e-Cigarette Use Among Youth in the United States, 2019

Karen A. Cullen, PhD; Andrea S. Gentzke, PhD; Michael D. Sawdey, PhD; Joanne T. Chang, PhD;
Gabriella M. Anic, PhD; Teresa W. Wang, PhD; MeLisa R. Creamer, PhD; Ahmed Jamal, MBBS;
Bridget K. Ambrose, PhD; Brian A. King, PhD

IMPORTANCE The prevalence of e-cigarette use among US youth increased from 2011 to 2018. Continued monitoring of the prevalence of e-cigarette and other tobacco product use among youth is important to inform public health policy, planning, and regulatory efforts.

OBJECTIVE To estimate the prevalence of e-cigarette use among US high school and middle school students in 2019 including frequency of use, brands used, and use of flavored products.

DESIGN, SETTING, AND PARTICIPANTS Cross-sectional analyses of a school-based nationally representative sample of 19 018 US students in grades 6 to 12 participating in the 2019 National Youth Tobacco Survey. The survey was conducted from February 15, 2019, to May 24, 2019.

MAIN OUTCOMES AND MEASURES Self-reported current (past 30-day) e-cigarette use estimates among high school and middle school students; frequent use (≥20 days in the past 30 days) and usual e-cigarette brand among current e-cigarette users; and use of flavored e-cigarettes and flavor types among current exclusive e-cigarette users (no use of other tobacco products) by school level and usual brand. Prevalence estimates were weighted to account for the complex sampling design.

RESULTS The survey included 10 097 high school students (mean [SD] age, 16.1 [3.0] years; 47.5% female) and 8837 middle school students (mean [SD] age, 12.7 [2.8] years; 48.7% female). The response rate was 66.3%. An estimated 27.5% (95% CI, 25.3%-29.7%) of high school students and 10.5% (95% CI, 9.4%-11.8%) of middle school students reported current e-cigarette use. Among current e-cigarette users, an estimated 34.2% (95% CI, 31.2%-37.3%) of high school students and 18.0% (95% CI, 15.2%-21.2%) of middle school students reported frequent use, and an estimated 63.6% (95% CI, 59.3%-67.8%) of high school students and 65.4% (95% CI, 60.6%-69.9%) of middle school students reported exclusive use of e-cigarettes. Among current e-cigarette users, an estimated 59.1% (95% CI, 54.8%-63.2%) of high school students and 54.1% (95% CI, 49.1%-59.0%) of middle school students reported JUUL as their usual e-cigarette brand in the past 30 days; among current e-cigarette users, 13.8% (95% CI, 12.0%-15.9%) of high school students and 16.8% (95% CI, 13.6%-20.7%) of middle school students reported not having a usual e-cigarette brand. Among current exclusive e-cigarette users, an estimated 72.2% (95% CI, 69.1%-75.1%) of high school students and 59.2% (95% CI, 54.8%-63.4%) of middle school students used flavored e-cigarettes, with fruit, menthol or mint, and candy, desserts, or other sweets being the most commonly reported flavors.

CONCLUSIONS AND RELEVANCE In 2019, the prevalence of self-reported e-cigarette use was high among high school and middle school students, with many current e-cigarette users reporting frequent use and most of the exclusive e-cigarette users reporting use of flavored e-cigarettes.

Supplemental content

CME Quiz at jamanetwork.com/learning and CME Questions page 2131

Author Affiliations: Center for Tobacco Products, US Food and Drug Administration, Silver Spring, Maryland (Cullen, Sawdey, Chang, Anic, Ambrose); Office on Smoking and Health, US Centers for Disease Control and Prevention, Atlanta, Georgia (Gentzke, Wang, Creamer, Jamal, King).

Corresponding Author: Karen A. Cullen, PhD, Center for Tobacco Products, US Food and Drug Administration, 10903 New Hampshire Ave, Silver Spring, MD 20993 (Karen.Cullen@fda.hhs.gov).

Most tobacco product use is initiated during youth and young adulthood.[1] In 2018, an estimated 4.0 million high school students and 840 000 middle school students were current (past 30-day) tobacco product users.[2,3] Since 2014, e-cigarettes have been the most commonly used tobacco product among youth.[2] The popularity of e-cigarettes shaped like USB flash drives and other similar devices likely has contributed to youth uptake; these devices can be used discreetly, may have a high nicotine content, and come in flavors that appeal to youth.[4] Most e-cigarettes contain nicotine, and nicotine exposure during adolescence can harm the developing brain, which continues to develop until about age 25 years.[5,6] Nicotine exposure during adolescence can affect learning, memory, and attention[5,6] and can increase risk for future addiction to other drugs.[1,5]

During 2011-2015, current e-cigarette use among US high school students increased from 1.5% to 16.0%, before declining to 11.3% in 2016 and remaining unchanged at 11.7% in 2017.[7] However, a substantial increase in current e-cigarette use by middle and high school students occurred during 2017-2018,[2,3] leading the Food and Drug Administration Commissioner and the US Surgeon General to declare youth e-cigarette use an epidemic in 2018.[6,8] A 2018 Surgeon General's Advisory called for aggressive steps to reduce e-cigarette use among youth, including evidence-based population-level strategies.[6,9,10] The advisory reinforced the importance of continued surveillance of e-cigarette use among youth, which is critical to inform the development, implementation, and sustainment of such strategies.[6]

However, whether the recent increase in e-cigarette use continued into 2019 is unknown. The objectives of this study were to (1) assess the most recent prevalence of self-reported current (past 30-day) e-cigarette use among US high school and middle school students; (2) describe use characteristics among current e-cigarette users; and (3) describe flavored e-cigarette use among current exclusive e-cigarette users.

