

Do e-cigarettes attract youths who are otherwise unlikely to use addictive substances? Cross-sectional analyses of Dutch and Flemish secondary school students

Thomas F. Martinelli^{1,2}, Hein De Vries³, Reinskje Talhout⁴, Onno C. P. van Schayck⁵, Gera E. Nagelhout^{1,3}

ABSTRACT

INTRODUCTION E-cigarettes are popular among youth. There are concerns that e-cigarettes attract youth that would otherwise not use addictive substances. While e-cigarettes are thought to be less harmful than tobacco, there is reason for caution. We examined to what extent adolescent e-cigarette users have characteristics associated with increased risk of substance use.

METHODS We collected cross-sectional survey data in 2018 among 10 schools throughout the Netherlands and Belgium (N=2794; age 10–18 years). We examined differences in characteristics and behaviors between e-cigarette ever users and never users, and former users and current users. We also explored differences in use of flavors and use of nicotine.

RESULTS Compared to never-users, e-cigarettes users more often were boys, older, had lower education level, non-Dutch or non-Belgian ethnicity, reported more combustible tobacco use, more smoking family members or family with problematic substance use, more smoking friends, more depressive symptoms, more impulsivity, more delinquent behavior, were more susceptible to smoking, had more positive smoking expectancies, and more ever use of substances. Users of non-tobacco flavored e-cigarettes and e-cigarettes without nicotine had fewer characteristics known to be related to an increased risk of substance use, compared to users of tobacco-flavored e-cigarettes and e-cigarettes with nicotine.

CONCLUSIONS Adolescent e-cigarette users are more like youths who experiment with addictive substances compared to non-users. Thus, e-cigarettes users were more likely to use substances, regardless of whether they used e-cigarettes first. This may not be true for all types of e-cigarettes, as users of e-cigarettes without nicotine or with non-tobacco flavors were less like youths who experiment with substances.

AFFILIATION

- 1 IVO Research Institute, The Hague, The Netherlands
- 2 Tranzo Scientific Center for Care and Wellbeing, School of Social and Behavioral Sciences, Tilburg University, Tilburg, The Netherlands
- 3 Department of Health Promotion, CAPHRI Institute, Maastricht University, Maastricht, The Netherlands
- 4 National Institute for Public Health and the Environment, Bilthoven, The Netherlands
- 5 Department of Family Medicine, CAPHRI Institute, Maastricht University, Maastricht, The Netherlands

CORRESPONDENCE TO

Thomas F. Martinelli. IVO Research Institute, Koningin Julianaplein 10, The Hague, The Netherlands. E-mail: martinelli@ivo.nl ORCID ID: <https://orcid.org/0000-0003-0055-5631>

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INTRODUCTION

Since the introduction of e-cigarettes to the market in 2003¹, their popularity has been rapidly growing^{2,3}. In the field of tobacco control, e-cigarettes are controversial. Some emphasize their potential as a smoking cessation tool⁴, while others raise concerns about their uptake among non-smoking youths⁵. For non-smoking youth, use of e-cigarettes has no health-

related utility but is prevalent nonetheless^{6–9}.

While e-cigarette use is thought to be less harmful than tobacco smoking^{10,11}, there are concerns about potential health risks¹² and about the impact of nicotine that is found in most e-cigarettes^{13,14}. It is argued that e-cigarettes may introduce new generations of youth into addiction and that e-cigarette use is a gateway to tobacco smoking⁵.

According to the gateway hypothesis, e-cigarette use would cause youth to start smoking tobacco, who otherwise would not have started. Nicotine addiction or 'similar hand-to-mouth actions for both behaviors' are considered plausible causal pathways of this hypothesis^{14,15}. However, analyses of associations between e-cigarette use and tobacco smoking shows that this relation may also be explained by shared risk factors^{16,17} and that youths who started with e-cigarettes are not more likely to smoke compared to youths with matched propensity scores¹⁸. Some argue that e-cigarette use is largely concentrated among youth that would otherwise likely have smoked tobacco¹⁹. These findings are more in line with the common liability hypothesis that argues that both behaviors stem from common risk factors, such as increased propensity to experiment with substances²⁰. This implies that youths that use e-cigarettes would be likely to use a range of psychoactive and potentially harmful addictive substances eventually, regardless of whether they used e-cigarettes first.

It is therefore crucial to explore characteristics of youth that use e-cigarettes. To find out whether e-cigarettes introduce new groups of youth into substance use, it is important to assess whether these characteristics are similar to characteristics that are known to be associated with increased risk for youth substance use. If certain types of e-cigarettes attract youth that would otherwise be unlikely to use substances, this may be cause for concern, as e-cigarettes do not fit within a healthy lifestyle for non-smoking youth.

To analyze youths who use e-cigarettes, differences in individual factors related to e-cigarette use (such as knowledge, perceived susceptibility, attitudes, social influence and intention) between never users, smokers, dual users, and e-cigarette users have been examined^{21,22}. Furthermore, the relation between flavor preferences and individual-level factors among these groups have been studied²³. However, no studies have described differences between youths in terms of current e-cigarette use and actual use of flavored e-liquids and nicotine. Analyzing these differences, enables us to: 1) distinguish former from current users, and 2) to explore whether different types of e-cigarettes (in terms of flavors and nicotine) are used by youth

with characteristics that are linked to substance use by literature. This will have important policy implications for regulating different types of e-cigarette products, such as non-tobacco flavored e-liquids.

