Trends in e-cigarette brands, devices and the nicotine profile of products used by youth in England, Canada and the USA: 2017–2019

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ABSTRACT

Background The e-cigarette market has rapidly evolved, with a shift towards higher nicotine concentration and salt-based products, such as *JUUL*; however, the implications for youth vaping remain unclear.

Methods Repeat cross-sectional online surveys were conducted in 2017, 2018 and 2019, with national samples of youth aged 16–19 years recruited from commercial panels in Canada (n=12 018), England (n=11 362) and the USA (n=12 110). Regression models examined differences between countries and over time in the types of e-cigarette products used (design and nicotine content), reasons for using brands and differences in patterns of use, sociodemographics and dependence symptoms by brand/nicotine content.

Results In 2019, the use of pod- or cartridge-style e-cigarettes was greater in Canada and the USA than England, with *Smok* and *JUUL* the leading brands in all countries. In 2019, youth vapers in England were less likely to report using e-cigarettes with ≥2% nicotine (12.8%) compared with Canada (40.5%; adjusted OR (AOR)=4.96; 95% CI 3.51 to 7.01) and the USA (37.0%; AOR=3.99, 95% CI 2.79 to 5.71) and less likely to report using nicotine salt-based products (12.3%) compared with Canada (27.1%; AOR=2.77, 95% CI 1.93 to 3.99) and the USA (21.9%; AOR=2.00, 95% CI 1.36 to 2.95). In 2019, self-reported use of products with higher nicotine concentration was associated with significantly greater frequency of vaping, urges to vape and perceived vaping addiction (p<0.05 for all).

Conclusions The use of high-nicotine salt-based products is associated with greater symptoms of dependence, including *JUUL* and other higher-nicotine brands. Greater use of high-nicotine salt-based products may account for recent increases in the frequency of vaping among youth in Canada and the USA.

BACKGROUND

The e-cigarette market has rapidly evolved over the last several years, largely driven by the ascendance of JUUL and similar 'pod'-style vaping products.[1 2] JUUL uses replaceable pod-style cartridges and is notable both for its sleek, modern design and the way it delivers nicotine. JUUL uses a nicotine salt that is created by combining free-base nicotine (the natural state of nicotine in tobacco leaves) and benzoic acid. Prior to JUUL, most free-base e-liquids contained nicotine concentrations below 20 mg/mL, whereas the standard version of JUUL on the market in the USA contains 59 mg/mL.[3 4] Such high nicotine concentrations would typically produce a bitter, aversive sensation in the mouth and throat for conventional e-cigarettes with free-base nicotine; however, JUUL's nicotine salt formulation with benzoic acid generates aerosols with a lower pH level, which is known to reduce unpleasant nicotine taste and irritation in the upper airways.[3 5–7] Ultimately, consumers determine nicotine uptake through their puffing behaviours;[8] however, nicotine salt e-liquids may facilitate greater nicotine delivery by making it easier to inhale high concentrations, particularly among novel users.

There are mixed findings as to whether nicotine concentration is associated with greater dependence among adult vapers.[9 10] Most studies to date were conducted prior to the emergence of high-nicotine salt-based (HNSB) products; in addition, most adult vapers have a history of tobacco smoking and nicotine dependence, which complicates efforts to characterise the abuse liability of e-cigarettes. Several studies suggest that youth vapers who use HNSB products are more likely to report symptoms of dependence, such as perceived addiction to vaping, compared with non-JUUL or non-pod products,[3 11–13] with one study finding no association.[14] Use of JUUL and similar pod devices among youth have also been associated with higher cotinine levels.[12]

A range of population-based studies in the USA have documented the popularity of JUUL among youth.[15 16] In 2019, more than half of youth in the USA who used e-cigarettes in 2019 reported using JUUL—approximately 10 times the market share of any other brand.[17 18] Other survey data also suggest that JUUL use is more prevalent among youth from higher socioeconomic strata, males and vapers of 'white' race/ethnicity.[13 16 19 20] The most commonly cited reasons for using JUUL are 'social' reasons and curiosity, similar to other brands; however, JUUL users are more likely to cite 'nicotine hit' as a reason for use, compared with other brands.[13 21] Qualitative research also highlights high levels of nicotine delivery as a motivation for use.[22] At the same time, many JUUL users appear to be unaware of its nicotine content: a 2018 survey of youth and young adults found that only 37% of past 30-day users correctly reported that JUUL always contains nicotine.[15] Another study of high school students in the USA found that only 35% of past-month JUUL

users characterised the nicotine content of JUUL as 'high', which decreased to 29% after users were told that JUUL contains 5% nicotine.[23] Previous studies have demonstrated generally low awareness of nicotine levels among youth vapers, particularly among infrequent vapers who do not purchase their own products.[24 25]

Although much of the attention has focused exclusively on JUUL, the nicotine salt technology pioneered by JUUL has been adopted by most other major brands, contributing to a broader market shift towards products with higher nicotine concentration.[26 27] For example, in 2019, all 15 of the leading brands reported by youth e-cigarette users in Canada, England and the USA in the ITC Youth Surveys were available in a nicotine salt format, including popular discount brands, such as Smok.[28] Trends in the use of JUUL and HNSB products in markets outside the USA provide potentially important information about the impact of these brands on youth vaping. In England, the European Union Tobacco Product Directive sets a maximum nicotine content of 20 mg/mL for e-cigarettes[29]; therefore, JUUL products in England contain approximately one-third of the nicotine concentration of JUUL products in the USA and Canada, and versions with lower nicotine concentrations were available in England that were not sold in the USA.[30 31] Several months after JUUL's introduction to Canada and England in 2018, JUUL's market share increased among youth, although to a lesser extent than in the USA.[28] However, the longer term youth trends regarding JUUL and other HNSB products in these markets has yet to be examined.

The current study examined changes in the types of e-cigarettes used among past 30-day youth vapers between 2017 and 2019 in three countries: the USA, Canada and England. More specifically, the study examined changes in the types of e-cigarette devices (eg, disposable, refillable and 'pods') and e-cigarette brands used by youth vapers, reasons for using brands, as well as self-reported nicotine levels and use of nicotine salt-based e-liquids. The study also examined differences in sociodemographic factors, patterns of use and dependence symptoms, based on e-cigarette brand, nicotine level and nicotine salt use.

METHODS

The International Tobacco Control Policy Evaluation Project (ITC) Youth Tobacco and Vaping Survey is a self-completed online survey examining use of tobacco and vaping products among youth in Canada, England and the USA. Repeat cross-sectional data are reported from the first three waves, conducted in July/August 2017 (wave 1; n=12 128), August/September 2018 (wave 2; n=11 753) and August/September 2019 (wave 3; n=11 609).

Sample

Respondents aged 16–19 years were recruited through Nielsen Consumer Insights Global Panel and their partners' panels, either directly or through their parents. A full description of the study methods can be found in the technical report.[32]

Protocol

Participants completed a 20 min survey, available in English in all countries, as well as French in Canada. The survey consisted of sociodemographic measures, detailed questions on e-cigarette and tobacco use and perceptions and additional questions on other health behaviours, including cannabis use. Measures were adapted from existing national benchmark surveys (eg, Population Assessment of Tobacco and Health Study[33]), as well as previous versions of the ITC surveys.[34] On completion, respondents received remuneration in accordance with their panel's usual incentive structure, which could include points-based or monetary rewards (redeemed for catalogue items, as cash or donated) and/or chances to win monthly prizes.

Measures

Complete versions of the ITC Youth Tobacco and Vaping Surveys—including all measures described below—are publicly available on the project website.[32]

Sociodemographic variables

Sociodemographic variables included sex at birth, age, student status and high school grades. In 2018 and 2019, perceived family financial situation was assessed (not meeting basic expenses, just meeting basic expenses, meeting needs with a little left over or living comfortably). Race/ethnicity was assessed using country-specific racial/ethnic questions with multiple categories, which were recoded to 'White (only)' or 'other' (including any other race/ethnicity and not stated) to allow for cross-country comparisons. Smoking behaviour was also assessed, as reported elsewhere,[28] and is included in the sample characteristics as ever smoking, past 30-day smoking and smoking on ≥20 days in the past month. In addition, respondents were classified as never smokers, experimental smokers (smoked <100 cigarettes lifetime), current smokers (smoked >100 cigarettes lifetime and smoked in past 30 days) or former smokers (smoked >100 cigarettes lifetime but did not smoke in past 30 days).