Methods

Data Source

The National Youth Tobacco Survey (NYTS) study protocol was approved by the institutional review board of the US Centers for Disease Control and Prevention (CDC). Participating schools determined whether parental consent would be received actively, whereby parents provided written permission allowing their child to participate in the survey, or passively, whereby parents signed and returned the permission form only if they did not want their child to participate in the survey. Parental consent and respondent assent were obtained for all participants. The NYTS is a cross-sectional, school-based, self-administered questionnaire that has been administered to US high school (grades 9-12) and middle school (grades 6-8) students since 1999.[11] A 3-stage cluster sampling procedure, including primary sampling units, schools, and classrooms within schools, is used to generate a nationally representative sample of US students attending public and private schools in grades 6 through 12. Detailed information about the

annual survey is available elsewhere.[11] Race and ethnicity were separately assessed by self-report with fixed category response options. Students could select 1 or more of the following categories for race: American Indian or Alaska Native, Asian, black or African American, Native Hawaiian or other Pacific Islander, or white. Students could select whether they were Hispanic, Latino, Latina, or of Spanish origin.

During 1999-2018, the survey was conducted using a paper-and-pencil questionnaire. The 2019 survey data were collected solely using an electronic mode of survey administration including skip patterns and product images following the implementation of an electronic pilot survey administration in 2018.[12] Data collection for the 2019 survey occurred from February 15, 2019, to May 24, 2019. Data were collected offline using a survey application that was loaded onto an electronic tablet.

Students absent on the day of survey administration could participate using a web-based version of the questionnaire, which was programmed to mimic the tablet-based application. Skip patterns were programmed in the 2019 questionnaire to reduce respondent burden; respondents were not asked about tobacco-specific use behaviors if they did not report using each respective tobacco product. Each product-specific section began with a product description and included non-branded example images. Brand examples also were included in the product description text for select tobacco products, which were identified as top brands based on dollar sales for the 52 weeks ending on April 21, 2018, using Nielsen Scantrack data[13] for total US convenience stores and all outlets combined. JUUL was added as a brand example to the e-cigarette section description in 2019; all other brand examples in 2019 were included in the previous survey year. The questions used in this study are listed in the eAppendix in the Supplement.

Measures

Current use of e-cigarettes was defined as use on 1 or more days of the past 30 days. Current exclusive e-cigarette users were those who reported past 30-day use of e-cigarettes but no other tobacco product. To be consistent with previous literature on frequent use,[6] among current e-cigarette users, frequency of use of e-cigarettes was dichotomized as use on 20 or more days or fewer than 20 days during the past 30 days. Measures of current use of any tobacco product and of cigarettes were

<div style="border: 1px solid #ccc; padding: 10px;">

Key Points

Question What is the estimated prevalence of the current (past 30-day) use of e-cigarettes among US high school and middle school students in 2019?

Findings In this cross-sectional survey conducted in 2019 that included 19 018 participants, the prevalence of self-reported current e-cigarette use was 27.5% among high school students and 10.5% among middle school students.

Meaning In 2019, the prevalence of self-reported current e-cigarette use was high among US high school and middle school students.

</div>

included to provide context for the current e-cigarette use estimates. Current "any tobacco product use" was defined as use of 1 or more tobacco products (cigarettes, e-cigarettes, cigars [cigars/cigarillos/little cigars], smokeless tobacco [chewing tobacco, snuff, dip, snus, and dissolvable tobacco], hookah tobacco, pipe tobacco, and bidis) on 1 or more days of the past 30 days. Current use of cigarettes was defined as use on 1 or more days of the past 30 days.

Usual brand use was first assessed in 2019 among current e-cigarette users by the question, "During the past 30 days, what brand of e-cigarettes did you usually use?" Respondents could select JUUL, blu, Logic, MarkTen, NJOY, Vuse, some other brand not listed here, or indicated that they did not have a usual brand of e-cigarette. Those who selected "Some other brand not listed here" could provide a write-in response; write-in responses were recoded into valid responses (2 additional brands, SMOK and Suorin, are reported based on the write-in responses).

Use of flavored e-cigarettes was determined by the response to the question, "Which of the following tobacco products that you used in the past 30 days were flavored to taste like menthol (mint), alcohol (wine, cognac), candy, fruit, chocolate, or other sweets?" Participants could select from a list of options to indicate the flavored tobacco product(s) they had used. Current e-cigarette users who selected e-cigarettes from the list of tobacco products were categorized as flavored e-cigarette users; current e-cigarette users who indicated "I did not use any flavored tobacco products in the past 30 days" were categorized as unflavored e-cigarette users, and those who skipped this question were categorized as unknown flavored e-cigarette users. Beginning in 2016, respondents who indicated they used 1 or more flavored tobacco products were asked, "What flavors of tobacco products have you used in the past 30 days?" Participants could select 1 or more of the following responses: menthol or mint, clove or spice, fruit, chocolate, alcoholic drink (such as wine, cognac, margarita, or other cocktails), candy, desserts, or other sweets, or some other flavor not listed here. Those who indicated "some other flavor not listed here" could specify with a write-in response.

Statistical Analysis

Statistical analyses were conducted using SAS-callable SUDAAN (SUDAAN version 11.0.3, Research Triangle Institute) to account for the complex sampling design. A weighting factor was applied to each student record to adjust for nonresponse and for varying probabilities of selection; weights were adjusted to ensure that the weighted proportions of students in each grade matched national population estimates. The weight adjustment for student nonresponse was made by sex and grade within schools so that the sum of student weights over participating students within a school matched the total enrollment by grade and sex in the school during data collection. At the school level, nonresponse adjustments used school type (public, nonpublic), National Center for Educational Statistics locale indicator, and school-level poverty status. Weighted prevalence estimates and 95% CIs for current use of any tobacco product, cigarettes, and

e-cigarettes were assessed among high school and middle school students separately. Estimates are considered statistically unreliable and are suppressed if the unweighted denominator is less than 50 or the relative standard error is greater than 30%.