The availability and marketing of a wide variety of e-liquid flavors other than tobacco flavor (e.g. candy, fruit and beverages) is considered an important factor that attracts youth to e-cigarette use^{24–28}. A representative household study in the US found that the majority (>80%) of youth ever users of tobacco and e-cigarette products started with a non-tobacco flavored product²⁹. For combustible cigarettes, many targeted policies to reduce youth smoking have been developed, including banning a variety of flavors^{30,31}. Recently, many countries extended these policies to e-cigarettes and some countries (including the Netherlands) have announced regulatory actions regarding e-cigarette flavors^{32–36}. To inform such policies, empirical data on adolescent users of different e-cigarette flavors are important.

In the current study, we focus on e-cigarette use by youths from the Netherlands and Flanders (Belgium). The Netherlands and Flanders have similar tobacco and e-cigarette legislation^{37,38}. While some small differences exist (e.g. package warnings), both regions legally treat e-cigarettes like combustible tobacco products. Marketing and sale to minors (aged <18 years) is prohibited, for example. In the Netherlands, around 20000 e-liquids with 245 distinct flavor descriptions were identified in 2017³⁹. Despite the age restriction (≥ 18 years) for the use and sale of e-cigarettes⁴⁰, around 25% of Dutch youth aged 11–16 years had tried or used an e-cigarette in 2019, compared to 17% who had smoked tobacco⁹. However, more than half (55%) of ever users of e-cigarettes have not used them recently, and only about 10% of ever users used e-cigarettes weekly or more⁹. Additionally, a Dutch cohort study from 2018 showed that e-cigarettes without nicotine are more popular than e-cigarettes with nicotine among adolescents⁴¹. For e-cigarette use without nicotine, lower age was associated with higher prevalence. In Belgium, around 25% of youths (aged 15–24 years) have ever tried e-cigarettes⁴². E-cigarette flavors other than tobacco are currently allowed in both countries, however, regulation of non-tobacco flavors was recently announced in the Netherlands³⁶.

To explore the question whether e-cigarettes attract youths who would otherwise be unlikely to experiment with substances, we examined and compared sociodemographic characteristics, intrapersonal characteristics, and behaviors that are known to be related to youth substance use among students at secondary schools in the Netherlands and Flanders. The primary aim of this study was to assess whether these characteristics differed among adolescents that use e-cigarettes compared to non-users. The secondary aim was to perform explorative analyses of: differences between current and former users; differences between users of different e-liquid flavors; and differences between users of e-cigarettes with nicotine versus without nicotine.

METHODS

Participants and procedure

Cross-sectional survey data were collected between September 2018 and December 2019 in different regions throughout the Netherlands and Flanders. High schools are very hard to recruit for research in the Netherlands and Flanders due to the large number of study requests and ongoing studies. Therefore, multiple recruitment strategies were employed. We presented the research as a study on smoking, alcohol, drugs, and other risk behaviors. Several national and regional organizations (including addiction services, school health promotion and youth organizations) were approached to help contact schools. Additionally, a representative selection of 82 schools was approached by telephone, of which 50 received a recruitment package. At 14 schools, we were able to contact the right persons by phone. Furthermore, 10 schools were approached through informal networks within the research group. Finally, 580 schools in the Netherlands and 1343 in Flanders (Belgium) were sent a recruitment e-mail and reminder. In total, 10 schools responded with interest in our study and of those all agreed to participate: 8 schools in the Netherlands, and 2 schools in Flanders. The schools were provided with informed consent forms for the study, which they disseminated among parents and students. Students enrolled through passive consent, meaning they were excluded if they or their parents actively refused participation. Students from first grade to fourth grade participated in the study and 30 gift cards (€30 each) were raffled among participants as incentive.

We provided participating schools with links to online surveys and the school arranged the administration on-site. The Maastricht University Ethical Review Board approved the study (METC 2018-0885).

Measures

Data collection for the current study was part of a larger replication study¹⁷. All measures used, except for measures on e-cigarette flavors, followed from the protocol of the study that was replicated by Leventhal et al.⁴³. All included measures represent characteristics that are known to be associated with experimenting with addictive substances by youths.

E-cigarette and combustible tobacco use

Items based on the Youth Behavior Risk Surveillance⁴⁴ and Monitoring the Future⁴⁵ assessed lifetime and past 30 days (yes/no) use of e-cigarettes and combustible tobacco, which included: combustible cigarettes ('a whole cigarette' and 'just a few puffs'), cigars, cigarillos (small cigars) and hookah (waterpipe) use. To measure whether participants started with e-cigarettes or tobacco cigarettes, they were asked: 'You have indicated that you have used a cigarette or rolling tobacco as well as an electronic cigarette. Which product did you use first?' (conventional cigarette/electronic cigarette). To assess whether the e-cigarettes used contained nicotine, they were asked: 'Did the electronic cigarette(s) you used in the past 6 months contain nicotine?' (Yes all of them/Yes some of them/No none/I don't know). The first two answer categories were coded as 'with nicotine'; 'No, none' coded as 'without nicotine'; and 'I don't know' as 'missing'. This item on nicotine was left out of the survey for participants with the lowest education level. These participants received a shorter questionnaire in which some items were taken out in order to make participation easier for them. Thus, the analyses of e-cigarette use, with versus without nicotine, did not include these participants. E-cigarette use was categorized as never use and ever use, and former use with no past 30-day use and current (past 30 days) use. Combustible tobacco use consisted of three categories: never use, former use with no past 30-day use, and current (past 30-days) use.