Patterns of e-cigarette use

Respondents were asked if they had 'ever tried an e-cigarette/vaped', the number of days they had used an e-cigarette/vaped in their lifetime and the last time they used an e-cigarette/vape. Past 30-day vapers were also asked on how many of the past 30 days they had vaped (continuous; analysed as ≤4 days, 5–19 days, ≥20 days or not stated) and how many times they had vaped each day (one time per day; 2–5 times per day; 6–10 times per day; 11–20 times per day; or more than 20 times per day). Vaping status is reported as ever vaping, past 30-day vaping and vaping on ≥20 days in the past month.

Nicotine content of e-cigarette products

In 2019, past 30-day vapers were asked four questions about nicotine content: (1) presence of nicotine ('Do the e-cigarettes, cartridges, pods, or e-liquids you currently use contain nicotine?': yes; no; some have nicotine, some do not; I don't know if they contain nicotine or not; refused); (2) awareness of nicotine salts ('Have you ever heard of e-cigarettes, cartridges, pods, or e-liquids that use nicotine salts?': yes; no; don't know; refused); (3) use of nicotine salts ('Do the e-cigarettes, cartridges, pods, or e-liquids you currently use contain nicotine salts?': yes; no; I don't know if they contain nicotine salt or not; refused); and (4) nicotine concentration ('How much nicotine do the e-cigarettes, cartridges, pods, or e-liquids you currently use contain? You can choose to report the % or mg/mL', see Results section for options). These measures were not assessed in 2017 and 2018 and are therefore only reported for 2019.

For the purpose of multivariate analyses, self-reported nicotine concentration was categorised into three groups: (1) no nicotine/don't know, (2) nicotine <2%/20 mg/mL or 3) nicotine ≥2%/20 mg/mL. Sensitivity analyses were conducted with two alternate approaches to representing nicotine and brand type. First, we examined self-reported use of nicotine and nicotine

salts: (1) no nicotine (those who had never used e-cigarettes with nicotine, or who reported that the e-cigarettes they currently used did not contain nicotine or they did not know if they contained nicotine); (2) nicotine but not nicotine salts (at least some of the e-cigarettes they currently used contained nicotine, but they had never heard of nicotine salts, or their current e-cigarettes did not contain nicotine salts or they did not know if they contained nicotine salts); or (3) nicotine salts (at least some of the e-cigarettes they currently used contained nicotine and contained nicotine salts). Second, responses for usual brand and use of nicotine salts were combined to classify vapers into three groups: (1) JUUL users (those who reported JUUL as their usual brand); (2) 'other' nicotine salt users (those who reported currently using nicotine salts and selected a usual brand other than JUUL); or (3) non-salt users (those who reported they did not currently use nicotine salts and selected a brand other than JUUL). JUUL was included because of its popularity in all three countries and because all pods use salt-based e-liquids.

Type of e-cigarette/vaping device

Ever-vapers were asked to indicate the type(s) of e-cigarettes/vaping devices they had ever tried, using either a precoded checklist (in 2017) or yes/no items with corresponding product images (in 2018 and 2019) for the following: disposable ('Disposable (not refillable or rechargeable) e-cigarette/vaping device'); pod/cartridge ('E-cigarette/vaping device with replaceable pre-filled cartridges (or pods)'); and tanks ('E-cigarette/vaping device with a tank that you fill with liquid'). Past 30-day e-cigarette users who had used more than one type were asked which type they used 'most often' and were allowed to select multiple options in 2017 and 2019.

Brand of e-cigarette/vaping device

Past 30-day vapers reported the specific brand of e-cigarette/vaping device they 'currently use most often', using country-specific precoded brand lists; respondents could also select 'Other' and enter the brand name, or select 'I don't have a usual brand', 'Don't know' or 'Refused'.

Reasons for using brand

In 2019, past 30-day vapers with a usual brand were asked, 'What are the main reasons you chose to use this brand of e-cigarettes instead of other brands?' and could select all that applied from a precoded checklist (see options in Results section), presented in random order, as well as 'Other', 'Don't know' or 'Refused'.

Perceived addiction

Past 30-day e-cigarette users reported whether they considered themselves addicted ('Do you consider yourself addicted to 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' vs 'Not at all', excluding 'Don't know' and 'Refused'.

Urges

Past 30-day e-cigarette users were asked how often they experienced strong urges to use an e-cigarette: ('In the past 30 days, how often did you have a strong urge to 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). A binary variable was created for modelling that combined 'Several times a day' and 'Every day or most days' versus less often, excluding 'Don't know' and 'Refused'.

Analysis

Poststratification sample weights were calculated for each country, based on age, sex, geographic 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 and 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. Participants who were not classified for sex or smoking status variables (n=24) were excluded from the analytic sample. Participants were also excluded if they failed a data integrity check, in which they were asked to select the current month from a list.

Adjusted ORs (AORs) and 95% CIs are reported, from logistic regression models used to estimate the differences between countries or between groups within countries, adjusting for age (grouped as 16–17 or 18–19 years), sex and race/ethnicity ('white' vs other). All analyses were weighted and conducted in SAS V.9.4 using survey procedures for all testing.

RESULTS

Sample

Table 1 presents the characteristics of respondents in each country by survey year.

Types of e-cigarette devices

Online supplemental table 1 shows the types of e-cigarette devices used most often among past 30-day vapers. In 2019, past 30-day vapers in the USA most commonly used cartridge/pod devices (58.0%), followed by tanks (41.4%) and disposables (12.9%). A similar pattern was observed in Canada: tanks (52.3%) and cartridges (47.6%), followed by disposables (6.5%). Between 2017 and 2019, the use of cartridge/pod devices increased significantly in the USA (AOR=2.66, 95% CI 2.01 to 3.50, p<0.0001) and Canada (AOR=5.19, 95% CI 3.53 to 7.63, p<0.0001), tanks decreased in the USA (AOR=0.60, 95% CI 0.46 to 0.79, p=0.0002) and Canada (AOR=0.53, 95% CI 0.39 to 0.72, p<0.0001), with no changes in disposable products in either country (AOR=0.90, 95% CI 0.60 to 1.34, p=0.60; and, AOR=0.66, 95% CI 0.39 to 1.12, p=0.12, respectively).

In England, refillable tanks (69.1%) were most common in 2019, while cartridge/pod devices were less common (27.7%), followed by disposables (12.1%). No changes over time were observed in the prevalence of cartridge/pod devices (AOR=1.01, 95% CI 0.72 to 1.42, p=0.97) or disposables (AOR=1.51, 95% CI 0.91 to 2.50, p=0.11), while use of refillable tanks increased in England (AOR=1.60, 95% CI 1.16 to 2.21, p=0.004).

Brands used among past 30-day vapers

Table 2 shows the top five vaping brands among past 30-day vapers in each country. In 2019, JUUL was the most popular brand in the USA (44.1%) and was the second leading brand in Canada (22.8%) and England (13.9%). Smok was the leading brand in Canada (23.7%) and England (17.9%), and the second leading brand in the USA (14.8%). The proportion of vapers who did not have a usual brand or 'did not know' decreased between 2017 and 2019 in all countries (p<0.05 for all) and was greater in England (27.5%) than the USA (10.1%) and Canada (18.8%) in 2019.

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)

*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.
‡Note that weighting procedures calibrated the past 30-day smoking trend to the trend over time from the National Youth Tobacco Survey in the USA and the Canadian Student Tobacco, Alcohol and Drugs Survey in Canada.

Nicotine content of vaping products

Table 3 shows the characteristics of current vaping products reported by past 30-day vapers in 2019. A majority in all countries reported that at least some of the products they currently used contained nicotine, although to a lesser extent in England (51.9%) compared with Canada (71.2%; AOR=2.53, 95% CI 1.94 to 3.31, p<0.0001) and the USA (68.6%; AOR=2.04, 95% CI 1.55 to 2.69, p<0.0001). The percentage of past 30-day vapers who reported using products with at least 2% or 20 mg/mL was greater in Canada (40.5%; AOR=4.96, 95% CI 3.51 to 7.01, p<0.0001) and the USA (37.0%; AOR=3.99, 95% CI 2.79 to 5.71, p<0.0001) compared with England (12.8%). The percentage of past 30-day vapers who reported currently using nicotine salt products was also higher in Canada (27.1%; AOR=2.77, 95% CI 1.93 to 3.99, p<0.0001) and the USA (21.9%; AOR=2.00, 95% CI 1.36 to 2.95, p=0.0004) compared with England (12.3%). Among vapers who reported currently using a nicotine salt product other than JUUL, 51.6% reported having used JUUL in the past 12 months, compared with 30.4% of vapers who reported neither current use of JUUL nor nicotine salts.