Among current e-cigarette users in high school and middle school, frequency of e-cigarette use (<20 days vs ≥20 days; daily use on all 30 days) was reported. Usual brand of e-cigarette used in the past 30 days was reported among current e-cigarette users only. Analyses of past 30-day flavored e-cigarette use, and specific flavor types used, were restricted to current exclusive e-cigarette users to reflect flavor types used in e-cigarettes only. Supplemental analyses compared characteristics of JUUL users with those who reported use of another brand or indicated no usual brand.

In 2018, a pilot survey of the NYTS was conducted using 2 electronic versions, one programmed to align with the paper-based survey and the other to take advantage of electronic administration, including programmed skip patterns and tobacco product images[12]; minimal differences in tobacco product use estimates were observed between the 2 electronic pilot survey versions in 2018.[12] However, due to various questionnaire improvements and the change in survey administration mode in 2019, statistical testing was not conducted for changes in tobacco product use behaviors (prevalence, frequent use) between 2019 and the previous year. Trends in each specific flavor type used from 2016 to 2019 were examined separately, with the annual percentage change calculated using Joinpoint regression[14]; analyses were not conducted for flavor categories if any of the estimates were suppressed. Two-sided *P* values less than .05 were considered statistically significant. Because of the lack of adjustment for multiple comparisons, findings from analyses of differences for flavored e-cigarette use and across survey years have the potential for type I error.

Results

A total of 19 018 high school and middle school students participated in the 2019 NYTS (overall response rate: 66.3%; product of school [77.2%] and student [85.8%] participation rates) (**Table 1**). Of these, 9099 were female (47.7%) and 9352 were non-Hispanic white (54.9%). The distribution of participants was similar across grades, ranging from 2306 (12.9%) in 12th grade to 3024 (14.6%) in seventh grade. Participants who indicated that they were ungraded, were in another grade, or who did not respond to that question (n = 84, 0.4%) were excluded from analyses stratified by school type. Among the 10 097 high school students who participated in the survey, the mean (SD) age was 16.1 (3.0) years and 47.5% were female; among the 8837 middle school students who participated, the mean (SD) age was 12.7 (2.8) years and 48.7% were female.

In 2019, an estimated 27.5% (95% CI, 25.3%-29.7%) of high school students reported current use of e-cigarettes and an estimated 5.8% (95% CI, 4.6%-7.3%) reported smoking cigarettes (**Table 2**). In total, an estimated 31.2% (95% CI, 29.1%-33.5%) of high school students reported current use of any

Table 1. Sociodemographic Characteristics of High School and Middle School Students, 2019

Characteristic[a]	High School Students		Middle School Students	
	Unweighted, No.	Weighted % (95% CI)	Unweighted, No.	Weighted % (95% CI)
Sex				
Female	4766	47.5 (44.8-50.1)	4310	48.7 (47.5-49.9)
Male	5291	52.5 (49.9-55.2)	4471	51.3 (50.1-52.5)
Race and ethnicity				
Non-Hispanic white	4698	52.9 (47.1-58.6)	3818	50.9 (46.0-55.7)
Non-Hispanic black	1189	12.6 (9.3-16.8)	1092	12.6 (9.9-15.9)
Hispanic	2897	24.0 (20.3-28.2)	2639	26.1 (22.7-29.7)
Non-Hispanic other race	1198	10.5 (8.6-12.8)	976	10.4 (9.1-11.9)
Grade				
6th			2944	33.2 (31.1-35.4)
7th			3024	33.3 (31.6-35.1)
8th			2869	33.5 (31.7-35.2)
9th	2790	27.4 (25.8-29.0)		
10th	2499	25.7 (24.4-27.0)		
11th	2502	23.9 (22.9-24.8)		
12th	2306	23.1 (21.8-24.4)		

[a] There were 116 respondents (0.54%) missing data on sex, 446 respondents (2.3%) missing data on race and ethnicity, and 84 respondents (0.39%) missing data on grade level.

Table 2. Estimated Percentage of Tobacco Use in the Past 30 Days, by Product and School, 2019

Tobacco Product	High School Students		Middle School Students	
	Unweighted, No.	Weighted % (95% CI)	Unweighted, No.	Weighted % (95% CI)
e-Cigarettes[a]	2709	27.5 (25.3-29.7)	902	10.5 (9.4-11.8)
Cigarettes[b]	549	5.8 (4.6-7.3)	190	2.3 (1.8-2.9)
Any tobacco product[c]	3091	31.2 (29.1-33.5)	1085	12.5 (11.2-13.9)

[a] Past 30-day use of e-cigarettes was determined by asking, "During the past 30 days, on how many days did you use e-cigarettes?" Those who reported using e-cigarettes on 1 or more days of the past 30 days were considered current (past 30-day) users. There were 96 respondents (0.51%) missing data on past 30-day e-cigarette use.

[b] Past 30-day use of cigarettes was determined by asking, "During the past 30 days, on how many days did you smoke cigarettes?" Those who reported smoking cigarettes on 1 or more days of the past 30 days were considered current (past 30-day) users. There were 37 (0.20%) missing data on past 30-day cigarette smoking.

[c] Any tobacco product use was defined as use of any tobacco product (e-cigarettes, cigarettes, cigars, smokeless tobacco, hookahs, pipe tobacco, dissolvables, snus, and/or bidis) on 1 or more days in the past 30 days. There were 13 (0.10%) respondents missing data on past 30-day any tobacco use.

tobacco product. Among middle school students, an estimated 10.5% (95% CI, 9.4%-11.8%) reported current e-cigarette use and 2.3% (95% CI, 1.8%-2.9%) reported current cigarette smoking. In total, an estimated 12.5% (95% CI, 11.2%-13.9%) of middle school students reported current use of any tobacco product. Data on current e-cigarette, cigarette, and any tobacco use from 2016 to 2018 can be found in eTable 1 in the Supplement.