E-cigarette flavors

The following item assessed the ever use of flavors:

'Which flavors of electronic cigarettes (shisha pen, e-cigarette, e-smoker, e-hookah, e-cigar), or liquids for electronic cigarettes have you ever used? You can select multiple answers'. The response categories were based on the flavor wheel developed by the Dutch National Institute for Public Health and the Environment⁴⁶ and included 'tobacco', 'mix of tobacco and menthol', 'menthol or mint', 'fruit', 'candy', 'beverages (including alcoholic drinks, such as wine, whiskey etc.)', and 'other (including flavorless)'.

Sociodemographic characteristics

These were self-reported through predefined forced choice items on age, gender, ethnicity, and highest parental education level. Parental education level consisted of the following response categories: 'none', 'primary or secondary vocational', 'vocational', 'secondary higher', and 'college or graduate degree'. The first three categories were coded as 'lower' and the last two as 'higher' education level. Education level of participants was recorded by a researcher during data collection and coded as 'lower' (including practical and lower general secondary education) and 'higher' (higher general education). Dutch and Belgian secondary schools have different systems for education levels; however, education levels are comparable in terms of 'higher' and 'lower' between the two countries. Both countries have distinct grades and classes where the 'higher' grades prepare for college or graduate degree education, while the 'lower' grades prepare for vocational education.

Environmental variables

Several items measured indicators of the environment of the participants. Family history of smoking was measured with the item: 'Does anyone in your immediate family (brothers, sisters, parents, grandparents) have a history of smoking cigarettes?' (yes/no). Peer smoking was assessed with the question: 'In the last 30 days, how many of your five closest friends have smoked cigarettes?' (range: 0–5)⁴⁷. Family history of substance use was measured with two items: 'Has anyone in your immediate family (brothers, sisters, parents, grandparents) ever had problems with: 1) alcohol use, or 2) drug use?' (yes/no).

Intrapersonal factors

Personality traits, mental health and psychological

factors that are linked to experimentation, risky behavior, and smoking behavior, were assessed with measures that have shown adequate psychometric properties in previous youth samples. Impulsivity was measured with the 15-item Temperament and Character Inventory Impulsivity subscale sum score. This assesses the tendency towards acting on instinct without conscious deliberation (e.g. 'I often do things based on how I feel at the moment'; range: 0–5)⁴⁸. Delinquent behavior was assessed with a mean score of frequencies of 11 items that described different behaviors (e.g. stealing, lying to parents; 1=Never to 6=Ten or more times) in the past 6 months⁴⁹. Depressive symptoms were measured with the 20-item Centre for Epidemiologic Studies Depression Scale⁵⁰ composite sum past week frequency rating (e.g. 0=Rarely or none of the time [0–1 days] to 3=Most or all of the time [5–7 days]). Ever use of substances was measured using items from the Youth Behavior Risk Surveillance⁴⁴ and Monitoring the Future⁴⁵ surveys. Ever use of alcohol and 13 separate illicit and prescription substances were assessed (yes/no). Susceptibility to smoking was assessed for both ever and never smokers using the summed average of a three-item index⁵¹, consisting of: 'Would you try smoking a cigarette if one of your best friends offered it to you?', 'Do you think you would smoke in the next 6 months?', and 'Are you curious about smoking?' (Responses: 1=Definitely not, 2=Probably not, 3=Probably yes, 4=Definitely yes). Smoking outcome expectancies were measured with the mean of two items stating: 'I think I might enjoy smoking cigarettes or rolling tobacco' and (reversed) 'I think I might feel bad or sick from smoking cigarettes or rolling tobacco' (Responses: 1=Strongly disagree, 2=Disagree, 3=Agree, 4=Strongly agree), a higher score represents more negative expectancies of smoking⁵².

Statistical analyses

Data were analyzed using SPSS 26. First, to present different characteristics of the total sample, frequencies were presented. To calculate differences in characteristics based on e-cigarette use, former versus current use, flavor categories, and with versus without nicotine, chi-squared and one-way ANOVA tests were performed, with additional *post hoc* analyses. For the analyses of flavors, each flavor category was treated

as a separate subsample despite overlap, since most participants (n=108; 64%) used multiple flavors. This means that some participants were included in more than one subsample. Because of this overlap, statistical calculators for chi-squared and one-way ANOVA tests were used for these analyses.