Additional analyses were conducted to examine self-reported presence of nicotine and nicotine salts among past 30-day vapers who reported JUUL as the brand they currently used most often. At the time of the survey, all versions of JUUL contained nicotine salt-based e-liquids. Among the 554 past 30-day vapers across all countries who reported JUUL as their usual brand in 2019, 61.8% (n=342) reported that the e-cigarettes they currently used contained nicotine, while 9.9% (n=55) said 'some' contained nicotine. More than half of JUUL users (53.5%; n=296) reported they had not heard of nicotine salts. Only 17.9% of JUUL users (n=99) reported that the e-cigarettes they currently used contained nicotine salts. When asked about the nicotine content of the e-cigarettes they currently used, 21.6% of JUUL users (n=120) reported 5%/40 mg/mL or more, 15.6% (n=86) reported 2%–4.9%/20–39 mg/mL, 18.5% (n=102) reported less than 2%/20 mg/mL, while 15.4% (n=85) did not know.

Reasons for choosing brands

Table 4 shows reasons cited by past 30-day vapers for selecting their usual brand of e-cigarettes in 2019. The top three reasons for brand choice were the same in all three countries: 'more popular among friends', 'easier to use' and 'better flavour/taste'. 'Less harmful' and 'better for quitting smoking' were among the least popular reasons in all countries. Relatively few differences across countries were observed in reasons for choosing brands. Compared with England, 'easier to hide' was selected by more respondents in Canada (AOR=1.78, 95% CI 1.18 to 2.70, p=0.0065) and the USA (AOR=2.06, 95% CI 1.35 to 3.15, p=0.0008), as was 'stronger nicotine hit' in Canada (AOR=2.06, 95% CI 1.30 to 3.27, p=0.0021) and the USA (AOR=2.11, 95% CI 1.32 to 3.37, p=0.0018). Finally, respondents in Canada were less likely than those in the USA to select 'better flavour' (AOR=0.67, 95% CI 0.52 to 0.88, p=0.003).

Table 4 also shows reasons stratified by past 30-day vapers of JUUL, other 'non-JUUL' nicotine salt brands and 'other' past 30-day vapers. Across countries, current JUUL users were less likely than users of other brand nicotine salt products to report using their current brand because it was better looking, less expensive, smoother to inhale, gave a stronger nicotine 'hit' or 'other' reasons; they were also less likely than users of other brands/non-nicotine salt products to report it was less expensive or 'other' reasons. However, JUUL users were more likely than users of other brands/non-nicotine salt products to report their brand was more popular among friends, easier to hide, gave a stronger nicotine 'hit' or that it was offered to them. Users of nicotine salt products were more likely than users of other brands/non-nicotine salt products to report their brand was more popular among friends, easier to use, better looking, smoother to inhale, more fun, better for quitting smoking and gave a stronger nicotine 'hit'. Online supplemental table 2 shows reasons by product nicotine type within each country.

Table 2 Top five vaping brands among past 30-day vapers in each survey year, by country, weighted % (n)

	Canada			England			USA		
	2017 (n=340)	2018 (n=463)	2019 (n=738)	2017 (n=347)	2018 (n=351)	2019 (n=439)	2017 (n=454)	2018 (n=635)	2019 (n=736)
Usual brand[5]	Eleaf 7.9 (27)	Smok 21.0 (98)	Smok 23.7 (175)	Smok 10.1 (35)	Smok 14.2 (50)	Smok 17.9 (79)	blu 16.9 (77)	JUUL 29.3 (186)	JUUL 44.1 (325)
	Aspire 7.8 (26)	Aspire 12.5 (58)	JUUL 22.8 (168)	E-lites 9.2 (32)	blu 12.9 (45)	JUUL 13.9 (61)	JUUL 9.4 (43)	blu 12.4 (79)	Smok 14.8 (109)
	eGo 7.6 (26)	JUUL 10.1 (47)	Aspire 7.9 (58)	blu 7.8 (27)	E-lites 7.1 (25)	blu 13.6 (60)	Vuse 7.6 (34)	Smok 11.0 (70)	blu 6.3 (46)
	V2 6.2 (21)	blu 4.0 (18)	STLTH 6.4 (47)	Vype 6.9 (24)	Vype 6.8 (24)	88Vape 6.5 (29)	KangerTech 5.2 (24)	Vuse 5.6 (36)	NJOY 5.2 (38)
	Smok 5.9 (20)	Eleaf 3.4 (16)	Vype 4.3 (32)	VIP 4.0 (14)	88Vape 4.4 (16)	Vype 5.1 (22)	Smok 4.9 (22)	Aspire 4.4 (28)	Suorin 4.6 (34)
No usual brand	20.9 (71)	18.9 (88)	11.8 (87)	23.5 (82)	17.8 (62)	18.3 (81)	15.2 (69)	10.0 (64)	7.6 (56)
Don't know	20.8 (71)	12.8 (59)	7.0 (52)	18.0 (62)	8.8 (31)	9.1 (40)	13.6 (62)	6.0 (38)	2.4 (18)

Column percentages do not add to 100, as only the five most popular brands are reported. Denominators include refusals (n_{2017}=9;n_{2018}=4; n_{2019}=3).

Table 3 Self-reported characteristics of product currently used by past 30-day vapers, 2019, by country

Current product characteristics	Canada (n=738)	England (n=439)	USA (n=736)
	% (n)	% (n)	% (n)
Contains nicotine			
Yes	59.2 (437)	40.4 (177)	60.3 (444)
No	7.3 (54)	11.4 (50)	7.6 (56)
Some have nicotine, some do not	11.3 (83)	11.2 (49)	8.2 (60)
I don't know if they contain nicotine or not	2.0 (15)	2.2 (10)	2.8 (20)
Refused	0.9 (7)*	0.6 (3)*	0.3 (2)*
N/A†	19.3 (143)	34.1 (150)	20.9 (154)
Contains nicotine salts			
Yes	27.1 (200)	12.3 (54)	21.9 (161)
No	14.4 (106)	6.7 (29)	11.1 (82)
I don't know if they contain nicotine salt or not	4.8 (36)	2.8 (12)	4.1 (30)
Refused	0	0	0
N/A‡	53.6 (396)	78.3 (344)	62.9 (463)
Nicotine concentration			
None	30.0 (221)	49.3 (216)	31.8 (234)
Less than 2%/20 mg/mL	18.8. (139)	27.9 (122)	18.7 (138)
2%–4.9%/20–39 mg/mL	17.5 (129)	9.3 (41)	15.0 (111)
5%/40 mg/mL or more	22.5 (166)	3.4 (15)	21.8 (160)
Don't know	11.1 (82)	10.1 (44)	12.6 (93)
Refused	0.1 (1)*	0	0

*High variability (coefficient of variation is >33.3 or the numerator is <10), interpret with caution.
†Not asked questionnaire item; previous response indicated never used nicotine.
‡Not asked questionnaire item; previous response indicated not currently using nicotine (n_{CA}=70, n_{EN}=43, n_{US}=57), never heard of nicotine salts (n_{CA}=287, n_{EN}=257, n_{US}=352), or responded 'don't know' or 'refused' to awareness of nicotine salts (n_{CA}=38, n_{EN}=44, n_{US}=54).

Sociodemographic predictors by product nicotine concentration

Table 5 shows measures of association between self-reported product nicotine concentration and sociodemographic variables. Use of nicotine-containing products (<2%/2 mg/mL or 2%/2 mg/mL nicotine or more, vs no nicotine) was associated with being male, age 18/19 years and non-white race/ethnicity, but did not have a significant association with student status, school grades or family financial situation.

Patterns of vaping and dependence symptoms by product nicotine concentration

Table 6 shows patterns of vaping and dependence symptoms among past 30-day vapers, based on self-reported nicotine concentration. Past 30-day vapers reporting higher nicotine concentrations reported more intensive vaping behaviour, including the number of days vaped in the past 30 days, the number of times vaping in an average day of use, the number of days ever vaped, experiencing frequent strong urges to vape and feeling 'a little' or 'very addicted' to vaping. In addition, past 30-day vapers reporting nicotine <2%/20 mg/mL were most likely to be current smokers, whereas than those vaping no nicotine were least likely to be current smokers.