Among current e-cigarette users, an estimated 34.2% (95% CI, 31.2%-37.3%) of high school students and 18.0% (95% CI, 15.2%-21.2%) of middle school students reported using e-cigarettes on 20 or more days in the past 30 days (Table 3). An estimated 21.4% (95% CI, 19.0%-24.0%) of current e-cigarette users in high school and 8.8% (95% CI, 6.9%-11.2%) of users in middle school reported daily e-cigarette use (data on 2018 frequency of e-cigarette use can be found in eTable 2 in the Supplement). An estimated 63.6% (95% CI, 59.3%-67.8%) of high school students and 65.4% (95% CI, 60.6%-69.9%) of middle school students reported exclusive use of e-cigarettes. Among current e-cigarette users, an estimated 13.8% (95% CI, 12.0%-15.9%) of high school users and 16.8% (95% CI, 13.6%-20.7%) of middle school users reported

not having a usual brand of e-cigarettes, and an estimated 59.1% (95% CI, 54.8%-63.2%) of high school users and 54.1% (95% CI, 49.1%-59.0%) of middle school users reported JUUL as their usual e-cigarette brand.

Among high school students, an estimated 72.2% (95% CI, 69.1%-75.1%) of current exclusive e-cigarette users reported current use of flavored e-cigarettes. Among middle school students, an estimated 59.2% (95% CI, 54.8%-63.4%) of current exclusive e-cigarette users reported current use of flavored e-cigarettes. The most frequently reported flavor categories were fruit (high school: 66.1% [95% CI, 62.4%-69.5%]; middle school: 67.7% [95% CI, 62.6%-72.5%]), menthol or mint flavor (high school: 57.3% [95% CI, 53.3%-61.3%]; middle school: 31.1% [95% CI, 25.6%-37.2%]), and candy, desserts, or other sweets (high school: 34.9% [95% CI, 31.3%-38.7%], middle school: 38.3% [95% CI, 32.6%-44.2%]). Data on flavored e-cigarette use in 2018 can be found in eTable 2 in the Supplement. Given the large proportion of JUUL use among youth, differences in the use of flavored e-cigarettes and specific flavor types used were examined among JUUL users and compared with those who reported use of another brand or indicated no usual brand

Table 3. Frequency of Use, Flavored Use, Flavor Types, and Usual Brand Among e-Cigarette Users, 2019

	High School Students		Middle School Students	
	Unweighted, No.	% (95% CI)	Unweighted, No.	% (95% CI)
Among Past 30-d e-Cigarette Users[a]				
Frequency of e-cigarette use in the past 30 d				
<20 d	1792	65.8 (62.7-68.8)	749	82.0 (78.8-84.8)
≥20 d	917	34.2 (31.2-37.3)	153	18.0 (15.2-21.2)
Daily e-cigarette use[b]	564	21.4 (19.0-24.0)	80	8.8 (6.9-11.2)
Exclusive e-cigarette use	1740	63.6 (59.3-67.8)	612	65.4 (60.6-69.9)
Usual brand[c]				
No usual brand	383	13.8 (12.0-15.9)	138	16.8 (13.6-20.7)
JUUL	1520	59.1 (54.8-63.2)	496	54.1 (49.1-59.0)
SMOK	205	7.8 (6.0-10.1)	40	4.1 (2.7-6.1)
Suorin	110	3.1 (2.1-4.5)	NA[d]	NA[d]
blu	77	2.6 (1.9-3.6)	32	4.0 (2.4-6.6)
Vuse	56	2.1 (1.4-3.1)	43	4.6 (3.0-7.0)
NJOY	32	1.2 (0.7-2.1)	NA[d]	NA[d]
Logic	23	0.8 (0.5-1.4)	NA[d]	NA[d]
MarkTen	20	0.8 (0.4-1.4)	NA[d]	NA[d]
Some other brand	256	8.4 (7.2-10.5)	90	10.5 (8.1-13.5)
Among past 30-d Exclusive e-Cigarette Users[e]				
Flavored e-cigarette use[f]				
Flavored	1257	72.2 (69.1-75.1)	376	59.2 (54.8-63.4)
Unflavored	440	25.4 (22.5-28.5)	216	38.1 (33.7-42.8)
Unknown	43	2.5 (1.7-3.6)	20	2.7 (1.6-4.5)
Flavor types reported used[g]				
Fruit	832	66.1 (62.4-69.5)	248	67.7 (62.6-72.5)
Menthol or mint	703	57.3 (53.3-61.3)	132	31.1 (25.6-37.2)
Candy, desserts, or other sweets	430	34.9 (31.3-38.7)	139	38.3 (32.6-44.2)
Chocolate	26	1.8 (1.2-2.9)	30	8.1 (5.1-12.7)
Alcoholic drink	28	2.3 (1.5-3.5)	14	4.4 (2.5-7.7)
Clove/spice	NA[d]	NA[d]	NA[d]	NA[d]
Other flavor not listed	112	8.8 (7.2-10.7)	40	9.4 (6.7-13.0)

Abbreviation: NA, not available.

[a] Past 30-day use of e-cigarettes was determined by asking, "During the past 30 days, on how many days did you use e-cigarettes?" Current use was defined as use on 1 or more days in the past 30 days.

[b] Daily e-cigarette use is defined as reported use on all 30 of the past 30 days.

