Characteristics and changes over time of nicotine vaping products used by vapers in the 2016 and 2018 ITC Four Country Smoking and Vaping Surveys

Nicholas J Felicione ,[1] Brian Vincent Fix ,[1] Ann McNeill ,[2,3] K. Michael Cummings ,[4] Maciej Lukasz Goniewicz ,[1] David Hammond,[5] Ron Borland,[6,7] Bryan W Heckman ,[4] Maansi Bansal-Travers,[1] Shannon Gravely,[8] Sara C Hitchman ,[2] David T Levy ,[9] Geoffrey T Fong ,[8,10] Richard O'Connor[1]

For numbered affiliations see end of article.

Correspondence to
Dr Nicholas J Felicione, Department of Health Behavior, Roswell Park Comprehensive Cancer Center, Buffalo, New York, USA; nicholas.felicione@roswellpark.org

Received 16 September 2020
Revised 28 January 2021
Accepted 23 February 2021

ABSTRACT

Objectives Regulation of nicotine vaping products (NVPs) varies between countries, impacting the availability and use of these products. This study updated the analyses of O'Connor *et al* on types of NVPs used and examined changes in NVP features used over 18 months in four countries with differing regulatory environments.

Design Data are from 4734 adult current vapers in Australia, Canada, England and the USA from Waves 1 (2016) and 2 (2018) of the International Tobacco Control Four Country Smoking and Vaping Survey. NVP characteristics included device description, adjustable voltage, nicotine content and tank size. Longitudinal analyses (n=1058) assessed movement towards or away from more complex/modifiable NVPs. A logistic regression was used to examine factors associated with changes in device description from 2016 to 2018.

Results Like 2016, box-tanks were the most popular NVP (37.3%) in all four countries in 2018. Over 80% of vapers continued using the same NVP and nicotine content between waves, though movement tended towards more complex/modifiable devices (14.4% of vapers). Box-tank users, exclusive daily vapers and older vapers were most likely to continue using the same device description. Certain NVPs and features differed by country, such as higher nicotine contents in the USA (11.5% use 21+ mg/mL) and greater device stability over time in Australia (90.8% stability).

Conclusions Most vapers continued using the same vaping device and features over 18 months. Differences in NVP types and features were observed between countries, suggesting that differing NVP regulations affect consumer choices regarding the type of vaping device to use.

To cite: Felicione NJ, Fix BV, McNeill A, *et al*. *Tob Control* Epub ahead of print: [*please include* Day Month Year]. doi:10.1136/tobaccocontrol-2020-056239

INTRODUCTION

Nicotine vaping products (NVPs) may be classified as disposable, rechargeable devices with replaceable prefilled cartridge/pods or devices with refillable liquid containers (tanks). They may also differ in appearance, such as cigarette-like, pen-like or box-like[1] or on other features, including voltage/power adjustability, tank capacity, flavour and nicotine concentration or formulation. 'Cigalike' NVPs were the most popular products in 2012–2013,[2] though by 2016–2017, tank-style and mod-style (ie, modified) NVPs had supplanted existing products.[3–5] JUUL, a high-nicotine pod-style NVP, emerged in 2015 and grew to 40% of the US NVP retail market share by the end of 2017.[6] While high-nicotine NVPs appear to be growing,[7 8] these studies generally use US Nielsen data, which does not capture vape shops and e-commerce purchasing.[9 10] These studies also do not fully capture patterns outside the USA, suggesting a need to gather data directly from consumers in various countries.

NVPs and popular features have evolved along with the marketplace. Vapers who started with cigalike devices more often transitioned to larger, more complex/modifiable models that can deliver nicotine more efficiently, as opposed to continuing with the same device.[1 11 12] Additionally, reducing nicotine content appears to be more common than increasing,[13] which may reflect more powerful batteries increasing the efficiency of nicotine delivery in more advanced models.[14] Few vapers move from more complex/modifiable to less complex/modifiable models.[11 12] Interviews with vapers suggest that cigalikes are perceived as starter products that are less satisfying than modifiable open systems.[15]

Few studies have examined how NVP designs and features may differentially impact public health. Different NVPs and features influence nicotine delivery and, ultimately, satisfaction[11 16 17] and may impact smoking cessation.[18] For instance, users of open (ie, refillable) systems may be exposed to more nicotine than users of closed systems,[19] and mod NVPs are associated with higher power, nicotine exposure and liquid consumption compared with tank or cigalike NVPs.[14 20] NVP type (ie, disposable, prefilled, tank) and brand influence total particulate matter yield,[21] suggesting certain NVPs, may be associated with increased nicotine and toxicant delivery. Increased NVP power is associated with increased total particulate matter and nicotine and toxicant yield.[21–23] However, determining the public health effects of device type is complicated by interactions among NVP features and the lack of long-term data on NVP health effects.

The regulatory environment shapes consumer behaviour by influencing the availability of NVPs, their features and purchasing.[9 24] Awareness and use of NVPs is negatively associated with the strength of regulatory policies in different countries.[24] In Australia (AU), where it is illegal

to sell or buy nicotine for NVPs without a medical prescription,[25] NVPs are procured online from outside the country.[9] In Canada (CA), prior to May 2018, independently owned vape shops were the primary NVP distributors due to regulations that discouraged mass marketed nicotine-containing NVPs. The 2018 Tobacco and Vaping Products Act removed premarket restrictions, permitting entry of international brands, such as JUUL and Vype, and increasing the retail availability of nicotine containing NVPs.[26] In England (EN), the Tobacco Products Directive introduced restrictions on nicotine content (≤20 mg/mL or 2.0%) and tank and refill sizes.[27] In EN and the USA, NVPs are sourced across a broader set of venues: vape shops, online and other locations.[9] Areas with more restrictive regulations generally have lower adult NVP use.[28]

The purpose of this study is to update and extend analyses conducted by O'Connor *et al*[55] describing the features of NVPs used by vapers in 2016, using data from a 2018 follow-up survey. Specifically, we assessed whether products and specific features of NVPs used by adult vapers changed over 18 months in AU, CA, EN and the USA, where access and marketing of NVPs vary.

METHODS

The ITC Four Country Smoking and Vaping Survey Wave 2 (W2) is an expansion of the ITC Four Country Survey infrastructure, conceptual model[29] and methodologies,[30] to examine NVP market and policy environments.[31] Data for this paper come from 4734 respondents who reported current daily, weekly or monthly NVP use. W2 data were collected from February to July 2018, approximately 18 months after Wave 1 in 2016 (W1). Respondents were recruited via random-digit-dialling sampling frames or a combination of random-digit-dialling and web-based or address-based panels. The survey sample consisted of (1) recontact smokers and former smokers who had participated in W1, (2) newly recruited current and former smokers from country-specific panels, (3) recontact vapers who had participated in W1 and (4) newly recruited current vapers from country-specific panels. Sampling and weighting were conducted to be representative of the respective countries' smoking populations with calibration figures obtained from nationally representative surveys. Additional methodological details are available via the ITC website (http://www.itcproject.org/methods). There were two components of our study. First, we updated O'Connor *et al*'s[5] analyses of NVPs and features to 2018. Second, we conducted longitudinal analyses (n=1058 current vapers at W1 and W2) to assess change in NVPs and features from 2016 to 2018.