RESULTS

Total sample characteristics

All students in the recruited schools were eligible to participate and enrolled (N=2845). Data were collected for 2794 participants (98%) that were present at the time of the survey. The total sample had a mean age of 13.89 ± 1.38 years, and 51.9% were girls. Distribution of education level was 55.3% lower and 44.7% higher. Table 1 shows that most participants never used e-cigarettes (78.4%). Among those that used e-cigarettes, there were 381 (13.6% of total sample) former users (but not in the past 30 days) and 223 (8% of total sample) current users (past 30 days). Participants reported having used the following flavors: tobacco and tobacco mix (n=31; 18.2%); menthol or mint (n=37; 21.8%); Fruit (n=136; 80.0%); candy (n=54; 31.8%); beverages including alcohol (n=40; 23.5%); and other or no flavor (n=43; 25.3%). More than half (58%) of the e-cigarette users

indicated that the e-cigarette that they used contained nicotine, and about 21% did not know.

Differences between ever and never users of e-cigarettes

Chi-squared and one-way ANOVA tests showed that users of e-cigarettes (n=603) differed from never users (n=2191) on all measures except for highest parental education level (Table 2). We found that users of e-cigarettes more often were boys; were older; more often had a non-Dutch/Belgian ethnicity; had a lower education level; reported more former and current combustible tobacco use; had a higher prevalence of family history of smoking, problematic alcohol use and problematic drug use; had more smoking peers; more depressive symptoms; higher rates of impulsivity; more delinquent behavior, were more susceptible to smoking; had more positive smoking expectancies; and more often had used other substances.

Characteristics and behaviors of former e-cigarette users versus current users

In Table 3, the differences in characteristics are described between former and current (past 30 days) e-cigarette users. Current users had a lower education level; reported more current combustible tobacco use; had a higher prevalence of family history of smoking; had more smoking peers; more delinquent behavior; were more susceptible to smoking; had more positive smoking expectancies; and more often had used other substances.

Characteristics and behaviors of e-cigarette users by flavors

Table 4 shows differences in characteristics between all (ever, former and current) e-cigarette users split by their (ever) use of different e-cigarette flavors. Most characteristics did not differ significantly between participants who used different flavor categories. Users of tobacco flavored e-cigarettes more often used e-cigarettes that contained nicotine (90%) compared to menthol or mint (68%), fruit (58%), candy (69%), and beverages (66%) flavors. Users of tobacco flavored e-cigarettes had most peers that smoked tobacco (mean=3.3) followed by menthol or mint (mean=3.0), other flavors (mean=2.9), beverages (mean=2.9), candy (mean=2.5), and fruit (mean=2.2). Users of tobacco flavored e-cigarettes also reported the most

Table 1. Frequencies of use of e-cigarette, flavors, and nicotine of total sample (N=2794)

E-cigarettes use	n (%)
Never	2190 (78.4)
Former user (but not in past 30 days)	381 (13.6)
Current user (past 30 days)	223 (7.8)
Flavors used	n (%) ^a
Tobacco (and tobacco mix)	31 (18.2)
Menthol of mint	37 (21.8)
Fruit	136 (80.0)
Candy	54 (31.8)
Beverages (including alcoholic)	40 (23.5)
Other (or no) flavor	43 (25.3)
Contained nicotine?	n (%) ^b
Yes	87 (58.0)
No	63 (33.2)
Don't know	40 (21.1)

a Responses without missing values, n=170. b Responses without missing values, n=190.

Table 2. Characteristics of e-cigarette ever users compared to never users (N=2794)

Characteristics	Ever users of e-cigarettes (n=603) n (%)	Never users of e-cigarettes (n=2191) n (%)	Test statistic value ^a	p
Sex, boys	366 (60.7)	978 (44.6)	48.85	<0.001***
Age (years), mean $\pm$ SD	14.71 $\pm$ 1.24	13.67 $\pm$ 1.33	300.88	<0.001***
Ethnicity, Dutch (or Belgian) ^b	526 (92.9)	2060 (96.4)	12.53	<0.001***
Education level ^c			8.15	0.004**
Lower	293 (60.7)	1001 (53.4)		
Higher	190 (39.3)	873 (46.6)		
Highest education level of parents ^d			0.85	0.358
Lower	149 (36.3)	462 (33.8)		
Higher	262 (63.7)	905 (66.2)		
Combustible tobacco			1001.46	<0.001
Never used	191 (31.7)	1994 (91.0)		
Former use	135 (22.4)	101 (4.6)		
Current past 30 days use (yes)	277 (45.9)	96 (4.4)		
Environmental variables				
Family history of smoking (yes)	521 (86.4)	1540 (70.3)	63.45	<0.001
Family history of problematic alcohol use (yes)	126 (20.9)	197 (9.0)	65.54	<0.001
Family history of problematic drug use (yes)	86 (14.3)	73 (3.3)	105.26	<0.001
Peer smoking, mean $\pm$ SD	2.01 $\pm$ 1.89	0.41 $\pm$ 1.04	750.46	<0.001
Intrapersonal factors				
CESD-depressive symptoms, mean $\pm$ SD	15.23 $\pm$ 11.35	10.23 $\pm$ 8.93	130.80	<0.001
TCI-impulsivity, mean $\pm$ SD	6.48 $\pm$ 2.84	7.98 $\pm$ 2.73	140.621	<0.001
Delinquent behavior, mean $\pm$ SD	19.85 $\pm$ 7.62	14.48 $\pm$ 4.25	509.28	<0.001
Smoking susceptibility, mean $\pm$ SD	6.02 $\pm$ 2.77	3.63 $\pm$ 1.42	837.31	<0.001
Smoking expectancies, mean $\pm$ SD	5.39 $\pm$ 1.74	6.79 $\pm$ 1.32	460.33	<0.001
Other substance ever use	529 (87.7)	792 (36.1)	504.71	<0.001

a Chi-squared tests were performed for categorical variables and one-way ANOVA tests for continuous variables: Pearson's chi-squared value or F-value is reported. b Due to missing values n=2704. c Due to missing values n=2357. d Due to missing values n=1778. **p<0.01, ***p<0.001.