[c] For 2019, usual brand of e-cigarettes was determined by response to the question, "During the past 30 days, what brand of e-cigarettes did you usually use?" Participants could select from a list of options to designate their usual brand used including I did not use a usual brand, blu, JUUL, Logic, MarkTen, NJOY, Vuse, or some other brand not listed here (specify). Those who selected "some other brand not listed here" could specify with a write-in response. The write-in responses were examined (n = 725) and recoded. Only recoded responses for SMOK and Suorin were included in this report. There were 38 students (1%) missing brand data.

[d] Data are statistically unreliable due to unweighted denominator less than 50 or relative standard error greater than 30%.

[e] Exclusive e-cigarette use was defined as use of only e-cigarettes in the past 30 days.

[f] Flavored e-cigarette use was determined by the response to the question, "Which of the following tobacco products that you used in the past 30 days were flavored to taste like menthol (mint), alcohol (wine, cognac), candy, fruit, chocolate, or any other flavors? (Select one or more)." Participants could select from a list of options to designate the flavored tobacco product they used in the past 30 days including cigars, cigarillos, or little cigars; chewing tobacco, snuff, or dip; e-cigarettes; tobacco in a hookah or waterpipe; pipe filled with tobacco (not waterpipe); snus; dissolvable tobacco products; bidis; roll-your-own cigarettes; or I did not use any flavored tobacco products in the past 30 days. Among those who reported past 30-day e-cigarette use, those who selected e-cigarettes were defined as current flavored e-cigarette users. Respondents who were past 30-day e-cigarette users and did not select e-cigarettes or selected I did not use any flavored tobacco products in the past 30 days were classified as unflavored. Respondents missing a response were classified as unknown.

[g] Among those who used flavored e-cigarettes in the past 30 days, flavor type was determined by responses to the question, "What flavors of tobacco products have you used in the past 30 days? (Select one or more)." Participants could select from a list of options to designate the flavor they had used including menthol or mint; clove or spice; fruit; chocolate; alcoholic drink (such as wine, cognac, margarita, or other cocktails); candy, desserts, or other sweets; or some other flavor not listed here (specify). Respondents could select 1 or more of the 7 prespecified flavors. Those who indicated some other flavor not listed here could specify with a write-in response; the qualitative assessment of these responses (n = 358) is not included in this report. Those who did not select any of the prespecified flavors were set to missing.

Figure. Flavor Types Reported Among Current Exclusive e-Cigarette Users Who Reported Flavored e-Cigarette Use, 2016-2019
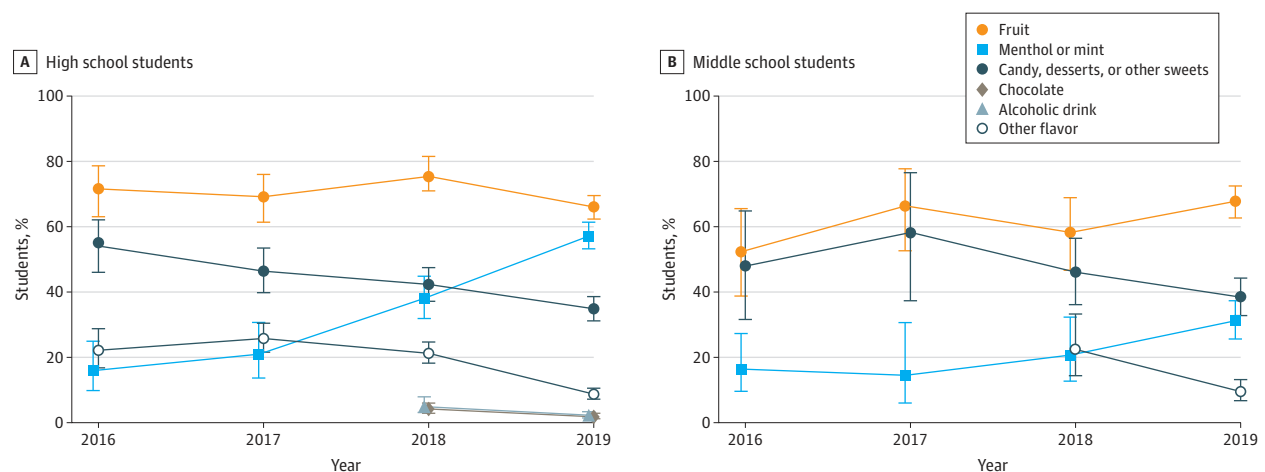
The error bars indicate 95% CIs. Data are statistically unreliable due to unweighted denominator less than 50 or relative standard error greater than 30%. Among high school students, estimates of chocolate (2016-2017), alcohol (2016-2018), and clove/spice (2016-2019) were suppressed. Among middle school students, estimates of chocolate (2016-2018), alcohol (2016-2018), clove/spice (2016-2019), and other (2016-2017) were suppressed.

Among past 30-day flavored e-cigarette users, flavor type was determined by responses to the question, "What flavors of tobacco products have you used in the past 30 days? (Select one or more)." Participants could select from a list of options to designate the flavor they had used including menthol or mint; clove or spice; fruit; chocolate; alcoholic drink (such as wine, cognac, margarita, or other cocktails); candy, desserts, or other sweets; or some other flavor not listed here (specify). Respondents could select 1 or more of the 7 prespecified flavors. Those who indicated "some other flavor not listed here" could specify with a write-in response; the qualitative assessment of these responses (n = 358) is not included in this report. Those who did not select any of the prespecified flavors were set to missing.

Past 30-day use of e-cigarettes was determined by asking, "During the past 30 days, on how many days did you use e-cigarettes?" Current use was defined use on 1 or more days in the past 30 days.

Exclusive electronic cigarette use was defined as use of only e-cigarettes in the past 30 days.