Measures

Vaping/smoking status. NVP use was dichotomied as daily or non-daily, as was cigarette smoking and combined to create six use status categories: (1) exclusive daily vaper, (2) exclusive non-daily vaper, (3) dual daily (daily NVP/daily cigarette, (4) predominant vaper (daily NVP/non-daily cigarette), (5) predominant smoker (non-daily NVP/daily cigarette) and (6) concurrent non-daily (non-daily NVP/non-daily cigarette).[32]

NVP characteristics. Questions and response options regarding NVPs were similar between W1 and W2 and asked participants to describe the NVP they currently use most (cf. O'Connor *et al*).[5] Five NVP types were based on two questions about NVP description ('Which of the following best describes the type of e-cigarette/vaping device you currently use most?', that is, disposable, prefilled cartridge, refillable tank) and appearance ('Which of the following best describes the appearance…?', that is, cigarette-like, cigarette-like but different colour, pen-like, box-like, other). The five NVP types were (1) cigalike (disposable or prefilled cartridge, cigarette-like with same or different colour), (2) pen-cartridge (prefilled cartridge, pen-like3) pen-tank (refillable tank, pen-like), (4) box-tank (refillable tank, box-like) and (5) any other combinations inconsistent with options 1–4. Other combinations (9.6% of W2 vapers) were as follows: 32.2% box-cartridge, 18.0% cigalike different colour-tank, 16.4% pen-disposable, 13.6% other-tank, 10.4% cigalike-tank, 6.2% other-cartridge, 2.0% tank-disposable and 1.1% other-disposable.

Reported NVP brand use was evaluated to further assess device type ('What specific brand of reusable/disposable…?'). Popular brands (eg, Aspire, Smok, Blu) offer multiple NVP designs, complicating assessment of device type using brand. One exception is JUUL, which only sold one pod-style device, though JUUL users (n=82 at W2) selected multiple description and appearance combinations. For analytic purposes, we categorised JUUL as pen-cartridge, the closest approximation among the existing categories. Brand data were not used to classify any NVPs other than JUUL.

Longitudinal analyses to examine changes in product complexity/modifiability between W1 to W2. For NVP description, tanks were considered most complex, with cartridges then disposables being least complex. For NVP appearance, complexity was ranked as follows: box-shaped (most complex), pen-like, cigarette-like but different colour/cigarette-like (others excluded). For NVP type, complexity was ranked as followed: box-tanks (most complex), pen-tanks, pen-cartridges, cigalikes (any other combinations excluded). Vapers who reported 'don't know' to either NVP description variable at W1 or W2 were excluded (n=43 at W2).

NVP features. Vapers who reported cartridge or tank NVP use were asked if their products had adjustable voltage ('Can you adjust the power, voltage, or temperature…?'), with response options: (1) 'Yes, but I don't change it', (2) 'Yes, and I change the settings occasionally', (3) 'Yes, and I regularly adjust the settings', (4) 'No' and (5) 'Don't know'. Vapers who reported changing settings occasionally or regularly were combined for analyses. For longitudinal analyses on directionality, adjustable voltage was ranked as follows: 'Yes, change' (most complex/modifiable), 'Yes, don't change' and 'No' (don't know excluded).

Vapers who reported tank NVP use were asked about the capacity of their tank in mL ('What is the volume/capacity of the tank…?'), with response options: (1) '<1', (2) '1–1.5', (3) '1.6–2.0', (4) '2.1–3', (5) '3.1–4.0' and (6) '>4'. For longitudinal analyses, movement towards >4 mL was considered increased complexity and movement towards <1 mL was considered decreased complexity.

All vapers were asked about the nicotine strength of the currently used e-liquid ('What is the strength of the e-liquid…?'), with response options: (1) '0 mg/mL (0%)', (2) '1–4 mg/mL (0.1%–0.4%)', (3) '5–8 mg/mL (0.5%–0.8%)', (4) '9–14 mg/mL (0.9%–1.4%)', (5) '15–20 mg/mL (1.5%–2.0%)', (6) '21–24 mg/mL (2.1%–2.4%)' and (7) '25 mg/mL (2.5%) or more'. Nicotine contents were combined into three groups: 0 mg/mL,≤20 mg/mL (1–20 mg/mL) or 21+ mg/mL (21–25+ mg/mL) to assess nicotine content based on current EU Tobacco Products Directive limits. For longitudinal analyses, movement towards 21+ mg/mL was considered increased

complexity and movement towards 0 mg/mL was considered decreased complexity.

Demographics. Participants were asked about their age, ethnicity and education and income . Education was categorised into three levels: low (≤high school), moderate (technical/community college, some university) or high (≥university degree). Income was categorised into three levels with cut-offs differing by country. Low income was defined as <$44 999 (AU/CA), ≤$29 999 (USA) or ≤£15 000 (EN). Moderate income was defined as $45 000–$74 999 (AU/CA), $30 000–$59 999 (USA), or £15 001–40 000 (EN). High income was defined as ≥$75 000 (AU/CA), >60 000 (USA) or ≥£40 001 (EN).

Data analyses

All data were weighted to country-representative samples. Cross-sectional analyses were weighted to country-representative samples using the rescaled cross-sectional weight for current NVP users. Descriptive analyses were conducted on the full sample and by country, with χ^2 analyses used to test for differences and followed with posthoc pairwise comparisons of proportions using the Bonferroni method. A multinomial logistic regression was conducted to examine if country and vaping/smoking status were associated with device type preference, while controlling for demographics. Pen-style cartridge was combined with 'any other combinations'.[5] Missing data were deleted listwise without imputing.

Longitudinal analyses were weighted to country-representative samples using the rescaled longitudinal weight for continuing NVP users from W1 to W2. Those who reported 'don't know' at W1 or W2 were excluded from analyses for the corresponding variable, thus longitudinal results reflect NVPs/features among vapers who know their product characteristics. Descriptive analyses were used to report changes in NVP features from W1 to W2 and followed with posthoc pairwise comparisons of proportions using the Bonferroni method. Logistic regression was used to predict the odds of changing device type based on W1 demographics, vaping/smoking status, device type and nicotine content. Switchers (vapers that changed device type) to increased and decreased NVP type complexity were grouped together due to relatively small sample sizes compared with those who stayed stable in device type. Analyses were conducted using IBM SPSS Statistics V.25 (IBM, Armonk, New York, USA).

Table 1 NVP characteristics overall and by country, ITC W2 (2018) survey

	Canada (n=1152)	USA (n=1092)	England (n=2214)	Australia (n=276)	Overall (n=4734)	χ^2
Vaping/smoking status (n=4734)						521.90
Exclusive daily vaper	17.3[a]	34.3[v]	40.2[c]	63.3[d]	34.6	
Exclusive non-daily vaper	13.0[a]	5.8[b]	7.2[b]	4.7[b]	8.2	
Predominant vaper	6.1[a]	13.3[b]	11.0[b]	13.5[b]	10.5	
Predominant smoker	27.2[a]	20.6[b]	18.3[b]	11.1[c]	20.6	
Dual daily user	15.2[a]	15.5[a]	17.3[a]	6.8[b]	15.8	
Concurrent non-daily user	21.2[a]	10.4[b]	5.9[c]	0.6[d]	10.4	
Device characteristics						
Type (n=4691)						328.58
Box-tank	30.3[a]	40.8[b]	35.6[b]	65.7[c]	37.3	
Pen-tank	21.2[a]	20.7[a]	32.4[b]	18.7[a]	26.2	
Pen-cartridge	10.2[a]	9.3[a]	7.6[a]	1.1[b]	8.2	
Cigalike	19.8[a]	23.2[b]	17.5[a]	7.1[c]	18.7	
All others	18.5[a]	6.0[b]	7.0[b]	7.4[b]	9.6	
Adjustable voltage (n=3867)						246.98
Yes, change	36.0[a]	36.7[a]	34.3[a]	66.8[b]	37.3	
Yes, do not change	35.4[a]	20.6[b]	18.6[b]	14.0[b]	22.2	
Not adjustable	25.1[a]	41.7[b]	45.0[b]	17.0[a]	38.3	
Do not know	3.5[a]	1.1[a]	2.1[a]	2.2[b]	2.2	
Capacity (n=4153)						334.39
<1 mL	3.3[a]	5.2[b]	1.6[a]	1.8[a,b]	2.8	
1–1.5 mL	14.6[a]	12.8[a,b]	12.3[a,b]	7.6[b]	12.6	
1.6–2.0 mL	22.5[a]	15.4[b]	29.6[c]	18.6[a,b]	24.1	
2.1–3 mL	12.2[a]	14.3[a]	13.0[a]	11.3[a]	13.0	
3.1–4.0 mL	9.4[a]	7.4[a,b]	6.0[b]	18.6[c]	7.9	
>4 mL	8.5[a]	10.7[a]	5.7[b]	30.0[c]	9.0	
Don't know	29.5[a]	34.2[a]	31.7[a]	12.1[b]	30.6	
Refill characteristics						
Nicotine content (n=4730)						262.32
No nicotine	12.9[a]	8.6[b]	6.0[c]	11.4[a,b]	8.6	
≤20 mg/mL	69.0[a]	68.4[a]	82.3[b]	79.6[b]	75.6	
21+ mg/mL	1.5[a]	11.5[b]	4.1[c]	2.0[a,c]	5.0	
Do not know	16.6[a]	11.4[b]	7.7[c]	7.1[b,c]	10.7	