The same outcomes are shown by self-reported presence of nicotine salts in online supplemental table 3 and by use of JUUL versus other nicotine salt brands in online supplemental table 4.

Table 4 Reasons for using current brand instead of other e-cigarette/vaping brands, among past 30-day vapers who selected a usual brand, 2019, by country and by usual brand

	Canada (n=599)	England (n=317)	USA (n=661)	All countries					
				JUUL (n=554)	Nicotine salt† (n=302)	Other‡ (n=722)	JUUL vs nicotine salt	JUUL vs other	Nicotine salt vs other
Reason*	% (n)	% (n)	% (n)	% (n)	% (n)	% (n)	AOR (95% CI); p value§	AOR (95% CI); p value§	AOR (95% CI); p value§
More popular among friends	31.6 (189)	23.9 (76)	27.0 (179)	34.5 (191)	29.8 (90)	22.6 (163)	1.34 (0.96 to 1.87); p=0.09	**1.96 (1.48 to 2.60)**; p<0.0001	**1.47 (1.05 to 2.04)**; p=0.02
Easier to use	27.1 (163)	26.4 (84)	30.7 (203)	30.3 (168)	35.5 (107)	24.1 (174)	0.88 (0.62 to 1.25); p=0.48	1.28 (0.95 to 1.73); p=0.10	**1.45 (1.04 to 2.04)**; p=0.03
Better flavour/taste	26.3 (158)	30.8 (98)	34.2 (226)	32.8 (182)	34.6 (105)	27.0 (195)	1.01 (0.72 to 1.41); p=0.97	1.26 (0.94 to 1.69); p=0.13	1.25 (0.90 to 1.73); p=0.18
Better looking	24.3 (146)	22.7 (72)	18.0 (119)	19.0 (105)	29.4 (89)	19.8 (143)	**0.67 (0.46 to 0.98)**; p=0.04	1.04 (0.74 to 1.45); p=0.83	**1.55 (1.08 to 2.21)**; p=0.02
I was offered it	23.8 (143)	20.9 (66)	23.7 (157)	27.9 (154)	17.5 (53)	21.9 (158)	1.52 (0.99 to 2.33); p=0.05	**1.48 (1.10 to 1.99)**; p=0.01	0.97 (0.65 to 1.45); p=0.89
Smoother to inhale	22.9 (137)	21.8 (69)	25.5 (168)	20.5 (113)	35.2 (106)	21.5 (155)	**0.53 (0.37 to 0.76)**; p=0.0006	0.88 (0.64 to 1.20); p=0.41	**1.65 (1.17 to 2.31)**; p=0.004
Less expensive	21.9 (131)	20.7 (66)	19.7 (130)	11.0 (61)	30.5 (92)	24.2 (174)	**0.32 (0.21 to 0.48)**; p<0.0001	**0.36 (0.25 to 0.51)**; p<0.0001	1.12 (0.80 to 1.56); p=0.51
Easier to hide	20.3 (121)	12.2 (39)	22.8 (150)	24.7 (137)	22.5 (68)	14.7 (106)	1.32 (0.88 to 1.95); p=0.16	**1.79 (1.29 to 2.50)**; p=0.0006	1.35 (0.92 to 1.98); p=0.12
Easier to get	19.5 (117)	20.7 (66)	20.1 (133)	20.3 (112)	19.9 (60)	19.9 (144)	1.09 (0.73 to 1.63); p=0.69	1.05 (0.76 to 1.44); p=0.77	0.96 (0.76 to 1.44); p=0.85
Stronger nicotine 'hit'	17.3 (103)	9.3 (29)	17.9 (119)	15.7 (87)	34.5 (104)	8.3 (60)	**0.44 (0.29 to 0.66)**; p<0.0001	**1.84 (1.24 to 2.73)**; p=0.002	**4.22 (2.81 to 6.34)**; p<0.0001
More fun	16.5 (99)	16.5 (52)	16.8 (111)	17.7 (98)	19.9 (60)	14.4 (104)	0.87 (0.58 to 1.29); p=0.48	1.32 (0.94 to 1.86); p=0.11	**1.53 (1.03 to 2.29)**; p=0.04
Less harmful	11.3 (67)	15.7 (50)	11.6 (76)	13.5 (75)	12.0 (36)	11.5 (83)	1.24 (0.75 to 2.05); p=0.40	1.30 (0.88 to 1.92); p=0.19	1.04 (0.65 to 1.68); p=0.86
Better for quitting smoking	10.4 (62)	13.3 (42)	8.7 (58)	10.4 (57)	14.6 (44)	8.4 (61)	0.84 (0.52 to 1.33); p=0.45	1.41 (0.93 to 2.15); p=0.11	**1.69 (1.07 to 2.66)**; p=0.02
Other reason(s)	2.3 (14)	1.8 (6)¶	2.5 (17)	0.7 (4)¶	3.7 (11)¶	2.9 (21)	**0.19 (0.05 to 0.78)**; p=0.02	**0.18 (0.05 to 0.60)**; p=0.005	0.94 (0.37 to 2.34); p=0.89

*Percentages do not add to 100, as respondents could choose multiple responses (mean=2.7).
†Specified they currently used nicotine salts but selected a brand other than JUUL.
‡Specified they did not currently use nicotine salts and selected a brand other than JUUL.
§From separate regression models for each reason, which included country, age group, sex, race/ethnicity, frequency of use in the past 30 days (≤4 days, 5–19 days, ≥20 days and not stated) and brand type (ie, the three categories shown).
¶High variability (coefficient of variation is >33.3 or the numerator is <10), interpret with caution.

Table 5 Sociodemographic characteristics of past 30-day vapers, by nicotine concentration, 2019

Characteristic	Currently not using nicotine* (n=876) % (n)	Currently using <2%/2 mg/mL nicotine† (n=398) % (n)	Currently using 2%/ 2 mg/mL nicotine or more‡ (n=622) % (n)	<2%/2 mg/mL nicotine vs no nicotine AOR (95% CI)§	2%/2 mg/mL nicotine or more vs no nicotine AOR (95% CI)§	2%/2 mg/mL nicotine or more vs <2%/2 mg/mL nicotine AOR (95% CI)§
Sex						
Male	47.3 (414)	57.6 (230)	51.2 (319)	Ref	Ref	Ref
Female	52.7 (462)	42.4 (169)	48.8 (303)	**0.66 (0.5 to 0.87)**	0.85 (0.66 to 1.09)	1.29 (0.96 to 1.72)
Age group (years)						
16/17	47.4 (415)	39.3 (157)	38.4 (239)	Ref	Ref	Ref
18/19	52.6 (461)	60.7 (242)	61.6 (384)	**1.48 (1.11 to 1.97)**	**1.48 (1.14 to 1.92)**	1.00 (0.74 to 1.36)
Race/ethnicity						
White (only)	67.7 (593)	75.9 (302)	75.4 (469)	Ref	Ref	Ref
Other (including mixed, don't know, refused)	32.3 (283)	24.1 (96)	24.6 (153)	**0.71 (0.53 to 0.96)**	**0.62 (0.48 to 0.81)**	0.87 (0.64 to 1.20)
Student status						
Current student	88.5 (776)	87.9 (350)	87.7 (546)	1.36 (0.94 to 1.96)	1.10 (0.78 to 1.55)	0.81 (.55 to 1.19)
Not current student	11.5 (100)	12.1 (48)	12.3 (76)	Ref	Ref	Ref
High school grades						
Below 70%, don't know, refused	16.1 (141)	17.1 (68)	11.2 (70)	Ref	Ref	Ref
70%–79% (mostly Cs)	22.4 (196)	25.6 (102)	21.3 (133)	1.22 (0.82 to 1.81)	1.13 (0.79 to 1.61)	0.93 (0.61 to 1.39)
80%–89% (mostly Bs)	36.5 (319)	37.2 (148)	42.0 (261)	1.20 (0.80 to 1.80)	1.24 (0.86 to 1.79)	1.03 (0.67 to 1.59)
90%–100% (mostly As)	25.1 (220)	20.1 (80)	25.5 (159)	1.04 (0.64 to 1.69)	1.04 (0.68 to 1.62)	1.00 (0.60 to 1.68)
Family financial situation						
Not meeting basic expenses	7.5 (65)	8.4 (34)	6.8 (42)	Ref	Ref	Ref
Just meeting basic expenses	29.5 (258)	29.8 (119)	21.5 (134)	1.00 (0.58 to 1.75)	0.92 (0.55 to 1.52)	0.91 (0.50 to 1.66)
Meeting needs with a little left over	29.3 (257)	33.8 (135)	36.6 (228)	1.11 (0.63 to 1.95)	1.56 (0.94 to 2.57)	1.40 (0.77 to 2.54)
Living comfortably	30.0 (263)	26.0 (103)	32.7 (203)	0.81 (0.45 to 1.44)	1.45 (0.87 to 2.42)	1.79 (0.97 to 3.32)
Don't know, refused	3.8 (33)	2.0 (8)¶	2.4 (15)	0.64 (0.25 to 1.64)	1.03 (0.43 to 2.45)	1.61 (0.58 to 4.47)