Table 3. Characteristics of e-cigarette ever users compared to current users (N=603)

Characteristics	Former users of e-cigarettes (not in past 30 days) (n=381) n (%)	Current (past 30 days) users of e-cigarettes (n=222) n (%)	Test statistic value ^a	p
Sex, boys	226 (59.3)	140 (62.8)	0.71	0.401
Age (years), mean $\pm$ SD	14.68 $\pm$ 1.25	14.79 $\pm$ 1.22	1.11	0.292
Ethnicity, Dutch (or Belgian) ^b	340 (94.2)	187 (90.8)	2.32	0.128
Education level ^c			18.72	<0.001***
Lower	166 (53.5)	128 (73.6)		
Higher	144 (46.5)	46 (26.4)		

Continued

Table 3. Continued

Characteristics	Former users of e-cigarettes (not in past 30 days) (n=381) n (%)	Current (past 30 days) users of e-cigarettes (n=222) n (%)	Test statistic value ^a	p
Highest education parents^d			0.01	0.921
Lower	99 (36.0)	50 (36.5)		
Higher	176 (64.0)	87 (63.5)		
Combustible tobacco^e			79.26	≤0.001***
Never used	155 (40.7)	36 (16.1)		
Former use (but not current)	103 (27.0)	32 (14.3)		
Current past 30 days use (yes)	123 (32.3)	155 (69.5)		
Dual users who started with e-cigarettes^f (vs combustible cigarettes)	34 (40)	23 (31.9)	1.09	0.296
Environmental variables				
Family history of smoking (yes)	321 (84.3)	201 (90.1)	4.15	0.042*
Family history of problematic alcohol use (yes)	73 (19.2)	53 (23.8)	1.81	0.179
Family history of problematic drug use (yes)	48 (12.6)	38 (17.0)	2.27	0.132
Peer smoking, mean ± SD	1.57 ± 1.75	2.75 ± 1.90	59.46	<0.001***
Intrapersonal factors				
CESD-depressive symptoms, mean ± SD	14.63 ± 10.89	16.23 ± 12.03	2.80	0.095
TCI-impulsivity, mean ± SD	6.57 ± 2.88	6.33 ± 2.76	0.99	0.321
Delinquent behavior, mean ± SD	18.57 ± 6.11	22.04 ± 9.27	30.58	<0.001***
Smoking susceptibility, mean ± SD	5.34 ± 2.49	7.19 ± 2.84	70.09	<0.001***
Smoking expectancies, mean ± SD	5.79 ± 1.61	4.69 ± 1.73	62.01	<0.001***
Other substance ever use	323 (84.8)	207 (92.8)	8.48	0.004**

a Chi-squared tests were performed for categorical variables and one-way ANOVA tests for continuous variables. b Due to missing values n=567. c Due to missing values n=484. d Due to missing values n=412. e Due to missing values n=148. f Due to missing values n=157. *p<0.05, **p<0.01, ***p<0.001.

Table 4. Characteristics of e-cigarette users per flavor category^c

Characteristics	Tobacco flavors (n=31) n (%)	Menthol or mint (n=37) n (%)	Fruit (n=136) n (%)	Candy (n=54) n (%)	Beverages ^d (n=40) n (%)	Other flavors (n=43) n (%)	Test statistic value ^a p	Post hoc test ^c
Sex, boys	23 (74.2)	24 (64.9)	83 (61.0)	36 (66.7)	32 (80.0)	32 (74.4)	0.140	
Age (years), mean ± SD	14.90 ± 1.14	14.81 ± 1.31	14.71 ± 1.15	14.72 ± 1.16	14.73 ± 1.38	14.88 ± 1.29	0.944	
Ethnicity, Dutch	30 (100)	37 (100)	126 (94.7)	51 (98.1)	39 (97.5)	39 (97.5)	0.394	
Education level							0.864	
Lower	13 (61.9)	18 (60.0)	52 (51.5)	20 (48.8)	18 (56.3)	16 (50.0)		
Higher	8 (38.1)	12 (40.0)	49 (48.5)	21 (51.2)	14 (43.8)	16 (50.0)		
Highest education level of parents							0.837	
Lower	5 (27.8)	12 (41.4)	31 (30.7)	13 (31.0)	8 (30.8)	8 (25.0)		
Higher	13 (72.2)	17 (58.6)	70 (69.3)	29 (69.0)	18 (69.2)	24 (75.0)		