P<0.001 for all χ^2 tests comparing across countries.
Superscript letters reflect posthoc comparisons across country, with different letters indicating significant differences.
.df_{type}, 12; $df_{voltage}$, 9; $df_{capacity}$, 18; $df_{nicotine}$, 9; df_{status}, 15; NVP, nicotine vaping product; W2, Wave 2.

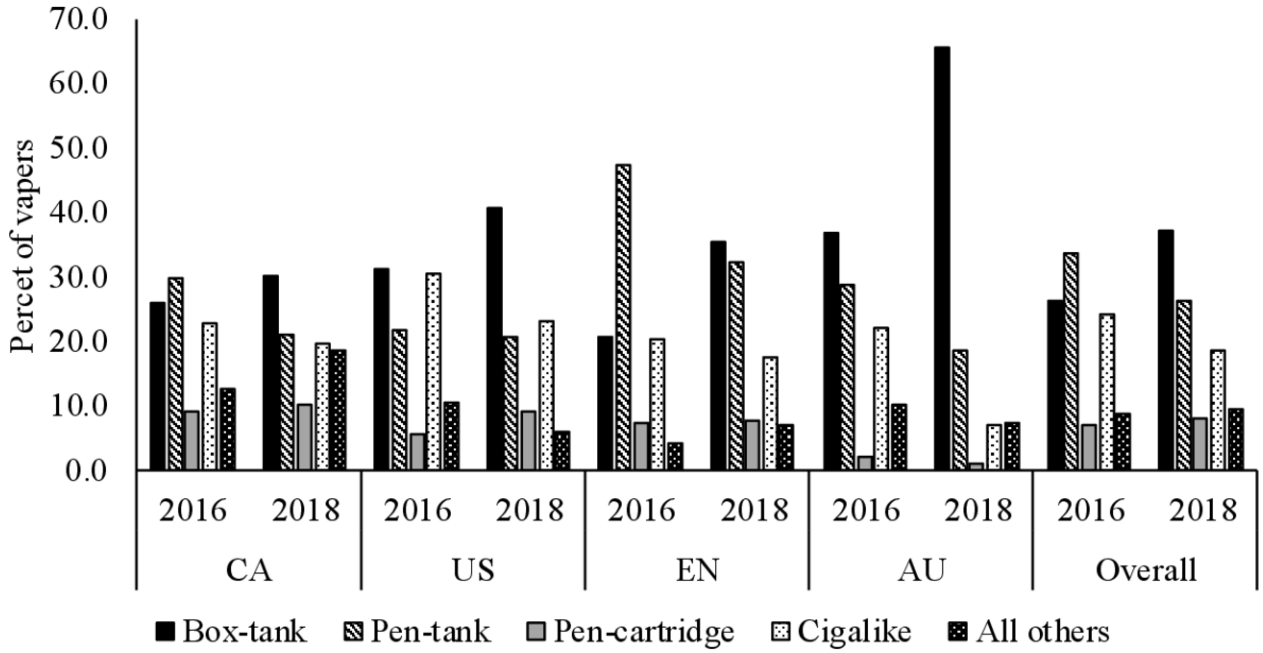

Figure 1 NVP type by country and overall at W1 (2016) and W2 (2018). NVP, nicotine vaping product; W1, Wave 1; W2; Wave 2.

RESULTS

NVP characteristics by country: cross-sectional results from Wave 2 (2018)

The W2 sample of vapers was 40.40 (SD=15.37) years old, predominately white (84.9%) and men (57.3%), had moderate-high income (72.0%) and moderate-high education (75.4%). Table 1 shows vaping/smoking status and NVP characteristics for the full sample and each country in 2018. Exclusive daily vaping was the most common use status in all countries except CA. Overall, 42.8% were exclusive vapers and 60.9% of the sample used NVPs daily. Box-tanks were the most popular device overall and within each country (see figure 1 for prevalence of device type by country and wave), although they were relatively more popular in USA and AU (40.8% and 65.7%) than in CA and EN (30.3% and 35.6%). Pen-tanks were second-most common in all countries except the USA, in which it was cigalikes. Reports of pen-cartridges (including JUUL) and 'any other combinations' were less common than other device types (≤10.2%), with the exclusion of 'any other combinations' in CA (18.5%). Cigalikes were less common in AU (7.1%) than other countries (17.5%–23.2%), and the use of 'any other combinations' was more common in CA (18.5%) than other countries (6.0%–7.4%). Adjustable voltage use differed by country, with 'yes, change' as the most common response in CA and AU (36.0% and 66.8%), but 'not adjustable' being most common in USA and EN (41.7% and 45.0%). The most common tank capacities were 1.6–2.0 mL, though larger tank sizes were more popular in AU (48.6% reported >3 mL). Nearly one third (30.6%) of vapers did not know their tank capacity, with lowest rates in AU (12.1%). Approximately three-quarters used ≤20 mg/mL nicotine, with few reporting no nicotine (8.6%) and 21+mg/ml (5.0%). Using 21+ mg/mL was more common in USA (11.5%), with other countries ranging from 1.5% to 4.1%. A further 10.7% did not know the strength, with higher rates in CA (16.6%) compared with EN and AU (7.7% and 7.1%).

Online supplemental tables 1–4 provide more detailed descriptions of NVPs by use status and country. Online supplemental table 1 shows device type as a function of vaping/smoking status and country. Online supplemental table 2 shows results of a multinomial logistic regression model comparing characteristics of box-tank, pen-tank and users of other combinations, to users of cigalikes in 2018. Online supplemental table 3 reports the self-reported nicotine content as a function of device type and country in 2018. Online supplemental table 4 shows the most commonly reported brands by country in 2016 and 2018.

Longitudinal change in device characteristics by country

Table 2 shows directional change in NVP characteristics from 2016 to 2018 overall and by country. More than 68% of vapers stayed the same from 2016 to 2018 for all NVP features except for tank capacity, where only 35.8% did. Directional change differed by country for all NVP features except tank capacity. Almost 80% of vapers remained with the same device type, though this stability was more common in AU (90.8%) than other countries (70.1%–81.3%). Additionally, increasing device type complexity was more common than decreasing in all countries except USA, where movement was similar in both directions. Online supplemental table 5 shows device type change from 2016 to 2018.

Stability was commonly observed for adjustable voltage—most vapers continued in the same adjustable voltage category, more commonly in AU (88.8%) than other countries (65.5%–69.2%). Similar percentages of vapers stayed stable (35.8%), increased (29.9%) and decreased (34.3%) tank capacity. Online supplemental table 6 shows NVP feature change as a function of device type change.