Note: weighted n's are rounded (counts may not total).
*Specified they did not currently use nicotine.
†Specified they currently used nicotine, concentration less than 2% or 2 mg/mL.
‡Specified they currently used nicotine, concentration of 2% or 2 mg/mL or more.
§From a multinomial regression model using nicotine concentration (none, less than 2% or 2 mg/mL, 2% or 2 mg/mL or more) as the outcome and including country, age group, sex, race/ethnicity (white only vs not), student status, high school grades, family financial situation and smoking status; respondents missing smoking status (n=7) were excluded from the model.
¶High variability (coefficient of variation is >33.3 or the numerator is <10), interpret with caution.

DISCUSSION

The current study depicts a considerable shift in the types of e-cigarettes used among youth, as well as differences between countries in the extent of this shift between 2017 and 2019. First, the data show increased use of e-cigarettes that use cartridges/pods, particularly among youth vapers in Canada and the USA. In 2017, refillable tanks were reported as usual devices by the majority of past 30-day vapers; by 2019, cartridge/pod devices were comparably or more popular among youth vapers in Canada and the USA, whereas refillable tanks remained the most popular in England.

The shift towards pod-based e-cigarettes in the USA and Canada was largely driven by JUUL and reflects the increase in JUUL's market share between 2017 and 2019. By 2019, almost half of past 30-day vapers in the USA reported JUUL as their usual brand. JUUL also increased in popularity among youth vapers in Canada and England following its introduction in 2018, although to a lesser extent than in the USA. In both Canada and England, the most popular brand was Smok, which offers a wide range of devices, including pod/cartridge and tank systems. Other leading brands, such as STLTH in Canada, closely resemble JUUL and are marketed as lower prices.

Youth vapers in all three countries reported similar reasons for choosing their specific brand: 'more popular among friends', 'easier to use' and 'better flavour/taste', consistent with previous studies.[35] Reasons associated with harm reduction relative to smoking, including 'less harmful' and 'better for quitting smoking', were among the least popular reasons for preferring their usual brand over other brands, in all countries. Few differences were observed across countries, although past 30-day vapers in the USA and Canada were more likely to report 'nicotine hit' as a reason for choosing their brand relative to youth in England. An examination of reasons by 'usual brand' found that 'nicotine hit' was more likely to be cited by JUUL users—and especially by users of other non-JUUL HNSB products—as a reason for choosing their brand. Indeed, 'nicotine hit' and 'smoother to inhale' were among the top reasons for choosing non-JUUL HNSB brands. The lesser role of 'nicotine hit' as a reason for selecting vaping brands among youth in England may reflect the nicotine limit of 20 mg/mL and the lower nicotine concentrations of most brands relative to the markets in Canada and the USA. 'Lower price' was also much more likely to be cited by users of non-JUUL HNSB products relative to JUUL and other brands, which is consistent with the premium price of JUUL within the pod-based segment of products in all

Table 6 Patterns of use among past 30-day vapers, by nicotine concentration, 2019

	Currently not using nicotine* (n=876)	Currently using <2%/2 mg/mL nicotine† (n=398)	Currently using 2%/2 mg/mL nicotine or more‡ (n=622)	<2%/2 mg/mL nicotine versus no nicotine	2%/2 mg/mL nicotine or more versus no nicotine	2%/2 mg/mL nicotine or more versus <2%/2 mg/mL nicotine
	% (n)	% (n)	% (n)	AOR (95% CI), p value§	AOR (95% CI), p value§	AOR (95% CI), p value§
Smoking status¶						
Current smoker	10.8 (95)	25.6 (102)	14.4 (89)	**2.74 (2.02 to 3.73)** p<0.0001	**1.61 (1.19 to 2.19)** p=0.002	**0.59 (0.43 to 0.81)** p=0.001
Experimental smoker	55.3 (482)	54.6 (217)	59.6 (370)			
Former smoker	1.9 (17)	7.6 (30)	6.2 (39)			
Never smoker	31.9 (278)	12.2 (48)	19.8 (123)			
Days ever vaped**						
100 days or more	15.4 (135)	38.8 (155)	58.3 (363)	**3.27 (2.39 to 4.46)** p<0.0001	**6.84 (5.19 to 9.01)** p<0.0001	**2.09 (1.56 to 2.80)** p<0.0001
51–99 days	7.7 (67)	11.5 (46)	10.1 (63)			
21–50 days	14.7 (129)	15.1 (60)	12.8 (80)			
11–20 days	14.1 (123)	11.5 (46)	7.3 (45)			
2–10 days	30.4 (266)	15.4 (61)	6.7 (41)			
One day	13.2 (115)	4.9 (20)	2.0 (13)			
Don't know	4.6 (40)	2.8 (11)††	2.8 (18)			
Mean days vaped in past 30 days‡‡ (SD)	7.6 (8.4)	15.7 (10.5)	19.7 (9.8)	**B=7.90 (6.38 to 9.41) p**<0.0001	**B=11.59 (10.31 to 12.87)** p<0.0001	**B=3.69 (2.05 to 5.34)** p<0.0001
Times vaped/day in past 30 days§§						
More than 20 times per day	4.8 (42)	16.0 (64)	30.6 (190)	**3.70 (2.44 to 5.60)** p<0.0001	**7.98 (5.56 to 11.45)** p<0.0001	**2.16 (1.56 to 2.99)** p<0.0001
11–20 times per day	5.7 (50)	10.3 (41)	11.6 (72)			
6–10 times per day	12.3 (107)	18.5 (74)	19.0 (118)			
2–5 times per day	39.4 (343)	35.4 (141)	25.0 (155)			
1 time per day	32.6 (284)	17.6 (70)	11.1 (69)			
Don't know	5.2 (45)	2.2 (9)††	2.7 (17)			
Urges to vape¶¶						
Several times a day	8.1 (70)	19.0 (76)	31.0 (192)	**3.56 (2.66 to 4.76)** p<0.0001	**4.89 (3.73 to 6.41)** p<0.0001	**1.37 (1.03 to 1.84)** p=0.03
Every day or most days	12.5 (109)	29.5 (118)	24.8 (154)			
At least once a week	16.9 (147)	22.7 (90)	21.0 (130)			
Less than once a week	16.2 (141)	10.1 (40)	7.5 (46)			
Never	43.0 (374)	16.4 (65)	14.1 (87)			
Don't know	3.4 (30)	2.3 (9)††	1.5 (10)			
Perceived addiction***						
Yes, very addicted	5.1 (45)	12.4 (49)	21.2 (132)	**3.15 (2.41 to 4.13)** p<0.0001	**4.61 (3.56 to 5.97)** p<0.0001	**1.46 (1.09 to 1.96)** p=0.01
Yes, a little addicted	24.1 (210)	44.0 (175)	45.1 (280)			
Not at all	67.3 (588)	40.0 (159)	32.1 (199)			
Don't know	3.4 (30)	3.6 (14)	1.6 (10)			

*Specified they did not currently use nicotine.
†Specified they currently used nicotine, concentration less than 2% or 2 mg/mL.
‡Specified they currently used nicotine, concentration of 2% or 2 mg/mL or more.
§From separate logistic regression models for each use outcome (linear regression model for mean days), adjusted for country, age group, sex, and race/ethnicity (white only vs not); outcomes analysed as heavy use category versus else.
¶Analysed as current smoker versus else; respondents missing smoking status (n=7) excluded from model.
**Analysed as '100 days or more' versus else, refusals (n=1) and don't know responses excluded.
††High variability (coefficient of variation is >33.3 or the numerator is <10), interpret with caution.
‡‡Analysed as a continuous outcome variable, refusals (n=9) and don't know responses (n=299) excluded.
§§Analysed as 'More than 20 times per day' vs else, refusals (n=6) and don't know responses excluded.
¶¶Analysed as 'Several times a day'/'Every day or most days' versus else, refusals (n=9) and don't know responses excluded.
***Analysed as 'Yes, very addicted'/'Yes, a little addicted' versus 'Not at all', refusals (n=8) and don't know responses excluded.

three countries. Given that a majority of HNSB product users had previously used JUUL within the past year, the data suggest that many users may be transitioning from JUUL to other lower-priced products for these reasons. To our knowledge, the current study is among the first to characterise users of nicotine salt-based products distinct from JUUL.