Continued

Table 4. Continued

Characteristics	Tobacco flavors (n=31) n (%)	Menthol or mint (n=37) n (%)	Fruit (n=136) n (%)	Candy (n=54) n (%)	Beverages ^d (n=40) n (%)	Other flavors (n=43) n (%)	Test statistic value ^a p	Post hoc test ^c
E-cigarettes								
Ever users of e-cigarettes (not in last 30 days) ^b	3 (9.7)	10 (27.0)	31 (22.8)	11 (20.4)	8 (20.0)	5 (11.6)	0.315	
Current (past 30 days) users of e-cigarettes	28 (90.3)	27 (73.0)	103 (76.9)	43 (79.6)	31 (79.5)	38 (88.4)		
Contained nicotine ^b	28 (93.3)	23 (67.6)	64 (58.2)	34 (69.4)	23 (65.7)	31 (86.1)	<0.001***	T>M*, F***, C***, B**, O>F**
Combustible tobacco							0.054	
Never used ^b	1 (3.2)	2 (5.4)	32 (23.5)	5 (9.3)	9 (22.5)	7 (16.3)		
Ever use (but not current)	5 (16.1)	7 (18.9)	24 (17.6)	11 (20.4)	4 (10.0)	5 (11.6)		
Current past 30 days use (yes)	25 (80.6)	28 (75.7)	80 (58.8)	38 (70.4)	27 (67.5)	31 (72.1)		
Started with e-cigarettes (vs combustible cigarettes)	8 (32.0)	11 (44.0)	22 (35.5)	14 (42.4)	11 (50.0)	10 (38.5)	0.797	
Environmental variables								
Family history of smoking, yes	25 (80.6)	33 (89.2)	111 (81.6)	46 (85.2)	35 (87.5)	35 (81.4)	0.859	
Family history of problematic alcohol use, yes	6 (19.4)	12 (32.4)	25 (18.4)	12 (22.2)	6 (15.0)	5 (11.6)	0.256	
Family history of problematic drug use, yes	4 (12.9)	6 (16.2)	14 (10.3)	7 (13.0)	4 (10.0)	2 (4.7)	0.659	
Peer smoking, mean ± SD	3.26 ± 1.91	2.97 ± 1.94	2.22 ± 1.88	2.52 ± 1.77	2.85 ± 2.03	2.86 ± 1.88	0.033*	Not significant
Intrapersonal factors								
CESD-depressive symptoms, mean ± SD	16.26 ± 12.68	13.92 ± 12.88	14.26 ± 11.32	17.11 ± 13.03	15.18 ± 12.24	17.49 ± 11.51	0.503	
TCI-impulsivity, mean ± SD	6.26 ± 2.84	5.30 ± 2.23	5.29 ± 2.66	5.06 ± 2.80	5.48 ± 3.15	5.53 ± 3.25	0.535	
Delinquent behavior, mean ± SD	27.71 ± 13.64	25.62 ± 11.61	20.85 ± 8.81	24.35 ± 10.01	23.41 ± 1.83	22.88 ± 10.90	0.010*	T>F*
Smoking susceptibility, mean ± SD	8.65 ± 2.44	7.30 ± 2.70	6.74 ± 2.71	7.52 ± 2.85	6.98 ± 2.78	7.79 ± 2.67	0.009**	T>F**
Smoking expectancies, mean ± SD	3.94 ± 1.77	4.19 ± 1.60	4.96 ± 1.68	4.74 ± 1.75	4.50 ± 1.69	4.35 ± 1.70	0.015*	T>F*
Other substance ever use	31 (100)	37 (100)	128 (94.1)	53 (98.1)	38 (95.0)	43 (100)	0.186	

a Chi-squared tests were performed for categorical variables and one-way ANOVA tests for the mean scores. b Fisher's exact test was performed because of values <5. c Each flavor category was treated as a separate subsample despite overlap. Originally n=170, but in current analyses n=371. d Including alcoholic. e Fisher's exact or Tukey's HSD.

*p<0.05, **p<0.01, ***p<0.001.

delinquent behavior, higher smoking susceptibility, and had the most positive smoking expectancies.

Characteristics and behaviors of e-cigarette users by nicotine use

Differences between (ever, former and current)

users of e-cigarettes, with versus without nicotine, are described in Table 5. Users of e-cigarettes with nicotine were significantly more often current e-cigarettes users (89% vs 66% among users without nicotine) and more often current combustible tobacco users (74% vs 46% among users without nicotine).

Table 5. Characteristics of users of e-cigarettes with nicotine compared to users of e-cigarettes without nicotine