Stability in nicotine content was the most common pattern, though the pattern of changes differed by country. Overall, 93.2% of vapers who had used ≤20 mg/mL nicotine continued using that nicotine content, while only 2.3% increased to 21+ mg/mL. Over 70% of vapers using 21+ mg/mL in each country in 2016 reduced their nicotine content by 2018. Increasing nicotine content was rare in EN (2.1%) and AU (0%) and non-significantly higher in the USA and CA (6.4% and 6.1%). Most vapers (64.9%) using 0 mg/mL nicotine continued using that

Table 2 Change in NVP characteristics from W1 (2016) to W2 (2018)

	Canada	USA	England	Australia	Overall	χ^2*	P value
Device type†	n=237	n=225	n=304	n=63	n=829	26.56	<0.001
Same	70.1[a]	80.8[b]	81.3[b]	90.8[b]	78.7		
Increase	21.5[a]	9.4[b]	13.9[a,b]	7.6[a,b]	14.4		
Decrease	8.4[a]	9.8[a]	4.7[a]	1.6[a]	6.9		
Device description*	n=320	n=247	n=337	n=80	n=984	51.47	<0.001
Same	76.7[a]	87.1[b]	89.2[b]	72.6[a]	83.3		
Increase	13.3[a]	6.4[b]	7.0[b]	27.2[c]	10.5		
Decrease	10.0[a]	6.5[a,b]	3.8[b]	0.2[b]	6.2		
Device appearance‡	n=310	n=241	n=334	n=79	n=964	33.02	<0.001
Same	63.5[a]	78.5[b]	77.5[b]	75.0[a,b]	73.1		
Increase	26.8[a]	11.6[b]	15.9[b,c]	23.8[a,c]	18.9		
Decrease	9.7[a]	9.9[a]	6.6[a]	1.3[a]	8.0		
Nicotine content§	n=277	n=218	n=289	n=74	n=859	21.41	0.002
Same	85.9[a,b]	79.4[b]	89.3[a]	82.4[a,b]	85.1		
Increase	6.1[a]	6.4[a]	2.1[a]	0.0[a]	4.3		
Decrease	7.9[a]	14.2[a]	8.7[a]	17.6[a]	10.6		
0 mg/mL	n=31	n=3	n=18	n=5	n=57	6.71	0.08
Same	54.8[a]	33.3[b]	54.8[a]	100.0[a]	64.9		
Increase	45.2[a]	66.7[a]	45.2[a]	0.0[a]	35.1		
Decrease	n/a	n/a	n/a	n/a	n/a		
≤20 mg/mL	n=238	n=188	n=251	n=55	n=732	24.74	<0.001
Same	92.9[a]	87.2[a]	96.8[a]	98.2[a]	93.2		
Increase	1.7[a,b]	6.4[b]	0.4[a]	0.0[a,b]	2.3		
Decrease	5.5[a]	6.4[a]	2.8[a]	1.8[a]	4.5		
21+ mg/mL	n=9	n=27	n=19	n=14	n=69	7.13	0.07
Same	0.0[a]	29.6b	5.3[a,c]	14.3[b,c]	15.9		
Increase	n/a	n/a	n/a	n/a	n/a		
Decrease	100.0[a]	70.4[a,b]	94.7[a]	85.7[b]	84.1		
Capacity	n=160	n=131	n=187	n=55	n=532	8.54	0.2
Same	32.9[a]	37.0[a]	38.4[a]	32.3[a]	35.8		
Increase	27.0[a]	25.4[a]	32.7[a]	39.3[a]	29.9		
Decrease	40.2[a]	37.5[a]	28.8[a]	28.4[a]	34.3		
Adjustable voltage¶	n=207	n=192	n=276	n=69	n=745	15.44	0.017
Same	65.5[a]	69.0[a]	69.2[a]	88.8[b]	69.9		
Increase	18.9[a]	15.5[a,b]	18.9[a]	5.4[b]	16.8		
Decrease	15.6[a,b]	15.4[b]	11.9[a]	5.8[a,b]	13.3		

χ^2 used to compare change within NVP feature across countries. df=6.
Superscript letters reflect posthoc comparisons across country, with different letters indicating significant differences.
*.Device description complexity (most – least): tank, cartridge, disposable.
†.Device type complexity (most-): box-tank, pen-tank, pen-cartridge, cigalike (excluded: all others).
‡.Device appearance complexity (most – least): box-like, pen-like, like cigarette different colour, like cigarette (excluded: other).
§.Nicotine content directionality are reported across nicotine content and within each nicotine content, separately.
¶.Voltage complexity (most – least): yes/change, yes/do not change, no.
NVP, nicotine vaping product; W1, Wave 1; W2, Wave 2.

content across waves. When considering NVP change from 2016 to 2018, 86.5% of vapers that continued with the same device also continued with the same nicotine content, and 81.8% of vapers that changed device type continued with the same nicotine concentration (online supplemental table 6).

Table 3 presents results of a logistic regression model assessing the likelihood of changing device types from 2016 to 2018. Vapers from 18 to 39 years old were more than twice as likely as 55+ years to change device type. All smoking/vaping statuses, except concurrent non-daily users, in 2016 were more likely to change device type by 2018 than exclusive daily vapers. Device type in 2016 also predicted device type changing, with box-tank users least likely to shift. Users of ≤20 mg/mL nicotine were half as likely to change device type than those who used 21+ mg/mL, though nicotine content was not a significant predictor in the regression model.

DISCUSSION

Overall, the type of NVPs used in 2018 was similar to those reported by vapers in 2016.[5] Refillable NVPs continued to be used by most vapers, adjustable voltage devices were more common than non-adjustable, and over 80% of vapers reported using NVPs that contain nicotine. Taken together, vapers seem to gravitate to NVPs and features that facilitate nicotine delivery.[14 20 21] Despite changes in the marketplace of products and changes in regulation governing access and marketing of NVPs, the general pattern of common NVPs and features remained similar. This finding of NVP consistency is in contrast with the rise in popularity of pod-style NVPs during 2015–2017 in the USA.[6] JUUL use was low in the current sample (1.7%) and only was a popular brand in the USA, though JUUL was not for sale in CA and became available in EN during data collection.

Table 3 Predictors of changing device type from W1 (2016) to W2 (2018)

	Changing device description (n=792)			
		95% CI		
	aOR	Lower bound	Upper bound	P value
Country				0.54
AU	0.97	0.47	1.98	0.93
CA	1.39	0.86	2.25	0.180
EN	1.19	0.71	1.99	0.52
USA				REF
Age				**0.014**
18–24	**2.46**	**1.17**	**5.18**	**0.017**
25–39	**2.10**	**1.27**	**3.47**	**0.004**
40–54	1.34	0.83	2.15	0.24
55+				REF
Education				0.053
Low	1.25	0.75	2.07	0.39
Moderate	0.74	0.46	1.19	0.22
High				REF
Income				0.70
Low	0.82	0.52	1.30	0.40
Moderate	0.88	0.57	1.37	0.57
High				REF
Sex				
Women	0.93	0.66	1.33	0.70
Men				REF
Ethnicity				
White	0.92	0.54	1.55	0.75
Non-White				REF
Vaping/smoking status at W1				**0.001**
Exclusive daily vaper				REF
Exclusive non-daily vaper	**1.92**	**1.01**	**3.68**	**0.048**
Predominant vaper	**3.21**	**1.70**	**6.05**	**<0.001**
Predominant smoker	**2.16**	**1.26**	**3.70**	**0.005**
Dual daily user	**2.57**	**1.54**	**4.28**	**<0.001**
Concurrent non-daily user	1.28	0.54	3.06	0.58
Device description at W1				**<0.001**
Box-tank				REF
Pen-tank	**4.46**	**2.68**	**7.42**	**<0.001**
Pen-cartridge	**9.98**	**4.67**	**21.31**	**<0.001**
Cigalike	**3.63**	**2.08**	**6.32**	**<0.001**
All others	**29.97**	**12.74**	**70.51**	**<0.001**
Nicotine content at W1				0.09
0 mg/mL	0.80	0.33	1.96	0.63
≤20 mg/mL	**0.53**	**0.29**	**0.99**	**0.045**
21+ mg/mL				REF

Bolded values are statistically significant at p<.05.
aOR, adjusted odds ratio; AU, Australia; CA, Canada; EN, England; W1, Wave 1; W2, Wave 2.