Flavored e-cigarette use was determined by the response to the question, "Which of the following tobacco products that you used in the past 30 days were flavored to taste like menthol (mint), alcohol (wine, cognac), candy, fruit, chocolate, or any other flavors? (Select one or more)." Participants could select from a list of options to designate the flavored tobacco product they used in the past 30 days including cigars, cigarillos, or little cigars; chewing tobacco, snuff, or dip; e-cigarettes; tobacco in a hookah or waterpipe; pipe filled with tobacco (not waterpipe); snus; dissolvable tobacco products; bidis; roll-your-own cigarettes; or I did not use any flavored tobacco products in the past 30 days. Among those who reported past 30-day e-cigarette use, those who selected e-cigarettes were defined as current flavored e-cigarette users. Respondents who were past 30-day e-cigarette users and did not select e-cigarettes or selected I did not use any flavored tobacco products in the past 30 days were classified as unflavored. Respondents missing a response were classified as unknown.

Between 2018 and 2019, the National Youth Tobacco Survey changed from paper and pencil to electronic administration. Please see the Methods section for a complete description of changes. Although direct comparisons between 2018 and 2019 are not conducted, trends using multiple years of data are not as affected by the mode change.

(eTable 3 in the Supplement). In sensitivity analyses recoding the 358 "other" flavor write-in responses, small increases in reported use of fruit and candy, desserts, and other sweet flavors were observed. However, the overall patterns did not change and the percentage of current users of fruit- and menthol- or mint-flavored e-cigarettes remained similar.

Sample sizes (overall response rates) for 2016, 2017, and 2018, were 20 675 (71.2%), 17 872 (68.1%), and 20 189 (68.2%), respectively.[11] From 2016 to 2019, there were significant changes in the reported flavor types used by current exclusive e-cigarette users in high school (**Figure**, A; eTable 4 in the Supplement). Current use of menthol- or mint-flavored e-cigarettes increased among current exclusive e-cigarette users in high school from 16.0% (95% CI, 9.8%-25.0%) in 2016 to 57.3% (95% CI, 53.3%-61.3%) in 2019 (annual percentage change = 55.2% [95% CI, 37.4%-75.2%]; P = .004). Current use of candy-, dessert-, and other sweet-flavored e-cigarettes decreased from 54.1% (95% CI, 46.0%-62.0%) in 2016 to 34.9% (95% CI, 31.3%-38.7%) in 2019 (annual percentage change = −13.3% [95% CI, −18.4% to −8.0%]; P = .009), and

use of fruit-flavored e-cigarettes did not significantly change (P > .05). No significant trends in the use of menthol- or mint-, candy-, or fruit-flavored e-cigarettes were observed among current exclusive e-cigarette users in middle school (Figure, B; eTable 4 in the Supplement).

Discussion

In 2019, the prevalence of self-reported current e-cigarette use was high among US high school and middle school students, while self-reported current cigarette smoking among high school students has declined to historic lows.[2] With the assumption that the prevalence estimates from this survey are nationally representative and could be used to project to national population totals for US high school and middle school students, the data would suggest that in 2019, an estimated 4.1 million high school students and 1.2 million middle school students currently use e-cigarettes, an estimated 1.6 million students reported frequent use of e-cigarettes, an estimated 970 000 students use e-cigarettes daily, and an estimated

2.4 million exclusive e-cigarette users use flavored e-cigarettes. The data also would suggest that among these exclusive e-cigarette users, an estimated 1.6 million high school and middle school students use fruit-flavored e-cigarettes, an estimated 1.2 million use menthol- or mint-flavored e-cigarettes, and an estimated 830 000 use candy-, dessert-, or other sweet-flavored e-cigarettes.

The results of this survey are particularly concerning given relatively high exposure to nicotine through the use of nicotine salt-based e-cigarette products such as JUUL,[15] which was the most commonly reported brand among youth using e-cigarettes in 2019. Nicotine salts allow particularly high levels of nicotine to be inhaled more easily, with less irritation than the free-base nicotine that has traditionally been used in tobacco products including e-cigarettes.[6] For young people, this is of particular concern because it could promote the development of nicotine dependence, making it easier to initiate and proceed to regular e-cigarette use or transition to cigarette or other combustible tobacco product use.[6] Furthermore, the aerosol that users inhale and exhale from e-cigarettes can potentially expose themselves and bystanders to other harmful substances including heavy metals, volatile organic compounds, and ultrafine particles that can be inhaled deeply into the lungs.[5,6]

This is, to our knowledge, the first national study to show the increasing popularity of menthol- and mint-flavored e-cigarettes among youth. In this study, the 2016 data showed that menthol or mint flavors were selected much less frequently than fruit- or candy-flavored e-cigarettes by high school students. This is consistent with findings from the Population Assessment of Tobacco and Health Study (2014-2015, wave 2), which found that mint- and menthol-flavored e-cigarettes were the fourth most popular flavor among youth aged 12 to 17 years.[16] Additionally, another study conducted in 2014-2015 found that among youth aged 12 to 17 years, mint/menthol (24%) was ranked the fourth most popular flavor, behind fruit (76%), candy/other sweets (57%), and other (46%).[17] However, the current study found a significant increase in reported use of menthol- or mint-flavored e-cigarettes among high school students between 2016 and 2019 to levels near that of fruit-flavored e-cigarettes.

