidentified data will be made available to researchers who provide a methodologically sound proposal for use in achieving the goals of the approved proposal. Proposals should be submitted to David Hammond (dhammond@uwaterloo.ca).

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Supplemental Table 1: Indicators of perceived vaping and cigarette smoking dependence among past 30-day users, 2017 to 2019, by country, weighted % (n)

	CANADA			ENGLAND			US		
	2017	2018	2019	2017	2018	2019	2017	2018	2019
VAPING	(n=340)	(n=463)	(n=738)	(n=347)	(n=351)	(n=439)	(n=454)	(n=635)	(n=736)
In the past 30 days, how often did you have a strong urge to use an e-cigarette/vape?									
Several times a day	13.5 (46)	9.7 (45)	18.7 (137)	10.3 (35)	12.3 (43)	9.5 (42)	15.7 (71)	15.9 (101)	21.9 (161)
Every day or most days	11.8 (40)	14.0 (64)	15.9 (116)	14.0 (48)	17.9 (63)	22.4 (98)	15.4 (70)	20.7 (131)	22.7 (166)
At least once a week	16.1 (55)	13.4 (62)	19.9 (145)	15.2 (52)	17.2 (60)	18.3 (80)	19.7 (89)	20.7 (131)	19.6 (143)
Less than once a week	12.0 (40)	13.4 (62)	11.6 (85)	8.6 (30)	10.6 (37)	13.2 (58)	14.0 (64)	11.7 (74)	11.6 (85)
Never	42.4 (143)	47.2 (217)	32.1 (235)	47.2 (162)	39.6 (139)	33.8 (148)	33.5 (152)	28.1 (178)	20.8 (152)
Don't know	4.1 (14)	2.2 (10)	1.8 (14)	4.6 (16)	2.5 (9)*	2.8 (12)	1.7 (8)*	2.9 (18)	3.4 (25)
Do you consider yourself addicted to using e-cigarettes/ vaping?									
Yes, very addicted	10.5 (35)	8.0 (37)	12.8 (94)	12.9 (44)	9.7 (34)	8.5 (37)	10.1 (46)	13.0 (83)	13.0 (95)
Yes, a little addicted	21.8 (73)	21.0 (97)	34.4 (251)	17.7 (61)	31.1 (109)	30.4 (133)	25.6 (116)	28.9 (183)	38.4 (282)
Not at all	61.8 (208)	68.2 (316)	50.4 (369)	61.0 (210)	54.9 (192)	58.1(254)	62.2 (282)	56.0 (355)	45.3 (333)
Don't know	5.9 (20)	2.7 (13)	2.4 (18)	8.4 (29)	4.2 (15)	3.0 (13)	2.1 (9)	2.1 (13)	3.4 (25)
CIGARETTE SMOKING	(n=431)	(n=383)	(n=384)	(n=622)	(n=645)	(n=519)	(n=451)	(n=470)	(n=315)
In the past 30 days, how often did you have a strong urge to smoke a cigarette?									
Several times a day	23.4 (101)	22.2 (85)	20.1 (77)	14.7 (91)	18.7 (121)	17.2 (89)	31.2 (141)	26.2 (123)	28.0 (88)
Every day or most days	25.1 (108)	27.4 (104)	21.6 (82)	21.0 (130)	25.9 (167)	21.6 (112)	26.8 (121)	25.5 (120)	30.8 (97)
At least once a week	18.2 (79)	19.8 (75)	24.1 (92)	13.6 (84)	17.0 (110)	18.7 (97)	15.2 (69)	22.8 (107)	18.3 (58)
Less than once a week	9.6 (41)	13.5 (51)	13.5 (52)	14.6 (90)	11.6 (75)	16.5 (86)	11.1 (50)	12.5 (59)	11.1 (35)
Never	22.2 (96)	16.1 (61)	19.7 (75)	34.3 (213)	26.0 (168)	25.1 (130)	14.5 (65)	11.6 (55)	11.1 (35)
Don't know	1.4 (6)*	1.0 (4)*	0.8 (3)*	1.8 (11)	0.8 (5)*	0.8 (4)*	1.1 (5)*	1.4 (6)*	0.7 (2)*
Do you consider yourself addicted to cigarettes?									
Yes, very addicted	18.1 (78)	23.9 (91)	19.9 (77)	11.7 (72)	14.6 (94)	14.3 (74)	14.1 (64)	18.4 (86)	18.7 (59)
Yes, a little addicted	46.4 (200)	38.6 (147)	39.1(150)	31.2 (193)	40.2 (259)	39.6 (206)	46.6 (210)	45.6 (214)	48.1 (152)
Not at all	32.8 (141)	35.9 (137)	39.4 (152)	54.3 (336)	45.1 (291)	44.6 (231)	37.8 (171)	34.2 (161)	32.0 (101)
Don't know	2.7 (12)*	1.6 (6)*	1.5 (6)*	2.9 (18)	0.1 (1)*	1.4 (7)*	1.5 (7)*	1.7 (8)*	1.2 (4)*

Note: Respondents replying "Refused" (<1.3% in every question) have been excluded from the cells of the table

*High variability (coefficient of variation >33.3%); interpret with caution

Supplemental Table 2: Indicators of perceived vaping and cigarette smoking dependence among past 30-day users, 2017 to 2019, by exclusive versus dual use and by country, weighted %

	2017				2018				2019			
	URGE TO USE ^a		PERCEIVED ADDICTION ^b		URGE TO USE ^a		PERCEIVED ADDICTION ^b		URGE TO USE ^a		PERCEIVED ADDICTION ^b	
	Smoking	Vaping	Smoking	Vaping	Smoking	Vaping	Smoking	Vaping	Smoking	Vaping	Smoking	Vaping
CANADA												
Exclusive vaper	-	15.9%	-	19.8%	-	16.7%	-	20.9%	-	31.5%	-	43.3%
Exclusive smoker	52.2%	-	66.3%	-	48.6%	-	64.2%	-	42.3%	-	58.8%	-
Dual user	44.3%	38.5%	66.3%	50.8%	51.7%	36.3%	62.8%	44.1%	41.9%	43.8%	60.8%	59.4%
US												
Exclusive vaper	-	15.9%	-	18.8%	-	25.8%	-	31.2%	-	41.0%	-	48.3%
Exclusive smoker	46.7%	-	55.0%	-	43.3%	-	59.5%	-	51.2%	-	62.1%	-
Dual user	68.8%	44.9%	67.1%	52.1%	59.6%	54.7%	69.7%	59.2%	63.7%	59.1%	70.6%	65.6%
ENGLAND												
Exclusive vaper	-	18.8%	-	24.2%	-	19.6%	-	31.3%	-	25.9%	-	30.2%
Exclusive smoker	31.0%	-	35.8%	-	40.6%	-	48.6%	-	32.2%	-	48.5%	-
Dual user	47.7%	30.6%	61.6%	40.1%	53.6%	38.2%	67.4%	49.8%	48.2%	39.3%	62.7%	49.6%

^aPercentage reporting strong urges to use an e-cigarette/smoke “several times a day, or every day/most days”

^bPercentage reporting they perceive themselves as “a little addicted” or “very addicted” to vaping/smoking.

Note: “Refused” and “Don’t know” responses excluded from denominators