The rapid rise in the popularity of JUUL among US adolescents by 2018[33 34] was not observed in our sample of adults in 2018. Though age differences may explain low JUUL use in this study, the characteristics of our sample of adult regular vapers are consistent with other reports from nationally representative samples.[35 36] However, the current study may underestimate the use of other JUUL-like pod NVPs, as no questions directly assessed these device types.

Still, some differences in NVP characteristic preferences emerged between 2016 and 2018 among vapers who know their product characteristics. Box-tank use increased, while cigalike and pen-tank use decreased, which may be related to greater nicotine exposure associated with these more complex NVPs.[14 20 21] Additionally, a larger percentage of vapers reported not knowing their nicotine content in 2018 compared with 2016, with highest rates in CA (16.6%) followed by the USA (11.4%) and EN (7.7%) and AU (7.1%). There was a reduction in use of high nicotine contents, which may result from changing other features that may impact nicotine delivery. However, nicotine content was asked as either mg/mL or %, which may have led to confusion or misreporting among some participants (ie, 49.5% of JUUL users reported ≤20 mg/mL, 25.9% reported 'don't know').

Consistent with 2016 data,[5] most vapers (75.6%) reported using ≤20 mg/mL nicotine in 2018, with some differences observed between countries. Use of 21+ mg/mL nicotine was higher in the USA and US vapers were more likely to increase nicotine content from ≤20 mg/mL to 21+ mg/mL compared with vapers in other countries. These patterns are consistent with the regulatory environment, as the USA and CA did not restrict nicotine content of NVPs, while EN has had an upper limit of 20 mg/mL, and the illegality of nicotine for NVPs in AU seemed to lead users to box-tanks with lower nicotine contents. These patterns may reflect a trend in the US market towards high nicotine contents,[6] despite lower levels of use than expected based on the proliferation of JUUL in the USA.[6–8] As mentioned previously, there were high rates of 'don't know' and some misreporting of nicotine content among some vapers, which suggests that product labels may not be understood or particularly salient to consumers. Tank users reported not knowing their nicotine content less than other device type users, which may be a result of using refillable NVPs rather than prefilled. This difference in awareness has been observed among young adult pod-users in the USA, which approximately half reported not knowing the nicotine concentration in their devices.[37] More awareness may reflect their use status or location of purchase (eg, vape shop, online, tobacco retail outlet), which may influence salience of specific product features. It may also reflect a reduced interest among vapers in product characteristics as vaping becomes more normalised.

Most vapers were stable in their device type, nicotine content and adjustable voltage use over time. Greater stability in device type in AU may reflect NVP illegality leading most consumers to purchase tank systems and nicotine solutions online.[9] Movement was mainly to more complex/modifiable designs, which may be followed by increases in nicotine exposure[19 20] and possibly total particulate matter exposure.[21] This pattern replicates findings from other studies in the USA.[11 12 15] Exclusive daily vapers were less likely to change device type, suggesting that these vapers may have a more stable pattern of behaviour and have identified the NVP that they found most satisfying.[11 16] If so, it would suggest no major improvements in product design have disseminated sufficiently to shift those who already have a satisfactory product. Future analyses should determine if pod NVPs such as JUUL have triggered any migration away from box-tanks by established users.

The rapidly changing NVP market and introduction of new and diverse products (eg, pods, nicotine salts) complicate the monitoring of trends and may contribute to measurement error. W2 questions may not have completely captured recent trends such as pod systems. For instance, high prevalence of 'any other combinations' in CA in 2018 (18.5%) may reflect emerging device types that were not categorised in this study. The ITC W3 survey (2020) includes an additional NVP appearance of 'USB/Flash Drive' to more directly assess use of pod systems. This study also focused on the most commonly used NVP by vapers, not accounting for those using multiple device types. Additionally, this study measured changes in NVPs used among those who know their product characteristics but may miss NVPs and features used by those who are less knowledgeable about their products. Regarding nicotine, this study did not specifically assess the use of salt-based nicotine products, which are common in pod NVPs and contain high nicotine concentrations[38] and reduce the pH to increase palatability, allowing high strength solutions which favours lower powered batteries and thus smaller devices.[7] Future research needs to take into account product innovation and seek novel ways to improve response accuracy. For example, uploading pictures of NVPs and liquid bottles within a survey may allow researchers to verify self-report data, but would only be workable if enough respondents were able and willing to provide such pictures.

Continued surveillance of NVPs in varying regulatory environments is crucial to assess how policies affect the NVP market and behaviour of user groups. Despite changing regulations in countries such as CA at the time of the survey, the data presented here likely reflect the preregulation environment for changes that occurred in 2018. Additionally, the market in the USA may change after the Premarket Tobacco Product Application deadline in September 2020, highlighting the importance of ongoing monitoring. Possible changes in exposure and health in response to NVP market changes are also needed to evaluate the public health implications of these behaviours.

What this paper adds

- Nicotine vaping product (NVP) regulations can influence the availability of NVPs and their features, thereby influencing consumer behaviour. The NVP market has experienced rapid change, demonstrating the need for surveillance of NVPs and assessment of how regulatory policies shape user behaviour.
- The influence of regulatory environment on change in NVPs over time has not been characterised.
- The NVP and features chosen by vapers generally stayed stable from 2016 to 2018, with over 80% of vapers continuing to use the same device description and same nicotine content. Changes in NVPs and features often differed in countries with different regulatory environments, demonstrating that regulations may influence the NVP market and behaviour over time.

Author affiliations
[1]Department of Health Behavior, Roswell Park Comprehensive Cancer Center, Buffalo, New York, USA
[2]Department of Addictions, King's College London, London, UK
[3]Shaping Public Health Policies to Reduce Inequalities and Harm (SPECTRUM), Nottingham, UK
[4]Department of Psychiatry & Behavioral Sciences, Medical University of South Carolina, Charleston, South Carolina, USA
[5]School of Public Health and Health Systems, University of Waterloo, Waterloo, Ontario, Canada
[6]School of Psychological Sciences, The University of Melbourne, Melbourne, Victoria, Australia
[7]Cancer Council Victoria, Melbourne, Victoria, Australia
[8]Department of Psychology, University of Waterloo, Waterloo, Ontario, Canada
[9]Department of Oncology, Lombardi Comprehensive Cancer Center, Georgetown University, Washington, District of Columbia, USA
[10]Ontario Institute for Cancer Research, Toronto, Ontario, Canada

Twitter Ann McNeill @kingsNRG

Contributors NJF, BVF and RO were responsible for data analyses and writing initial drafts. GTF is the Chief PI of the ITC Project. AM, MC, DH and RB are PIs, and MLG, BWH (former), MB-T, SCH, DTL and RO are Co-Is of the project. All authors provided review of drafts and approved the final manuscript.

Funding The ITC Four Country Smoking and Vaping Survey was supported by grants from the US National Cancer Institute (P01 CA200512), the Canadian Institutes of Health Research (FDN-148477) and the National Health and Medical Research Council of Australia (APP1106451).

Disclaimer The views expressed in this article are hers and not necessarily those of the NIHR, or the UK Department of Health and Social Care.

Competing interests AM is a UK National Institute for Health Research (NIHR) Senior Investigator. MC has received payment as a consultant to Pfizer, Inc. for service on an external advisory panel to assess ways to improve smoking cessation delivery in health care settings. MC and DH also have served as a paid expert witness in litigation filed against cigarette manufacturers. MLG has received a research grant from Pfizer and served as a member of scientific advisory board to Johnson & Johnson. DH and GTF have served as expert witnesses on behalf of governments in litigation involving the tobacco industry and vaping industry (DH).

Patient consent for publication Not required.