The current study also depicts a marked shift towards the use of higher nicotine concentration products among youth in the USA and Canada. Approximately half of past 30-day youth vapers in the USA and Canada reported using nicotine concentrations at or above 2% or 20 mg/mL—approximately twice the proportion as England. Similar differences between countries were observed for self-reported use of salt-based e-liquids. The similar pattern of results for higher nicotine and salt-based products is unsurprising: although salt-based e-liquids can include the same range of nicotine concentration as free-base liquids, they are predominantly offered at higher nicotine levels. The lower nicotine concentration reported by youth vapers in England is consistent with the EU Tobacco Product Directive maximum nicotine limit on e-cigarette products of 2% or 20 mg/mL, which requires brands such as JUUL to be offered at substantially lower nicotine concentrations than the most popular varieties in North America.[29 30] It remains unclear whether the lower popularity of JUUL among youth vapers in England is attributable to lower nicotine concentrations, greater marketing restrictions or other market factors in England.

The self-reported nature of the nicotine content of products represents an important limitation of these findings. Consistent with other studies, substantial proportions of youth vapers reported not knowing the nicotine level of their product, while many report using 'non nicotine' products, despite the scarcity of these products among popular brands.[23–25] For example, more than half of past 30-day vapers who reported JUUL as their usual brand reported they had not heard of nicotine salts, and less than one-fifth reported that their usual brand contained nicotine salts. This may reflect infrequent use, as well as inconsistent labelling on packages, in which nicotine content is labelled using inconsistent formats (either as percentages or mg/ml) and often in obscure ways, such as small print. This is particularly true for the use of 'salt-based' e-liquid, which is not labelled on all salt-based products, including JUUL. Therefore, the proportion of youth vapers using nicotine salt products is likely underestimated in the current study. Given the importance of assessing product attributes in population-based surveys of vaping, future research should examine the reliability of self-reported product attributes to a greater extent. Nevertheless, the trends over time and between countries are consistent with the market trends in terms of sales data on nicotine levels and the increase in salt-based products.[2 20 26 27]

The most notable study finding is the association between the use of HNSB products and more intensive vaping and greater symptoms of dependence. The magnitude of differences in patterns of use were marked. For example, past 30-day vapers reporting salt-based products had a substantially greater history of vaping: 60% had vaped more than 100 days in their lifetime, compared with 40% for non-salt nicotine users, and 11% among non-nicotine users. In addition, salt-based users reported vaping an average of 21 days per month, compared with 15 for non-salt nicotine users and six for non-nicotine users, with equally large differences in the percentage who reported vaping more than 20 times per day (16%, 15% and 3%, respectively). Among salt users, two-thirds reported strong urges to vape 'several times a day' or 'every day/most days', while three-quarters reported they were 'a little' or 'very addicted' to vaping. The pattern of results was highly consistent regardless of whether products were analysed based on nicotine salts or nicotine level (no nicotine, less than 2% or 2% or more). The magnitudes of difference were somewhat greater for nicotine salts, perhaps because awareness of salts is lower than nicotine content, and vapers who are aware they are vaping salt-based products represent a more selective, frequent group of vapers. The current findings are consistent with previous studies reporting more frequent use and greater symptoms of dependence among JUUL and other 'pod' users, as well as greater nicotine reinforcement among adult smokers.[3 11–13 36]

Youth vapers who reported using high-nicotine products were no more likely to report current or former smoking; in fact, past 30-day vapers who reported using <2% nicotine products were more likely to be a current smoker than those who used products with >2% nicotine. Therefore, the more intensive patterns and greater symptoms of dependence among HNSB product users is not simply attributable to a greater proportion of dual users or smoking history.

The current study provides additional support for the hypothesis that JUUL has attracted users from higher sociodemographic groups, consistent with previous findings.[13 16 19 20] JUUL users—but not vapers of other HNSB products—were more likely to report higher academic achievement and more comfortable financial backgrounds compared with other vapers. This may be attributable to the broad general appeal of JUUL or the higher price point relative to most other e-cigarette brands. Finally, users of JUUL and other HNSB products were also more likely to be male and older, as noted in other studies.[13 16 20]

Limitations

The current study is subject to limitations common to survey research, including response bias. 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, and poststratification weights were used to weight the sample on population estimates of sex, age, region and race (USA only), as well as past 30-day smoking rates from national benchmark surveys in Canada and the USA.[32] As noted above, recall of product data, including brand and nicotine profile, is subject to recall bias: some degree of misclassification would be expected, particularly among infrequent vapers who may be less familiar with specific brands. To promote more accurate reporting, the study used precoded checklists with options to include other brands, as well as 'I don't have a usual brand' and 'Don't know' options. In addition, a recent paper found self-reported nicotine concentration to be associated with presence of nicotine salt.[37] Finally, product data were collected for the 'usual brand' currently used by past 30-day vapers. However, many vapers use multiple brands and patterns of use may reflect a combination of products or history with other brands.

CONCLUSIONS

The youth e-cigarette market has undergone considerable change between 2017 and 2019, characterised by a shift towards HNSB products. These products are associated with more frequent use and greater symptoms of dependence. The greater popularity of HNSB products in Canada and the USA provide one possible reason for increased prevalence of vaping and symptoms of vaping dependence in these countries compared with England, where e-cigarettes containing more than 20 mg/mL are prohibited.[38] Several Canadian provinces are adopting similar nicotine limits, which will provide an opportunity to examine the impact of these HNSB product restrictions on youth vaping, as well as the potential impact on the use of e-cigarettes as smoking cessation aids among adult smokers.

Although the transition to HNSB products is largely attributable to the emergence of JUUL, the current findings highlight the importance of other HNSB brands, which were associated with equal or even greater symptoms of dependence compared

with JUUL. Given the number of major brands now offering HNSB products, it remains to be seen whether JUUL's market share will continue to increase in Canada and England, or whether it will plateau short of the peak in the USA. The uptake of HNSB products other than JUUL is particularly important in the USA given recent declines in JUUL's market share.[39] The broader market shift towards HNSB products—which are now available in a wide range of brands and device styles—may also limit the potential impact of regulatory actions that are selectively focused on subcategories of products, such as the flavour ban in the USA that applies only to pod-style devices.[40]

What this paper adds

- The e-cigarette market has rapidly evolved, with a shift towards higher nicotine concentration and salt-based products, such as JUUL; however, the implications for youth vaping remain unclear.
- The current study examined the types of e-cigarettes used and nicotine content of products, by patterns of use, sociodemographics and dependence symptoms, and differences between countries and over time, among youth in Canada, England and the USA, between 2017 and 2019, finding that use of pod-style e-cigarettes, high-nicotine, and salt-based products was greater in Canada and the USA than in England.
- Self-reported use of products with higher nicotine concentration was associated with significantly greater frequency of vaping and symptoms of dependence (urges to vape and perceived vaping addiction), suggesting that greater use of high-nicotine salt-based products may account for recent increases in the frequency of vaping among youth in Canada and the USA.

