Prevalence of Awareness and Use of JUUL E-cigarettes in a National Probability Sample of Adolescents in the United States

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Objective: In this study, we estimate the prevalence of awareness and use of the JUUL e-cigarette among adolescents in the United States (US). Methods: We conducted a cross-sectional, self-report online survey between September 21 and October 3, 2018 that assessed awareness and use of JUUL e-cigarettes, other e-cigarettes, and combustible cigarettes in a national probability sample of 1017 US adolescents aged 13-17 years. Results: Approximately 45.5% of adolescents aged 15-17 years and 29.1% of adolescents aged 13-14 years had ever seen or heard of a brand of e-cigarette called 'JUUL'. Among adolescents aged 15-17 years, 7.6% had ever used a JUUL, 4.0% had used a JUUL in the past 30 days, and 0.3% had used a JUUL on 20-30 of the past 30 days. Among adolescents aged 13-14 years, 1.5% had ever used a JUUL, 0.8% had used a JUUL in the past 30 days, and 0.0% had used a JUUL on 20-30 of the past 30 days. Conclusion: In September-October 2018, we estimated that about 39 in 100 US adolescents aged 13-17 years were aware of the JUUL brand of e-cigarette, and about 3 in 100 were estimated to have used a JUUL e-cigarette in the past 30 days. Close to half of all past 30-day e-cigarette use involved use of a JUUL e-cigarette. Present prevalence estimates may be limited to online modes of survey data collection and to the time period in which the data were collected. Findings reinforce the public health importance of acting to reduce youth access to JUUL vaping products, and of routinely monitoring youth awareness and use of specific e-cigarette brands. .

Key words: adolescent health; e-cigarettes; public health; smoking prevention; tobacco control; vaping
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Electronic cigarettes ('e-cigarettes') are battery-powered devices that can deliver nicotine and flavorings to the user in the form of an aerosol by heating a liquid rather than by burning tobacco. Although e-cigarette aerosol typically contains fewer and lower concentrations of toxicants and carcinogens than are typically present in smoke from combustible tobacco cigarettes, e-cigarette aerosol is not harmless, and regular, long-term inhalation is unlikely to be without biological effects in humans.[1,2] E-cigarette aerosol can contain metals, organic volatile compounds, and flavoring additives that may cause respiratory harm when inhaled, particularly to adolescents.[2] Using e-cigarettes also has been shown to increase adolescents' risk of ever smoking combustible tobacco cigarettes, and increase adolescents' frequency and intensity of subsequent combustible tobacco cigarette smoking.[2] Therefore, preventing and reducing youth use of e-cigarettes is critically important to the protection of youth's future health.

E-cigarettes are the most commonly used tobacco product among middle and high school students in the United States (US), and have been so since 2014.[3] National data suggest youth use of e-cigarettes surged considerably between 2017 and 2018, with around 5 out of 100 (4.9%) middle school students and 21 out of 100 (20.8%) high school students in 2018 now estimated to have used an e-cigarette in the past 30 days (compared to 3.3% and

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11.7%, respectively, in 2017).[4] These data indicate around 3.5 million middle and high school students have used an e-cigarette in the past 30 days, up from around 2 million in 2017. In September 2018, in response to these data, the US Food and Drug Administration (FDA) announced e-cigarette use among youth had become an "epidemic," and that much of the youth use of e-cigarettes is being driven by one manufacturer – JUUL.[5]

The JUUL e-cigarette is a tech-inspired vaping device popularly thought to resemble a USB flash drive in size and shape, which, at 9.45cm by 1.50cm x 0.69 cm and weighing 100 grams, is small enough to fit in a closed fist. The JUUL e-cigarette is a pod-based e-cigarette – also called "pod vapes" or "pod vaping systems" – that is based on a 2-part system: a pre-filled, disposable e-liquid pod that clicks into a small battery. All 0.7mL e-liquid pods marketed by JUUL in the US are designed to contain either 23 mg of nicotine (3% nicotine by weight) or 40 mg of nicotine (5% nicotine by weight).