Ethics approval The survey protocols and all materials of W1 and/or W2 ITC Four Country Smoking and Vaping Survey, including the survey questionnaires, were cleared for ethics by Office of Research Ethics, University of Waterloo, Canada (ORE#20803/30570, ORE#21609/30878); Research Ethics Office, King's College London, UK (RESCM-17/18–2240); Human Research Ethics, Cancer Council Victoria, Australia (HREC1603) and Human Ethics, Research Management Office, University of Queensland, Australia (2016000330/HREC1603) and Institutional Review Board Medical University of South Carolina (waived due to minimal risk). All participants provided consent to participate.

Provenance and peer review Not commissioned; externally peer reviewed.

Data availability statement Data are available on reasonable request. Data were obtained through the ITC Project (https://itcproject.org/request-data-form/).

ORCID iDs
Nicholas J Felicione http://orcid.org/0000-0001-9034-3477
Brian Vincent Fix http://orcid.org/0000-0001-9135-4290
Ann McNeill http://orcid.org/0000-0002-6223-4000
K. Michael Cummings http://orcid.org/0000-0002-7103-7017
Maciej Lukasz Goniewicz http://orcid.org/0000-0001-6748-3068
Bryan W Heckman http://orcid.org/0000-0003-4148-2467
Sara C Hitchman http://orcid.org/0000-0001-6155-6916
David T Levy http://orcid.org/0000-0001-5280-3612
Geoffrey T Fong http://orcid.org/0000-0001-9098-6472

REFERENCES

1 National Academies of Sciences, Engineering, and Medicine. *Public health consequences of e-cigarettes*. Washington, DC: The National Academies Press, 2018.
2 Giovenco DP, Hammond D, Corey CG, *et al*. E-Cigarette market trends in traditional U.S. retail channels, 2012-2013. *Nicotine Tob Res* 2015;17:1279–83.
3 Action on Smoking and Health. Use of e-cigarettes (vaporisers) among adults in Great Britain, 2019. Available: https://ash.org.uk/wp-content/uploads/2019/09/Use-of-e-cigarettes-among-adults-2019.pdf [Accessed July 2020].
4 Hsu G, Sun JY, Zhu S-H. Evolution of electronic cigarette brands from 2013-2014 to 2016-2017: analysis of brand websites. *J Med Internet Res* 2018;20:e80.
5 O'Connor RJ, Fix BV, McNeill A, *et al*. Characteristics of nicotine vaping products used by participants in the 2016 ITC four country smoking and Vaping survey. *Addiction* 2019;114:15–23.
6 Huang J, Duan Z, Kwok J, *et al*. Vaping versus JUULing: how the extraordinary growth and marketing of JUUL transformed the US retail e-cigarette market. *Tob Control* 2019;28:146–51.
7 Jackler RK, Ramamurthi D. Nicotine arms race: JUUL and the high-nicotine product market. *Tob Control* 2019;28:623–8.
8 Romberg AR, Miller Lo EJ, Cuccia AF, *et al*. Patterns of nicotine concentrations in electronic cigarettes sold in the United States, 2013-2018. *Drug Alcohol Depend* 2019;203:1–7.

9 Braak DC, Cummings KM, Nahhas GJ, *et al*. Where do Vapers buy their Vaping supplies? findings from the International tobacco control (ITC) 4 country smoking and Vaping survey. *Int J Environ Res Public Health* 2019;16:338.
10 Zhu S-H, Sun JY, Bonnevie E, *et al*. Four hundred and sixty brands of e-cigarettes and counting: implications for product regulation. *Tob Control* 2014;23:iii3–9.
11 Yingst JM, Veldheer S, Hrabovsky S, *et al*. Factors associated with electronic cigarette users' device preferences and transition from first generation to advanced generation devices. *Nicotine Tob Res* 2015;17:1242–6.
12 Yingst J, Foulds J, Veldheer S, *et al*. Device characteristics of long term electronic cigarette users: a follow-up study. *Addict Behav* 2019;91:238–43.
13 McNeill A, Brose L, Calder R, *et al*. *Vaping in England: an evidence update including mental health and pregnancy, March 2020: a report commissioned by public health England*. London: Public Health England, 2020.
14 Farsalinos KE, Spyrou A, Tsimopoulou K, *et al*. Nicotine absorption from electronic cigarette use: comparison between first and new-generation devices. *Sci Rep* 2014;4:4133.
15 Cooper M, Harrell MB, Perry CL. A qualitative approach to understanding real-world electronic cigarette use: implications for measurement and regulation. *Prev Chronic Dis* 2016;13:15052.
16 Etter J-F. Characteristics of users and usage of different types of electronic cigarettes: findings from an online survey. *Addiction* 2016;111:724–33.
17 Yong H-H, Borland R, Cummings KM, *et al*. Reasons for regular vaping and for its discontinuation among smokers and recent ex-smokers: findings from the 2016 ITC four country smoking and Vaping survey. *Addiction* 2019;114:35–48.
18 Hitchman SC, Brose LS, Brown J, *et al*. Associations between e-cigarette type, frequency of use, and quitting smoking: findings from a longitudinal online panel survey in Great Britain. *Nicotine Tob Res* 2015;17:1187–94.
19 Rostron BL, Coleman B, Cheng Y-C, *et al*. Nicotine exposure by device type among adult electronic nicotine delivery system users in the population assessment of tobacco and health study, 2015-2016. *Cancer Epidemiol Biomarkers Prev* 2020;29:1968–72.
20 Wagener TL, Floyd EL, Stepanov I. *Have combustible cigarettes Met their match? the nicotine delivery profiles and harmful constituent exposures of second-generation and third-generation electronic cigarette users*, 2020.
21 El-Hellani A, Salman R, El-Hage R, *et al*. Nicotine and carbonyl emissions from popular electronic cigarette products: correlation to liquid composition and design characteristics. *Nicotine Tob Res* 2018;20:215–23.
22 Talih S, Balhas Z, Eissenberg T, *et al*. Effects of user puff topography, device voltage, and liquid nicotine concentration on electronic cigarette nicotine yield: measurements and model predictions. *Nicotine Tob Res* 2015;17:150–7.
23 Ward AM, Yaman R, Ebbert JO. Electronic nicotine delivery system design and aerosol toxicants: a systematic review. *PLoS One* 2020;15:e0234189.
24 Gravely S, Driezen P, Ouimet J, *et al*. Prevalence of awareness, ever-use and current use of nicotine vaping products (NVPs) among adult current smokers and ex-smokers in 14 countries with differing regulations on sales and marketing of NVPs: cross-sectional findings from the ITC project. *Addiction* 2019;114:1060–73.
25 Australian Government Department of Health. Smoking and tobacco laws in Australia. Available: https://www.health.gov.au/health-topics/smoking-and-tobacco/about-smoking-and-tobacco/smoking-and-tobacco-laws-in-australia#ecigarette-laws [Accessed April, 2020].
26 Health Canada. Vaping product regulations. Available: https://www.canada.ca/en/health-canada/services/smoking-tobacco/vaping/product-safety-regulation.html [Accessed April, 2020].
27 Medicines and Healthcare Products Regulatory Agency. E-Cigarettes: regulations for consumer products. Available: https://www.gov.uk/guidance/e-cigarettes-regulations-for-consumer-products [Accessed April, 2020].
28 Du Y, Liu B, Xu G, *et al*. Association of electronic cigarette regulations with electronic cigarette use among adults in the United States. *JAMA Netw Open* 2020;3:e1920255.
29 Fong GT, Cummings KM, Borland R, *et al*. The conceptual framework of the International tobacco control (ITC) policy evaluation project. *Tob Control* 2006;15:iii3–11.
30 Thompson ME, Fong GT, Hammond D, *et al*. Methods of the International tobacco control (ITC) four country survey. *Tob Control* 2006;15:iii12–18.
31 ITC Project. *Itc four country smoking and Vaping survey, wave 2 (2018) technical report*. London, United Kingdom: University of Waterloo, Waterloo, Ontario, Canada; Medical University of South Carolina, Charleston, South Carolina, United States; Cancer Council Victoria, Melbourne, Australia; the University of Queensland, Australia; King's College London, 2020.
32 Borland R, Murray K, Gravely S, *et al*. A new classification system for describing concurrent use of nicotine vaping products alongside cigarettes (so-called 'dual use'): findings from the ITC-4 Country Smoking and Vaping wave 1 Survey. *Addiction* 2019;114:24–34.
33 Hammond D, Reid JL, Rynard VL, *et al*. Prevalence of vaping and smoking among adolescents in Canada, England, and the United States: repeat national cross sectional surveys. *BMJ* 2019;365:l2219.
34 Vallone DM, Bennett M, Xiao H, *et al*. Prevalence and correlates of JUUL use among a national sample of youth and young adults. *Tob Control* 2019;28:603–9.
35 Coleman B, Chang JT, Rostron BL, *et al*. An examination of device types and features used by adult electronic nicotine delivery system (ends) users in the path study, 2015-2016. *Int J Environ Res Public Health* 2019;16:2329.
36 Mayer M, Reyes-Guzman C, Grana R, *et al*. Demographic characteristics, cigarette smoking, and e-cigarette use among US adults. *JAMA Netw Open* 2020;3:e2020694.
37 McKelvey K, Halpern-Felsher B. How and why California young adults are using different brands of pod-type electronic cigarettes in 2019: implications for researchers and regulators. *J Adolesc Health* 2020;67:46–52.
38 Eissenberg T, Soule E, Saliba N. *JUUL: the prototypical "pod mod": design characteristics, toxicant yield, and preliminary nicotine delivery and subjective effect profile*. Bethesda, MD: Presented at: National Institutes of Health (NIH) Tobacco Regulatory Science Meeting; June 19, 2018.