Characteristics	Users of e-cigarettes with nicotine (n=87) n (%)	Users of e-cigarettes without nicotine (n=63) n (%)	Test statistic value ^a	p
Sex, boys	58 (66.7)	42 (66.7)	0	1.000
Age (years), mean $\pm$ SD	14.83 $\pm$ 1.17	14.44 $\pm$ 1.17	3.89	0.500
Ethnicity, Dutch ^b	81 (97.6)	58 (92.1)	2.40	0.122
Education level ^{c,d}			1.06	0.304
Lower	37 (58.7)	24 (49.0)		
Higher	26 (41.3)	25 (51.0)		
Highest education level of parents ^e			2.02	0.155
Lower	15 (25.4)	18 (38.3)		
Higher	44 (74.6)	29 (61.7)		
E-cigarettes ^f			11.39	0.001**
Ever users of e-cigarettes (not in last 30 days)	10 (11.5)	21 (34.4)		
Current (past 30 days) users of e-cigarettes	77 (88.5)	40 (65.6)		
Combustible tobacco			24.94	<0.001***
Never used	8 (9.2)	28 (44.4)		
Ever use (but not current)	15 (17.2)	6 (9.5)		
Current past 30 days use (yes)	64 (73.6)	29 (46.0)		
Started with e-cigarettes ^g (vs combustible cigarettes)	15 (25.4)	9 (50.0)	3.88	0.049
Environmental variables				
Family history of smoking, yes	74 (85.1)	51 (81.0)	0.44	0.506
Family history of problematic alcohol use, yes	19 (21.8)	7 (11.1)	2.94	0.087
Family history of problematic drug use, yes	11 (12.6)	5 (7.9)	0.85	0.357
Peer smoking, mean $\pm$ SD	2.91 $\pm$ 1.88	1.60 $\pm$ 1.83	18.04	<0.001***
Intrapersonal factors				
CESD-depressive symptoms, mean $\pm$ SD	15.99 $\pm$ 11.91	12.89 $\pm$ 10.77	2.68	0.104
TCI-impulsivity, mean $\pm$ SD	5.79 $\pm$ 2.92	5.51 $\pm$ 2.53	0.39	0.534
Delinquent behavior, mean $\pm$ SD	22.71 $\pm$ 10.89	18.38 $\pm$ 6.11	8.12	0.005**
Smoking susceptibility, mean $\pm$ SD	7.97 $\pm$ 2.67	5.70 $\pm$ 2.67	26.32	<0.001***
Smoking expectancies, mean $\pm$ SD	4.18 $\pm$ 1.65	5.51 $\pm$ 1.51	25.16	<0.001***
Other substance ever use	86 (98.9)	53 (84.1)	11.66	0.001

a Chi-squared tests were performed for categorical variables and one-way ANOVA tests for the mean scores. b Due to missing values n=146. c Participants with practical education received a shorter version of the questionnaire without the nicotine item and are missing in this analysis. d Due to missing values n=112. e Due to missing values n=106. f Due to missing values n=148. g Due to missing values n=77.

About half of users of e-cigarettes without nicotine, who also smoked tobacco, reported that they started with combustible cigarettes (50%), compared to three quarters (75%) of users of e-cigarettes with nicotine. Those who used e-cigarettes with nicotine had more smoking peers (mean=2.9) compared to those who

used e-cigarettes without nicotine (mean=1.6). Delinquent behavior and smoking susceptibility were higher among participants who used e-cigarettes with nicotine. Users of e-cigarettes with nicotine had more positive smoking expectancies compared to those that used e-cigarettes without nicotine. Almost all (99%)

users of e-cigarettes with nicotine also used other substances, while 84% of users of e-cigarettes without nicotine did so.

DISCUSSION

In this study, we described characteristics and behavior, that are known to be related to the use of addictive substances^{44,48,50-54} of Dutch and Flemish adolescent e-cigarette users compared to non-users. In our sample of high school students, the majority (78%) never tried e-cigarettes. Those that did use e-cigarettes differed in most characteristics and behaviors from never users and used a variety of different e-cigarette flavors. About 58% reported that the e-cigarettes they used contained nicotine and 21% did not know.

Our findings show that users of e-cigarettes had several characteristics that are likely to be found in youth that experiment with substances. Compared to never users, e-cigarette users more often were boys, were older, had lower education level, more often had a non-Dutch or non-Belgian ethnicity, reported more (former and current) combustible tobacco use, more often had smoking family members or family with problematic alcohol and drug use, had more smoking friends, more depressive symptoms, more impulsivity, more delinquent behavior, were more susceptible to smoking, had more positive smoking expectancies, and more ever use of substances. Current use of e-cigarettes was more strongly associated with characteristics related to youth substance use. Compared to former users, current (past 30 days) users of e-cigarettes had a lower education level, reported more current combustible tobacco use, more often had smoking family members, had more smoking peers, reported more delinquent behavior, were more susceptible to smoking, had more positive smoking expectancies, and reported more ever use of substances. This may mean that former users are otherwise unlikely to use substances. Collectively, these findings suggest that adolescent e-cigarette users share several characteristics with youth that are likely to use substances. This is consistent with the common liability model, that argues that e-cigarette users have a higher propensity to use substances in general²⁰. This may indicate that e-cigarettes do not attract youth that otherwise would not use

substances.