In 2018, JUUL became the fastest growing and highest selling brand of e-cigarette/vapor product in the US. [6] Contemporaneous with this growth in sales, however, has been an alarming increase in the frequency of media and anecdotal reports from parents, educators, school superintendents, and public health experts of widespread use of JUUL e-cigarettes among middle and high school students, both on school grounds and in social settings outside of school.[7-15] The perceived escalating prevalence of the use of JUUL e-cigarettes among youth and young adults also has been described in academic publications as "an urgent concern" and "an epidemic" occurring in US schools and colleges.[16,17] A new and pressing challenge for US public health then is to understand how the speed and size of JUUL's growth in the US e-cigarette market that has occurred since early 2017 has impacted the prevalence of adolescent use of JUUL e-cigarettes.

Population surveillance measures of e-cigarette use are only now being adapted to capture data specific to JUUL e-cigarettes, and to date, few studies have reported national probability-based quantitative estimates of the prevalence, frequency and patterns of use of JUUL e-cigarettes among US youth. A 2017 online survey of a convenience sample of adolescents aged 15-17 years found 21% recognized the JUUL e-cigarette and 7% had ever used a JUUL e-cigarette.[18] A 2018 online survey of a national probability sample of adolescents aged 15-17 years found 9.5% had ever used a JUUL e-cigarette and 6.1% had used a JUUL e-cigarette in the past 30 days.[19] An online survey of 445 9th and 12th grade students across 10 California schools reported that 51.5% of students had heard of JUUL e-cigarettes, and 15.6% had ever used a "pod-type" e-cigarette (though not necessarily a JUUL e-cigarette).[20] One online survey of a national probability sample of youth and young adults aged 16-19 years estimated the prevalence of ever use and past 30-day use of a JUUL e-cigarette at 16% and 8.4%, respectively.[21]

In view of the concern about perceived high rates of youth use of JUUL e-cigarettes, and the assertion that the JUUL e-cigarette was a significant contributor to the "epidemic" of youth e-cigarette use that emerged between 2017 and 2018, in this study, we estimated the prevalence of awareness and use of JUUL e-cigarettes in September-October 2018 in a national probability sample of US adolescents.

METHODS

Procedure and Sample

Data were collected through a cross-sectional online survey of a national random probability sample of US adolescents aged 13-17 years who were children of adult panelists drawn from GfK's *KnowledgePanel.* Adult panel members were selected randomly with probabilities proportional to size (PPS) using a base panel weight after post-stratification adjustment for sampling and non-sampling sources of error (eg, panel nonresponse and panel attrition). GfK's *KnowledgePanel* is the largest probability-based online research panel in the US designed to be representative of the non-institutionalized US population aged 18 years and older. Adults sampled via residential address-based sampling or random digit dialing are eligible to join *KnowledgePanel*. *KnowledgePanel* covers 97% of US residential addresses, including households without Internet access at the time of recruitment. Data collection occurred between September 21 and October 3, 2018. The survey instrument took participants approximately 20 minutes to complete. Upon completion of the survey, a credit equivalent to $25 was posted to the parent's *KnowledgePanel* account, which the parent then disbursed to the child who participated.

KnowledgePanel members who were profiled as

having a child aged 13-17 years living in the household (N = 3672) received an email invitation that explained GfK was seeking the parent's permission to invite their child to take part in an online survey about their child's views and experiences of tobacco products, like cigarettes and electronic cigarettes. Clicking the Web-link in the email displayed a Parent Permission Form that provided information about the purpose of the study, what their child's participation would involve, what their child would receive for participating, their child's rights as a study participant (eg, right to withdraw at any point), how their child's information would be protected, and the contact details of the study director and the *KnowledgePanel* support center. Parents were asked to allow their child to complete the survey and submit their answers privately. Of the 3672 adults who received the invitation, 1397 (38%) completed the screener, of whom 1227 (88%) qualified. Of those who qualified, 1042 (85%) gave consent for their child to participate.

When a parent gave permission for their child to participate, GfK sent a second email to the parent, which contained a link to the Youth Permission Form. Parents were asked to instruct their child to read this form before deciding whether to participate. The Youth Permission Form provided similar information and assurances as the Parent Permission Form, including statements that participants were free to withdraw from the survey at any time simply by closing the browser and that they could refuse to participate in the survey. Children were asked to answer questions in private and were assured that none of their answers would be shown to their parents or anyone else.