Supplementary Table 1. NVP type as a function of vaping/smoking status and country

	Canada	United States	England	Australia	Overall	X^2	*p*
Exclusive daily vaper	n = 199	n = 370	n = 873	n = 176	n = 1619	219.9	<.001
Box-tank	42.2	56.2	49.4	77.8	53.1		
Pen-tank	22.6	19.5	33.4	14.8	26.9		
Pen-cartridge	8.0	7.8	2.2	0.0	4.0		
Cigalike	4.5	11.9	11.7	0.6	9.6		
All others	22.6	4.6	3.3	6.8	6.4		
Exclusive non-daily vaper	n = 148	n = 59	n = 159	n = 11	n = 381	59.74	<.001
Box-tank	43.2	45.8	20.8	0.0	32.8		
Pen-tank	23.0	25.4	36.5	36.4	29.1		
Pen-cartridge	4.1	8.5	15.7	0.0	9.7		
Cigalike	6.8	16.9	15.1	36.4	12.9		
All others	23.0	3.4	11.9	27.3	15.5		
Predominant vaper	n = 70	n = 145	n = 244	n = 37	n = 495	115.05	<.001
Box-tank	30.0	43.4	36.5	75.7	40.4		
Pen-tank	7.1	24.1	45.1	21.6	31.9		
Pen-cartridge	17.1	13.8	6.6	0.0	9.7		
Cigalike	15.7	12.4	8.2	0.0	9.9		
All others	30.0	6.2	3.7	2.7	8.1		
Predominant smoker	n = 313	n = 224	n = 405	n = 31	n = 972	45.55	<.001
Box-tank	22.4	24.1	20.5	25.8	22.1		
Pen-tank	25.6	21.4	31.4	25.8	27.1		
Pen-cartridge	11.8	6.3	15.1	3.2	11.6		
Cigalike	24.0	40.2	24.2	32.3	28.1		
All others	16.3	8.0	8.9	12.9	11.1		
Dual daily user	n = 174	n = 169	n = 379	n = 19	n = 740	23.64	0.023
Box-tank	24.1	36.7	27.7	36.8	29.1		
Pen-tank	23.6	17.8	28.2	31.6	25.0		
Pen-cartridge	12.6	7.7	6.9	10.5	8.5		
Cigalike	24.7	30.8	25.9	15.8	26.4		
All others	14.9	7.1	11.3	5.3	11.1		
Concurrent nondaily user	n = 242	n = 113	n = 129	n = 1	n = 487	17.17	0.14
Box-tank	27.7	23.9	30.2	100.0	27.3		

Pen-tank	15.7	22.1	11.6	0.0	16.0
Pen-cartridge	9.5	17.7	14.0	0.0	12.5
Cigalike	32.6	31.0	31.8	0.0	32.2
All others	14.5	5.3	12.4	0.0	11.9

X^2 used to compare NVP description within tobacco status across countries. *df*=12

Supplementary Table 2. Multinomial logistic regression model comparing characteristics of box-shaped tank users, pen-shaped tank users, and users of "any other" NVP types to users of cigalikes (n = 4687) in 2018

					95% CI		
		n	*%*	*aOR*	*Lower Bound*	*Upper Bound*	*p*
Box-tank	Country						
	Australia	180	10.3	3.52	2.05	6.04	< .001
	Canada	348	19.9	1.41	1.08	1.84	0.01
	England	779	44.6	1.12	0.88	1.42	0.35
	United States	441	25.2				REF
	NVP use status						
	Exclusive daily vaper	860	49.2	10.73	7.62	15.12	< .001
	Exclusive nondaily vaper	125	7.1	3.55	2.29	5.52	< .001
	Predominant vaper	200	11.5	6.81	4.33	10.72	< .001
	Predominant smoker	215	12.3	1.34	0.96	1.88	0.09
	Dual daily user	215	12.3	1.88	1.32	2.66	< .001
	Concurrent nondaily user	133	7.6				REF
Pen-tank	Country						
	Australia	51	4.2	2.55	1.42	4.59	0.002
	Canada	243	19.8	1.61	1.21	2.14	0.001
	England	710	57.8	1.81	1.41	2.33	< .001
	United States	224	18.2				REF
	NVP use status						
	Exclusive daily vaper	435	35.4	4.84	3.33	7.04	< .001
	Exclusive nondaily vaper	111	9.0	3.28	2.04	5.26	< . 001
	Predominant vaper	158	12.9	7.62	4.73	12.25	< .001
	Predominant smoker	263	21.4	1.79	1.25	2.56	0.001

	Dual daily user	185	15.0	1.77	1.22	2.59	0.003
	Concurrent nondaily user	78	6.3				REF
All other + pen-cartridge	Country						
	Australia	23	2.8	1.39	0.69	2.79	0.35
	Canada	330	39.5	2.61	1.97	3.47	< .001
	England	318	38.0	1.48	1.13	1.96	0.001
	United States	165	19.7				REF
	NVP use status						
	Exclusive daily vaper	167	20.0	2.52	1.75	3.64	< .001
	Exclusive nondaily vaper	96	11.4	2.73	1.74	4.29	< .001
	Predominant vaper	88	10.6	4.55	2.83	7.33	< .001
	Predominant smoker	220	26.4	1.55	1.11	2.16	0.01
	Dual daily user	145	17.4	1.50	1.05	2.14	0.028
	Concurrent nondaily user	119	14.2				REF

Reference group for multinomial logistic regression is 'cigalike.' Model is adjusted for age, sex, race/ethnicity, income, and education. CI = confidence interval; aOR = adjusted odds ratio.

Supplementary Table 3. Nicotine content as a function of NVP type and country.