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SUPPLEMENTAL TABLES

Table S1. Types of vaping devices used most often[1] among past 30-day vapers, weighted %(n)

	2017	**2018**	**2019**	**2019 vs. 2017**
	% (n)	% (n)	% (n)	AOR (95%CI), p value[2]
Canada	(n=340)	(n=463)	(n=738)	
Disposable	10.0% (34)	7.9% (36)	6.5% (48)	0.66 (0.39-1.12), p=0.12
Cartridge/pod	14.9% (51)	19.2% (88)	47.6% (351)	**5.19 (3.53-7.63), p<0.0001**
Refillable tank	66.2% (225)	71.9% (328)	52.3% (385)	**0.53 (0.39-0.72), p<0.0001**
Don't know/Refused	2.3% (8)*	1.0% (5)*	1.6% (12)	--
More than 1 product[3]	2.3% (8)*	N/A	8.8% (65)	--
England	(n=347)	(n=351)	(n=439)	
Disposable	8.5% (30)	11.4% (39)	12.1% (53)	1.51 (0.91-2.50), p=0.11
Cartridge/pod	27.8% (96)	18.4% (63)	27.7% (122)	1.01 (0.72-1.42), p=0.97
Refillable tank	58.5% (203)	68.5% (236)	69.1% (304)	**1.60 (1.16-2.21), p=0.004**
Don't know/Refused	1.8% (6)*	1.6% (6)*	1.7% (7)*	--
More than 1 product[3]	2.8% (10)*	N/A	9.3% (41)	--
US	(n=454)	(n=635)	(n=736)	
Disposable	14.4% (66)	12.8% (81)	12.9% (95)	0.90 (0.60-1.34), p=0.60
Cartridge/pod	34.5% (157)	42.9% (271)	58.0% (427)	**2.66 (2.01-3.50), p<0.0001**
Refillable tank	53.8% (244)	43.6% (275)	41.4% (305)	**0.60 (0.46-0.79), p=0.0002**
Don't know/Refused	0.9% (4)*	0.7% (4)*	1.0% (7)*	--
More than 1 product[3]	5.4% (25)	N/A	11.9% (87)	--

[1]Device type used "most often" inferred for respondents who only ever used one type (those who used more than one type were asked which they used most often).

[2]From separate logistic regression models for each device type, stratified by country, adjusted for age group, sex, and race/ethnicity (white only vs. not)

[3]Respondents could select more than one response in 2017 and 2019; row percentages within country may not add to 100. Each device type was analyzed separately, so those who selected more than one type are included in more than one group.

*High variability (coefficient of variation is > 33.3 or the numerator is <10), interpret with caution

Table S2: Reasons for using current brand instead of other e-cigarette/vaping brands, among past 30-day vapers who selected a usual brand, 2019, by country and usual brand, weighted %(n)

	Canada				England				US			
REASON[1]	**Total** (n=599)	**JUUL** (n=168)	**Nicotine salt[2]** (n=153)	**Other[3]** (n=280)	**Total** (n=317)	**JUUL** (n=61)	**Nicotine salt[2]** (n=43)	**Other[3]** (n=213)	**Total** (n=661)	**JUUL** (n=325)	**Nicotine salt[2]** (n=106)	**Other[3]** (n=230)
More popular among friends	**31.6% (189)**	34.5 (58)	40.1 (61)	25.1 (70)	**23.9% (76)**	29.5 (18)	25.0 (11)	22.1 (47)	**27.0% (179)**	35.2 (114)	17.0 (18)	20.0 (46)
Easier to use	**27.1% (163)**	23.2 (39)	34.0 (52)	25.8 (72)	**26.4% (84)**	34.4 (21)	43.2 (19)	20.7 (44)	**30.7% (203)**	33.2 (108)	34.6 (37)	25.3 (58)
Better flavor / taste	**26.3% (158)**	24.4 (41)	31.6 (48)	24.4 (68)	**30.8% (98)**	36.1 (22)	40.9 (18)	27.2 (58)	**34.2% (226)**	36.4 (118)	36.4 (39)	30.0 (69)
Better looking	**24.3% (146)**	19.0 (32)	28.9 (44)	25.1 (70)	**22.7% (72)**	34.4 (21)	34.9 (15)	17.0 (36)	**18.0% (119)**	16.3 (53)	28.0 (30)	15.7 (36)
I was offered it	**23.8% (143)**	30.4 (51)	13.2 (20)	25.7 (72)	**20.9% (66)**	36.1 (22)	18.2 (8)*	17.4 (37)	**23.7% (157)**	25.2 (82)	23.4 (25)	21.7 (50)
Smoother to inhale	**22.9% (137)**	19.2 (32)	27.0 (41)	22.6 (63)	**21.8% (69)**	19.7 (12)	43.2 (19)	18.3 (39)	**25.5% (168)**	21.3 (69)	43.4 (46)	23.0 (53)
Less expensive	**21.9% (131)**	11.3 (19)	32.2 (49)	22.6 (63)	**20.7% (66)**	6.6 (4)*	16.3 (7)*	25.4 (54)	**19.7% (130)**	11.7 (38)	33.6 (36)	24.8 (57)
Easier to hide	**20.3% (121)**	25.0 (42)	24.3 (37)	15.1 (42)	**12.2% (39)**	18.0 (11)	9.3 (4)*	11.3 (24)	**22.8% (150)**	25.8 (84)	24.5 (26)	17.5 (40)
Easier to get	**19.5% (117)**	25.6 (43)	19.1 (29)	16.1 (45)	**20.7% (66)**	13.1 (8)*	15.9 (7)*	23.9 (51)	**20.1% (133)**	18.8 (61)	23.4 (25)	20.5 (47)
Stronger nicotine 'hit'	**17.3% (103)**	16.1 (27)	35.9 (55)	7.9 (22)	**9.3% (29)**	11.5 (7)*	22.7 (10)	6.1 (13)	**17.9% (119)**	16.3 (53)	37.7 (40)	11.3 (26)
More fun	**16.5% (99)**	17.9 (30)	17.8 (27)	15.1 (42)	**16.5% (52)**	21.3 (13)	27.9 (12)	12.7 (27)	**16.8% (111)**	17.2 (56)	19.6 (21)	14.8 (34)
Less harmful	**11.3% (67)**	8.3 (14)	9.2 (14)	14.0 (39)	**15.7% (50)**	27.9 (17)	20.5 (9)*	11.7 (25)	**11.6% (76)**	13.6 (44)	12.3 (13)	8.3 (19)
Better for quitting smoking	**10.4% (62)**	10.1 (17)	13.1 (20)	9.3 (26)	**13.3% (42)**	14.8 (9)*	25.6 (11)	10.3 (22)	**8.7% (58)**	9.8 (32)	12.3 (13)	5.7 (13)
Other reason(s)	**2.3% (14)**	1.2 (2)*	3.9 (6)*	1.8 (5)*	**1.8% (6)***	0	0	2.8 (6)*	**2.5% (17)**	0.6 (2)*	4.7 (5)*	4.4 (10)*

[1]Percentages do not add to 100, as respondents could choose multiple responses (mean=2.7)

[2]Specified they currently used nicotine salts, but selected a brand other than JUUL

[3]Specified they did not currently use nicotine salts and selected a brand other than JUUL

*High variability (coefficient of variation is > 33.3 or the numerator is <10), interpret with caution

Table S3. Patterns of use and symptoms of dependence among past 30-day vapers, by self-reported current nicotine use, 2019, weighted %(n)