In November 2018, the Food and Drug Administration announced several new steps to protect youth, including restricting sales of flavored e-cigarettes (other than tobacco, menthol, mint, or nonflavored) to physical locations with age restrictions or online with heightened age-verification procedures.[18] After that announcement, certain manufacturers announced they would stop selling flavored e-cigarettes, except for mint/menthol.[19,20] However, after the announcement, stores could sell any remaining stock of flavored products from these manufacturers; moreover, mint-, menthol-, and tobacco-flavored products continued to be available in retail stores.[20] Additionally, flavored pods, in particular, were still available online[20] and youth could use compatible nonbranded flavored pods in their devices, consistent with recent reports showing increases in sales of these compatible pods in fruit flavors.[21] While data collection for the 2019 NYTS occurred after the announcement by certain manufac-

turers, supplemental analyses from the 2019 survey showed that most youth users were using flavored e-cigarettes in the spring of 2019, most of whom reported using mint or menthol flavors. The shift in the availability of e-cigarette flavors, due in part to the removal of flavors other than mint or menthol by certain manufacturers, may partially explain the increase in use of menthol- or mint-flavored e-cigarettes over time in this study. However, use of fruit-flavored e-cigarettes remains high among e-cigarette users in both high school and middle school.

Usual brand of e-cigarette used was first assessed in the 2019 survey. Most youth who were current e-cigarette users reported JUUL as their usual e-cigarette brand in 2019; the next most frequent response was "no usual brand." This mirrors trends in retail sales data showing that JUUL has held the majority of the market share of US e-cigarette sales since December 2017.[4,22] In the past year, public awareness of JUUL use by youth has expanded due to coverage in the popular media[23-25] and public health messaging[6] focused on the risks of e-cigarette use among youth. Estimates for JUUL use from the 2019 survey are based on a measure asking about usual brand used during the past 30 days. This question may underestimate use if casual users do not identify JUUL as their usual brand. Conversely, as the term "Juuling" has become synonymous for "vaping" for some youth,[26] youth users may believe they are using a JUUL device when they are actually using a device or pod that mimics this brand. Furthermore, youth users may incorrectly identify using JUUL due to brand recognition alone, which could result in an overestimation of use.[27]

Limitations

This study has several limitations. First, several improvements were made to the NYTS in 2019, including switching from a paper-and-pencil to an electronic survey administration, adding skip patterns and unbranded example product images, and updating brand examples to reflect the current tobacco marketplace. Although brand examples in the survey are added or removed as needed to account for changes in the current tobacco product market share, the rapid increase in JUUL use before 2019[4,20] and subsequent inclusion as a brand example in 2019 may limit the comparability of e-cigarette and overall tobacco product use estimates with previous years. As the exact magnitude of the effect of these survey improvements in 2019 cannot be fully quantified, direct statistical comparisons of tobacco product use estimates between 2019 and previous years were not conducted. However, trend analyses of flavor types used during 2016 to 2019 were conducted; this analysis uses more data points and is thus less dependent on methods changes during a single year.

Second, for the survey measure assessing flavor types used, response options allowed respondents to check all that apply, rather than a forced-choice option, which may yield different results.

Third, information on flavor types used for individual tobacco products cannot be determined for youth who report using multiple flavored tobacco products. Therefore, data on flavor types used were only reported among current exclusive e-cigarette users for the current analysis, which

account for approximately two-thirds of all current e-cigarette users.

Fourth, the response rate was 66.3% and there may be differences in tobacco use between those who participated in the survey and those who did not.

Fifth, data were collected from youth who attended public or private school; therefore, the findings may not be generalizable to youth who are homeschooled, have dropped out of school, or are in detention centers. However, data from the Current Population Survey indicate that nearly 97% of US youth aged 10 to 17 years were enrolled in a traditional school in 2017.[28]

Sixth, the underlying assumptions used for the population estimates should be considered in interpreting the data for projections to national estimates of e-cigarette use.

Conclusions

In 2019, the prevalence of self-reported e-cigarette use was high among high school students and middle school students, with many current e-cigarette users reporting frequent use and most of the exclusive e-cigarette users reporting use of flavored e-cigarettes.

REFERENCES

1. US Department of Health and Human Services. *Preventing Tobacco Use Among Youth and Young Adults: A Report of the Surgeon General*. Rockville, MD: US Dept of Health and Human Services, Public Health Service, Office of the Surgeon General;2012.

2. Gentzke AS, Creamer M, Cullen KA, et al. Vital signs: tobacco product use among middle and high school students—United States, 2011–2018. *MMWR Morb Mortal Wkly Rep*. 2019;68(6):157-164. doi:10.15585/mmwr.mm6806e1

3. Cullen KA, Ambrose BK, Gentzke AS, Apelberg BJ, Jamal A, King BA. Notes from the field: use of electronic cigarettes and any tobacco product among middle and high school students—United States, 2011-2018. *MMWR Morb Mortal Wkly Rep*. 2018;67(45):1276-1277. doi:10.15585/mmwr.mm6745a5

4. King BA, Gammon DG, Marynak KL, Rogers T. Electronic cigarette sales in the United States, 2013-2017. *JAMA*. 2018;320(13):1379-1380. doi:10.1001/jama.2018.10488

5. US Department of Health and Human Services. *E-Cigarette Use Among Youth and Young Adults: A Report of the Surgeon General*. Atlanta, GA: US Dept of Health and Human Services, Centers for Disease Control and Prevention, National Center for Chronic Disease Prevention and Health Promotion, Office on Smoking and Health; 2016.

6. US Department of Health and Human Services. Surgeon General's advisory on e-cigarette use among youth. https://e-cigarettes.surgeongeneral.gov/documents/surgeon-generals-advisory-on-e-cigarette-use-among-youth-2018.pdf. Accessed September 10, 2019.

7. Wang TW, Gentzke A, Sharapova S, Cullen KA, Ambrose BK, Jamal A. Tobacco product use among middle and high school students—United States, 2011-2017. *MMWR Morb Mortal Wkly Rep*. 2018;67(22):629-633. doi:10.15585/mmwr.mm6722a3

8. Statement from FDA Commissioner Scott Gottlieb, MD, on new steps to address epidemic of youth e-cigarette use [press release]. Silver Spring, MD: US Food and Drug Administration; September 11, 2018. https://www.fda.gov/news-events/press-announcements/statement-fda-commissioner-scott-gottlieb-md-new-steps-address-epidemic-youth-e-cigarette-use. Accessed September 10, 2019.