However, the answer may not be that simple. Our explorative analyses of differences between flavor categories, showed that users of tobacco flavored e-cigarettes, used e-cigarettes that contained nicotine more often, had more smoking peers and reported more delinquent behavior, higher smoking susceptibility, and had the most positive smoking expectancies, compared to users of non-tobacco flavors, such as candy, fruit, and beverages. We also found that students that reported e-cigarette use with nicotine, more often were current e-cigarette and tobacco users, had more smoking peers and reported more delinquent behavior, higher smoking susceptibility, and the most positive smoking expectancies, compared to users without nicotine. This means that participants that used non-tobacco flavors and e-cigarettes without nicotine share fewer characteristics with youths who are likely to experiment with substances, compared to users of tobacco flavors and nicotine. This may mean that e-cigarettes with non-tobacco flavors or without nicotine attract youth that are otherwise unlikely to use substances. An explanation may be that since they are less likely to be smokers, they do not like tobacco flavors, whereas smokers are more interested in trying tobacco flavored e-cigarettes⁵⁵. Similarly, non-smokers may be less interested in nicotine. Lastly, e-cigarettes without nicotine or tobacco flavors may be perceived as less harmful and less like other substances because they contain no psychoactive substance. However, these analyses were explorative and these findings must be further investigated and confirmed in studies with larger samples of e-cigarette users of different flavors and nicotine.

Implications

First, our findings suggest that adolescent users of e-cigarettes have several characteristics that are known to be related to substance use in youth. Thus, common liability may play an important role in e-cigarette experimentation: users of e-cigarettes may have been likely to experiment with (any) substances, regardless of whether they used e-cigarettes first. Second, non-tobacco flavored e-cigarettes (e.g. fruit, candy, beverages) and e-cigarettes without nicotine appear to be used by youths that share fewer characteristics

with likely substance users. This may mean that non-tobacco flavors and e-cigarettes without nicotine attract youth that otherwise would not have been likely to use substances. Further studies are needed to determine which types of e-cigarettes attract youths who are unlikely to experiment with substances. Furthermore, if reducing the chance of uptake of any e-cigarette use in youth is a policy goal, then banning flavored e-cigarettes and e-cigarettes without nicotine may be a strategy, although future research is required to examine whether this is effective⁵⁶. Concerning flavors, it is important to consider that although they make e-cigarettes attractive to youths, they also make them attractive to adult smokers who want to quit smoking^{55,57}. So far, there is no evidence that certain flavors are linked more with youth smoking initiation, and non-tobacco flavors are more strongly associated with adult smoking cessation compared to tobacco flavors⁵⁸. If e-cigarettes without nicotine would be banned, it would mean that the least harmful products would be banned. Another policy option may be to regulate e-cigarettes via medical prescription, although research is also needed to determine the effectiveness and unwanted effects of this policy.

Limitations

This study used cross-sectional data, so we were unable to determine the direction of found differences. Additionally, a convenience sample was used and the response rate of participating (versus invited) schools was low, which may have resulted in selection bias. However, we do not expect students from participating schools to differ from students at non-participating schools as the response rate of students within participating school classes was high. Therefore, no crucial self-selection bias is expected. We coded Flemish (Belgian) participants as Dutch in the main analyses, because they are part of the (native) ethnic majority of their schools. Thus, we did not assess differences between Dutch and Belgian participants in the analyses, even though (cultural) differences may exist. All outcome variables were non-forced response items in the questionnaire. This has resulted in several missing values in the analyses. Using multiple subcategories, such as e-cigarette use frequency and flavors resulted in low statistical power in some analyses. Furthermore, although coded as former and current users, it may be possible that

the e-cigarette(s) used was not more than a one-time experimentation. Also, susceptibility to smoking was included as an outcome, however, most e-cigarette users had already smoked tobacco. Flavor categories were analyzed as separate samples, while there was overlap with participants having used flavors from multiple categories. As a result, participants that used multiple flavors were included in multiple samples. Further (longitudinal) research is needed to compare substance use (including smoking tobacco) among different subgroups of e-cigarette users.

CONCLUSIONS

We described differences in characteristics and behaviors between e-cigarette users and non-users in Dutch and Flemish youths. We found that users of e-cigarettes have more characteristics that are known to be associated with use of addictive substances, compared to never users. Furthermore, current users had more characteristics related to substance use compared to former users and were more likely to experiment with substances regardless of e-cigarette use. Explorative analyses suggests that users of non-tobacco flavored e-cigarettes and users of e-cigarettes without nicotine have fewer characteristics known to be related to substance use. This may mean that e-cigarettes without nicotine or with flavors other than tobacco attract youths who might otherwise be less likely to try substances. Our results suggest that users of e-cigarettes are more likely to use (any) substances (including tobacco and e-cigarettes) compared to never users, regardless of whether they used e-cigarettes first. However, this may not be true for all types of e-cigarettes and more studies are needed to determine whether e-cigarettes with non-tobacco flavors or without nicotine attract a different type of youth.

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CONFLICTS OF INTEREST

The authors have completed and submitted the ICMJE Form for Disclosure of Potential Conflicts of Interest and none was reported.

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ETHICAL APPROVAL AND INFORMED CONSENT

This research was approved by the Maastricht University Ethical Review Board (METC 2018-0885). Participants enrolled through passive consent after being informed about the study. The Central Committee on Research Involving Human Subjects in the Netherlands required no informed consent forms for non-medical survey research.

DATA AVAILABILITY

The data supporting this research are available from the Data Archiving and Networked Services (DANS) website: <https://doi.org/10.17026/dans-zh6-sank>

AUTHORS' CONTRIBUTIONS

TM performed the analysis of the results and the writing of the manuscript; HV, RT, OS and GN contributed to the design and implementation of the research, discussion of the results, and comments on the manuscript.

PROVENANCE AND PEER REVIEW

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