	Currently NOT using nicotine[1] (n=645)	**Currently use nicotine (not salts)**[2] (n=831)	**Currently use nicotine salts**[3] (n=414)	**Nicotine (non-salt) vs no nicotine**	**Nicotine salts vs no nicotine**
	% (n)	% (n)	% (n)	AOR (95%CI), p value[4]	AOR (95%CI), p value[4]
Smoking status[5]					
Current smoker	9.5 (62)	19.2 (160)	15.6 (65)	**2.50 (1.84-3.41)**	**2.06 (1.42-2.99)**
Experimental smoker	53.6 (346)	58.1 (483)	58.1 (241)	p<0.0001	p=0.0001
Former smoker	1.5 (9)	5.2 (43)	8.0 (33)		
Never smoker	35.4 (228)	17.4 (145)	18.2 (76)		
Days ever vaped[6]					
100 days or more	10.5 (68)	40.1 (335)	60.2 (250)	**5.27 (3.85-7.20)**	**11.59 (8.14-16.50)**
51 to 99 days	7.4 (48)	11.6 (97)	7.6 (31)	p<0.0001	p<0.0001
21 to 50 days	13.6 (88)	17.8 (148)	7.8 (32)		
11 to 20 days	14.1 (91)	10.2 (85)	8.9 (37)		
2 to 10 days	33.5 (216)	13.9 (116)	8.8 (36)		
One day	16.5 (107)	3.0 (25)	3.7 (15)		
Don't know	4.4 (29)	3.4 (28)	3.0 (12)		
Mean days vaped in past 30d[7] **(SD)**	6.4 (7.4)	15.2 (10.4)	20.5 (9.9)	**B=8.45 (7.27-9.62)** p<0.0001	**B=13.47 (12.01-14.94)** p<0.0001
Times vaped/day in past 30d[8]	3.0 (19)	15.1 (126)	36.3 (151)	**5.35 (3.39-8.44)**	**17.51 (10.94-28.01)**
More than 20 times per day	4.4 (28)	11.0 (92)	10.4 (43)	p<0.0001	p<0.0001
11 to 20 times per day	11.6 (74)	18.0 (150)	17.9 (74)		
6 to 10 times per day	37.8 (243)	37.4 (312)	20.5 (85)		
2 to 5 times per day	37.7 (242)	15.9 (133)	11.5 (48)		
1 time per day	5.6 (46)	2.5 (21)	3.4 (14)		
Don't know					
Urges to vape[9]					
Several times a day	7.0 (45)	18.2 (152)	34.3 (141)	**3.12 (2.37-4.12)**	**7.67 (5.50-10.71)**
Every day or most days	11.2 (72)	23.1 (192)	28.2 (116)	p<0.0001	p<0.0001
At least once a week	16.6 (107)	21.8 (182)	19.2 (79)		
Less than once a week	14.8 (95)	13.4 (112)	5.0 (21)		
Never	47.2 (304)	21.2 (176)	11.3 (46)		
Don't know	3.2 (20)	2.3 (20)	2.1 (9)		
Perceived addiction[10]					
Yes, very addicted	5.1 (33)	10.1 (84)	26.4 (109)	**2.85 (2.22-3.64)**	**8.23 (5.90-11.48)**
Yes, a little addicted	20.9 (135)	40.0 (334)	47.5 (196)	p<0.0001	p<0.0001
Not at all	71.1 (458)	46.8 (390)	23.6 (97)		
Don't know	2.8 (21)	3.1 (26)	2.5 (10)		

Note: Weighted n's are rounded

[1]Specified they did not currently use nicotine

[2]Specified they currently used nicotine, but not nicotine salts

[3]Specified they currently used nicotine salts

[4]From separate logistic regression models for each use outcome (linear regression model for mean days), adjusted for country, age group, sex, and race/ethnicity (white only vs. not); outcomes analyzed as heavy use category vs else

[5]Analyzed as current smoker vs else

[6]Analyzed as "100 days or more" vs else, refusals (n=1) and don't know responses excluded

[7] Analyzed as a continuous outcome variable, refusals (n=9) and don't know responses (n=299) excluded

[8]Analyzed as "More than 20 times per day" vs else, refusals (n=6) and don't know responses excluded

[9]Analyzed as "Several times a day"/"Every day or most days" vs else, refusals (n=9) and don't know responses excluded

[10]Analyzed as "Yes, very addicted"/"Yes, a little addicted" vs "Not at all", refusals (n=8) and don't know responses excluded

*High variability (coefficient of variation is > 33.3 or the numerator is <10), interpret with caution

Table S4. Patterns of use and symptoms of dependence among past 30-day vapers, by current use of JUUL and nicotine salts, 2019

	Currently NOT using nicotine salts or JUUL[1] (n=1043)	**Currently use JUUL** (n=554)	**Currently use nicotine salts (other than JUUL)[2]** (n=316)	**JUUL vs not nicotine salts or JUUL**	**Nicotine salts vs not nicotine salts or JUUL**
	% (n)	% (n)	% (n)	AOR (95%CI), p value[3]	AOR (95%CI), p value[3]
Smoking status[4]					
Current smoker	16.8 (175)	11.7 (64)	16.2 (51)	0.80 (0.58-1.09)	1.04 (0.74-1.46)
Experimental smoker	54.6 (567)	58.4 (323)	58.1 (183)	p=0.16	p=0.83
Former smoker	3.6 (38)	4.0 (22)	8.5 (27)		
Never smoker	24.9 (259)	25.9 (143)	17.2 (54)		
Days ever vaped[5]					
100 days or more	25.3 (264)	34.9 (193)	61.9 (196)	1.26 (0.97-1.63)	**4.19 (3.11-5.64)**
51 to 99 days	10.0 (104)	9.9 (55)	6.3 (20)	p=0.089	**p<0.0001**
21 to 50 days	15.1 (158)	15.6 (86)	8.1 (26)		
11 to 20 days	11.5 (120)	12.3 (68)	8.7 (27)		
2 to 10 days	23.2 (242)	19.5 (108)	8.1 (26)		
One day	9.8 (102)	6.1 (33)	4.2 (13)		
Don't know	5.1 (53)	1.7 (9)*	2.7 (9)*		
Mean days vaped in past 30d[6] (SD)	11.1 (10.1)	13.7 (10.6)	20.4 (9.8)	**B=1.58 (0.11-3.04) p=0.035**	**B=8.43 (6.82-10.03) p<0.0001**
Times vaped/day in past 30d[7]	10.0 (104)	13.3 (74)	37.4 (118)	1.24 (0.86-1.79)	**4.99 (3.55-7.02)**
More than 20 times per day	8.2 (86)	8.5 (47)	10.2 (32)	p=0.24	**p<0.0001**
11 to 20 times per day	15.1 (157)	15.1 (84)	18.4 (58)		
6 to 10 times per day	36.8 (382)	37.9 (210)	16.6 (52)		
2 to 5 times per day	25.8 (268)	21.8 (121)	13.0 (41)		
1 time per day	4.0 (41)	3.4 (19)	4.5 (14)		
Don't know					
Urges to vape[8]					
Several times a day	12.5 (129)	17.9 (98)	35.5 (112)	**1.47 (1.13-1.91)**	**4.14 (3.05-5.61)**
Every day or most days	16.1 (167)	23.2 (128)	27.3 (86)	**p=0.0036**	**p<0.0001**
At least once a week	18.2 (189)	22.5 (124)	17.9 (56)		
Less than once a week	14.1 (146)	11.7 (65)	5.5 (17)		
Never	36.0 (374)	22.6 (125)	11.8 (37)		
Don't know	3.2 (33)	2.1 (11)*	2.0 (6)*		
Perceived addiction[9]					
Yes, very addicted	7.1 (74)	12.5 (69)	26.5 (83)	**1.49 (1.16-1.91)**	**5.03 (3.65-6.94)**
Yes, a little addicted	29.7 (309)	37.1 (205)	48.6 (153)	**p=0.0017**	**p<0.0001**
Not at all	59.8 (621)	47.8 (264)	22.9 (72)		
Don't know	3.4 (35)	2.6 (14)	2.0 (6)*		

Note: Weighted n's are rounded

[1]Specified they did not currently use nicotine salts and selected a brand other than JUUL

[2]Specified they currently used nicotine salts, but selected a brand other than JUUL

[3]From separate logistic regression models for each use outcome (linear regression model for mean days), adjusted for country, age group, sex, and race/ethnicity (white only vs. not); outcomes analyzed as heavy use category vs else

[4]Analyzed as current smoker vs else

[5]From responses to the item,"On how many days have you used an e-cigarette/vaped in your entire life?" with response options "One day", "2 to 10 days", "11 to 20 days", "21 to 50 days", "51 to 99 days", "100 days or more"; Analyzed as "100 days or more" vs else, Refusals (n=1) and don't know responses excluded

[6]From responses to the item, "In the past 30 days, on how many days did you use e-cigarettes/vape?"; Analyzed as a continuous outcome variable, refusals (n=9) and don't know responses (n=299) excluded

[7]From responses to the item, "In the past 30 days, on the days you used an e-cigarette/vaped, how many times did you use it each day?" with response options "1 time per day", "2 to 5 times per day", "6 to 10 times per day", "11 to 20 times per day", "More than 20 times per day"; Analyzed as "More than 20 times per day" vs else, Refusals (n=6) and don't know responses excluded

[8]From responses to the item, "In the past 30 days, how often did you have a strong urge to use an e-cigarette/vape?" with response options "Several times a day", "Every day or most days", "At least once a week", "Less than once a week", "Never"; Analyzed as "Several times a day"/"Every day or most days" vs else, Refusals (n=9) and don't know responses excluded

[9]From responses to the item, "Do you consider yourself addicted to e-cigarettes/vaping?" with response options "Not at all", "Yes, a little addicted", "Yes, very addicted"; Analyzed as "Yes, very addicted"/"Yes, a little addicted" vs "Not at all", Refusals (n=8) and don't know responses excluded

*High variability (coefficient of variation is > 33.3 or the numerator is <10), interpret with caution