	Canada	United States	England	Australia	Overall	X^2	*p*
Box-tank	n = 349	n = 440	n = 779	n = 180	n = 1748	62.69	<.001
0 mg/ml	11.5	9.3	5.5	8.9	8.0		
≤ 20 mg/ml	80.8	81.4	89.9	86.1	85.5		
21+ mg/ml	0.9	7.0	2.1	2.8	3.1		
Don't Know	6.9	2.3	2.6	2.2	3.3		
Pen-tank	n = 242	n = 223	n = 711	n = 52	n = 1229	77.73	<.001
0 mg/ml	20.2	13.5	5.8	19.2	10.6		
≤ 20 mg/ml	64.6	71.3	82.6	75.0	76.6		
21+ mg/ml	1.2	8.5	4.1	1.9	4.2		
Don't Know	14.0	6.7	7.6	3.8	8.5		
Pen-cartridge	n = 118	n = 101	n = 165	n = 3	n = 386	54.99	<.001
0 mg/ml	9.3	5.0	15.1	0.0	10.4		
≤ 20 mg/ml	72.9	46.5	68.1	66.7	64.0		
21+ mg/ml	2.5	24.8	4.8	0.0	9.3		
Don't Know	15.3	23.8	12.1	33.3	16.3		
Cigalike	n = 228	n = 250	n = 382	n = 19	n = 880	104.5	<.001
0 mg/ml	8.3	3.6	1.3	10.5	4.0		
≤ 20 mg/ml	71.9	55.2	83.3	57.9	71.8		
21+ mg/ml	2.2	17.2	3.7	0.0	7.0		
Don't Know	17.5	24.0	11.8	31.6	17.2		
All others	n = 212	n = 62	n = 152	n = 20	n = 448	30.64	<.001
0 mg/ml	13.7	8.1	13.2	10.0	12.7		
≤ 20 mg/ml	50.0	59.7	65.8	60.0	56.9		
21+ mg/ml	1.4	11.1	3.3	0.0	3.6		
Don't Know	34.9	20.6	17.8	30.0	26.8		

X^2 used to compare nicotine content within device type across countries. $df = 9$

Supplementary Table 4. Most common brands by country and survey wave

W1 (2016)

Canada		*United States*		*England*		*Australia*	
Brand	%	Brand	%	Brand	%	Brand	%
Kanger	4.7	Blu	5.7	Kanger	4.9	eLeaf	7.1
eLeaf	3.9	Kanger	4.0	Vype	3.8	Sigelei	6.2
eGo	3.9	Mark Ten	3.6	Elites	3.3	Joyetech	4.4
Aspire	3.5	Aspire	3.1	Blu	2.8	eGo	4.0
Joyetech	3.1	Vuse	3.1	Aspire	2.7	Aspire	3.9
v2	2.8	NJOY	3.0	Innokin	2.7	eLeaf	3.2
Evod	2.6	IPV	2.9	VIP	2.5	VaporFi	2.1
iSTICK	2.1	Sigelei	2.6	eLeaf	2.1	Reuleaux	1.8
Smoke NV	1.9	VaporFi	2.3	Vapourlites	2.1	Kanger	1.6
Blu	1.6	V2	2.2	Vivid	2.0	iStick	1.5
iTaste	1.5	eLeaf	2.0	iTaste	2.0	Vapor Empire	1.4
Don't Know	1.9	Don't Know	0.7	Don't Know	1.2	Don't Know	3.7
Refused	n/a	Refused	4.0	Refused	n/a	Refused	3.3
Other	15.3	Other	13.0	Other	17.9	Other	20.2

W2 (2018)

Canada		*United States*		*England*		*Australia*	
Brand	%	Brand	%	Brand	%	Brand	%
Aspire	7.5	Smok	9.0	Aspire	7.5	Smok	14.0
Smok	5.6	JUUL	5.6	Smok	6.5	Aspire	11.3
Joyetech	3.8	Kanger	4.9	Blu	5.6	Vaporesso	7.6
Kanger	3.5	Blu	4.7	Vype	4.7	eLeaf	7.4
eLeaf	2.7	Mark Ten	4.1	eGo	3.8	Joyetech	5.3
Cloudmaker	2.5	Vuse	3.3	Totally Wicked	3.4	Sigelei	2.9
Blu	2.1	eLeaf	3.3	Innokin	3.2	Kanger	2.7
Evape	1.8	Aspire	2.6	VIP	3.1	Veppo	2.3
eGo	1.7	NJOY	1.5	88 Vape	2.7	Innokin	2.2
Halo	1.6	iStick	1.3	Elites	2.4	Apollo	2.0
EVO Vapor	1.6	V2	1.0	Logic	2.4	Vuse	1.7
Don't Know	21.9	Don't Know	9.2	Don't Know	10.9	Don't Know	7.0
Refused	3.2	Refused	28.4	Refused	n/a	Refused	1.5
Other	5.5	Other	2.4	Other	3.9	Other	17.0

Supplementary Table 5. Change in NVP type from W1 (2016) to W2 (2018). Percentages are within country and W1 device type.

	Canada	United States	England	Australia	Overall		
	n = 323	n = 244	n = 334	n = 78	n = 981	X^2	*p*
Box-Tank W1	n = 72	n = 107	n = 87	n = 44	n = 311	24.63	0.017
Box-Tank	87.5	83.2	93.1	100	89.1		
Pen-Tank	2.8	11.2	6.9	0	6.4		
Pen -Cartridge	1.4	1.9	0	0	1.3		
Cigalike	5.6	3.7	0	0	2.6		
All Others	2.8	0	0	0	0.6		
Pen-Tank W1	n = 96	n = 56	n = 163	n = 8	n = 321	19.27	0.08
Box-Tank	20.8	25.0	19.6	37.5	21.5		
Pen-Tank	60.4	69.6	74.8	62.5	69.8		
Pen -Cartridge	7.3	0	1.8	0	3.1		
Cigalike	3.1	0	1.2	0	1.2		
All Others	8.3	5.4	2.5	0	4.4		
Pen-Cartridge W1	n = 33	n = 6	n = 16	n = 1	n = 56	14.04	0.30
Box-Tank	6.1	0	18.8	0	8.9		
Pen-Tank	12.1	0	12.5	0	10.7		
Pen -Cartridge	39.4	50.0	25.0	0	35.7		
Cigalike	12.1	50.0	18.8	100	19.6		
All Others	30.3	0	25.0	0	25.0		
Cigalike W1	n = 75	n = 66	n = 53	n = 25	n = 220	73.53	<.001
Box-Tank	13.3	3.0	3.8	4.0	7.3		
Pen-Tank	12.0	4.5	5.7	56.0	13.2		
Pen -Cartridge	21.3	9.1	5.7	0	10.9		
Cigalike	42.7	77.3	75.5	28.0	59.5		
All Others	10.7	6.1	9.4	12.0	9.1		
All Others W1	n = 47	n = 9	n = 15	n = 0	n = 73	2.77	0.99
Box-Tank	19.1	33.3	26.7	0	21.9		
Pen-Tank	27.7	22.2	26.7	0	27.4		
Pen -Cartridge	14.9	0	13.3	0	12.3		
Cigalike	21.3	22.2	13.3	0	20.5		
All Others	17.0	22.2	20.0	0	17.8		

X^2 used to compare W2 device type within W1 device type across countries. $df = 12$

Supplementary Table 6. Cross-tabulation of NVP type switching and NVP feature switching (nicotine, voltage, capacity)

	Column Percent (within switching category)		Total Percent	
	Same Description	Change Description	Same Description	Change Description
Nicotine Content (n =857)				
Same 0mg/ml	4.7	3.8	3.3	1.2
Increase 0mg/ml (to <20 or 21+)	1.0	5.4	0.7	1.6
Same <20 mg/ml	80.5	76.5	56.1	23.2
Decrease <20 mg/ml (to 0)	4.5	2.3	3.2	0.7
Increase <20 mg/ml (to 21+)	2.2	1.5	1.5	0.5
Same 21+ mg/ml	1.3	1.5	0.9	0.5
Decrease 21+ mg/ml (to <0)	1.2	4.6	0.8	1.4
Decrease 21+ mg/ml (to <20)	4.5	4.2	3.2	1.3
Adjustable Voltage (n = 743)				
Same Voltage	72.6	62.1	53.6	16.3
Increase Voltage	13.0	27.7	9.6	7.3
Decrease Voltage	14.4	10.3	10.6	2.7
Capacity (n = 530)				
Same Capacity	37.3	31.8	26.8	8.9
Increase Capacity	29.7	30.4	21.4	8.5
Decrease Capacity	33.1	37.8	23.8	10.6