9. Food and Drug Administration. FDA's Youth Tobacco Prevention Plan. https://www.fda.gov/tobacco-products/youth-and-tobacco/fdas-youth-tobacco-prevention-plan. Updated June 19, 2019. Accessed September 10, 2019.

10. Public Health Law Center at Mitchell Hamline School of Law. US e-cigarette regulations: 50 state review (2019). https://www.publichealthlawcenter.org/resources/us-e-cigarette-regulations-50-state-review. Updated June 15, 2019. Accessed September 6, 2019.

11. Centers for Disease Control and Prevention. National Youth Tobacco Survey (NYTS). https://www.cdc.gov/tobacco/data_statistics/surveys/nyts/index.htm. Updated February 28, 2019. Accessed September 10, 2019.

12. Hu SS, Gentzke A, Jamal A, Homa DM, Neff LJ. Feasibility of conducting an electronic version of the National Youth Tobacco Survey (NYTS), 2018. Paper presented at: 2019 National Conference on Tobacco or Health; August 27, 2019; Minneapolis, MN.

13. Nielsen Scantrack. https://www.nielsen.com/pk/en/solutions/measurement/retail-measurements/. Accessed October 22, 2019.

14. National Cancer Institute. Surveillance Research Program: Joinpoint. https://surveillance.cancer.gov/help/joinpoint. Accessed November 9, 2018.

15. Goniewicz ML, Boykan R, Messina CR, Eliscu A, Tolentino J. High exposure to nicotine among adolescents who use Juul and other vape pod systems ("pods") [published September 7, 2018]. *Tob Control*. doi:10.1136/tobaccocontrol-2018-054565

16. Schneller LM, Bansal-Travers M, Goniewicz ML, McIntosh S, Ossip D, O'Connor RJ. Use of flavored electronic cigarette refill liquids among adults and youth in the US: results from wave 2 of the Population Assessment of Tobacco and Health Study (2014-2015). *PLoS One*. 2018;13(8):e0202744. doi:10.1371/journal.pone.0202744

17. Harrell MB, Weaver SR, Loukas A, et al. Flavored e-cigarette use: characterizing youth, young adult, and adult users. *Prev Med Rep*. 2016;5:33-40. doi:10.1016/j.pmedr.2016.11.001

18. Statement from FDA Commissioner Scott Gottlieb, MD, on proposed new steps to protect youth by preventing access to flavored tobacco products and banning menthol in cigarettes [press release]. Silver Spring, MD: US Food and Drug Administration; November 15, 2018. https://www.fda.gov/news-events/press-announcements/statement-fda-commissioner-scott-gottlieb-md-proposed-new-steps-protect-youth-preventing-access. Accessed September 10, 2019.

19. Giammona C. Altria pulls e-cig flavors after FDA cracks down on youth usage. Bloomberg. https://www.bloomberg.com/news/articles/2018-10-25/altria-pulls-e-cig-flavors-after-fda-cracks-

down-on-youth-usage. Published October 25, 2018. Accessed September 10, 2019.

20. JUUL labs action plan: message from Kevin Burns, CEO, JUUL Labs [press release]. San Francisco, CA: JUUL Labs; November 13, 2018. https://newsroom.juul.com/2018/11/13/juul-labs-action-plan/. Accessed September 10, 2019.

21. Kaplan S. "Juul-alikes" are filling shelves with sweet, teen-friendly nicotine flavors. *New York Times*. https://www.nytimes.com/2019/08/13/health/juul-flavors-nicotine.html. Published August 13, 2019. Accessed September 10, 2019.

22. Craver R. JUUL ends 2018 with 76 percent market share. *Winston-Salem Journal*. https://www.journalnow.com/business/juul-ends-with-percent-market-share/article_6f50f427-19ec-50be-8b0c-d3df18d08759.html. Published January 8, 2019. Accessed September 10, 2019.

23. Ducharme J. Teens are "juuling" at school: here's what that means. *Time*. https://time.com/5211536/what-is-juuling/. Updated March 27, 2018. Accessed September 10, 2019.

24. Hoffman J. The price of cool: a teenager, a Juul and nicotine addiction. *New York Times*. https://www.nytimes.com/2018/11/16/health/vaping-juul-teens-addiction-nicotine.html. Published November 16, 2018. Accessed September 10, 2019.

25. Balingit M. In the "Juul room": e-cigarettes spawn a form of teen addiction that worries doctors, parents and schools. *Washington Post*. https://www.washingtonpost.com/local/education/helpless-to-the-draw-of-nicotine-doctors-parents-and-schools-grapple-with-teens-addicted-to-e-cigarettes/2019/07/25/e1e8ac9c-830a-11e9-933d-7501070ee669_story.html. Published July 26, 2019. Accessed September 10, 2019.

26. JUUL Labs files complaint with the United States International Trade Commission [press release]. San Francisco, CA: JUUL Labs; October 4, 2018. https://newsroom.juul.com/2018/10/04/juul-labs-files-complaint-with-the-united-states-international-trade-commission/. Accessed September 10, 2019.

27. Willett JG, Bennett M, Hair EC, et al. Recognition, use and perceptions of JUUL among youth and young adults. *Tob Control*. 2019;28(1): 115-116.

28. US Census Bureau. School enrollment in the United States: October 2017—detailed tables. https://www.census.gov/data/tables/2017/demo/school-enrollment/2017-cps.html. Published December 11, 2018. Accessed September 10, 2019.