Of the 1042 children invited to participate, 1017 (98%) completed the survey, producing a survey completion rate of 72.8% among all who were invited and eligible to participate. Of the 1017 qualified completers, 407 (40.0%) were aged 13-14 years and 610 (60.0%) were aged 15-17 years. A study-specific post-stratification weight was computed using an iterative proportional fitting (raking) procedure to adjust for survey non-response. Demographic and geographic distributions from the March 2017 supplement of the US Census Bureau's Current Population Survey (CPS) were employed as benchmarks for adjustment, and included sex (male, female) by age (13, 14, 15, 16, 17), race/ethnicity (white non-Hispanic, black non-Hispanic, other non-Hispanic, 2+ race non-Hispanic, and Hispanic), census region (Northeast, Midwest, South, West) by metropolitan area (metro, non-metro), household income, and primary language.

Measures

Most questions, response options, descriptions, and instructions used in this survey were extracted directly or closely adapted from the US Centers for Disease Control and Prevention's (CDC) 2017 National Youth Tobacco Survey (NYTS) instrument. A smaller number of questions were extracted or closely adapted from the FDA Population Assessment of Tobacco and Health (PATH) Study, Wave 1 Youth Interview Form, and from items recommended by the FDA Tobacco Centers for Regulatory Science (TCORS) for use in studies assessing youth use and perceptions of e-cigarettes.[22] To assess adolescents' use of the JUUL e-cigarette specifically, we adapted NYTS and PATH questions that assessed adolescents' use of e-cigarettes by adding the word "JUUL" to make the questions JUUL-specific, eg, the NYTS question: "Have you ever used an e-cigarette, even once or twice?" was adapted to "Have you ever used a JUUL e-cigarette, even once or twice?" The informed consent documents and survey instrument used in this study are available online as a supplementary file (https://www.csures.com/juul-youth-survey).

Demographic characteristics. Questions assessed age, sex, ethnicity, race, school grade and US state of residence.

Awareness of e-cigarettes and JUUL e-cigarettes. All participants were shown the following text:

> *"The next questions are about electronic cigarettes or e-cigarettes. E-cigarettes are electronic devices that produce an aerosol by heating a liquid. E-cigarettes come in many shapes and sizes. Most have a battery, a heating element, and a place to hold a liquid. Some e-cigarettes are made to look like regular cigarettes, while some look like USB flash drives, pens, and other everyday items. Larger e-cigarettes such as tank systems, or "mods," do not resemble other tobacco products. E-cigarettes are known by many different names. They are sometimes called "e-cigs," "e-hookahs," "mods," "vape pens," "vapes," "tank systems," and "electronic*

nicotine delivery systems." Using an e-cigarette is sometimes called "vaping" or "JUULing." Some common brands include JUUL, blu, Vuse, MarkTen, Logic and eGo."

The last sentence in this description makes explicit that JUUL is a brand of e-cigarette. In line with guidance offered to the researchers by the FDA Center for Tobacco Products (CTP) at a pre-study meeting, no images of e-cigarettes were displayed to participants as part of this question to reduce the possibility of raising awareness of and potential interest in using e-cigarettes among youth who were unaware of these products. Awareness of e-cigarettes was determined by a "yes" response to the subsequent question: "Have you ever seen or heard of e-cigarettes before this study?" Participants who responded "no" to this question were not asked any further questions about e-cigarettes or JUUL e-cigarettes. By logical extension, participants who indicated they had never seen or heard of an e-cigarette before taking part in this study were automatically coded as never users of an e-cigarette and never users of a JUUL e-cigarette.

Participants who indicated they were aware of e-cigarettes before this study were shown the following text:

"The next questions are about a specific brand of e-cigarette called "JUUL." The JUUL e-cigarette is a rectangular device that is small enough to fit in a closed fist. JUUL e-cigarettes use replaceable cartridges containing e-liquid called 'JUUL pods'."

Again, in line with guidance offered to the researchers by FDA CTP during a pre-study meeting, no images of the JUUL device, refill pods, or packaging were displayed to participants as part of this question to reduce the possibility of raising awareness of and potential interest in using JUUL products among youth who were unaware of these products. Awareness of JUUL e-cigarettes was determined by a "yes" response to the subsequent question: "Have you ever seen or heard of a brand of e-cigarette called 'JUUL' before this study?" Participants who responded "no" to this question were not asked any further questions about JUUL e-cigarettes. By logical extension, participants who indicated they had never seen or heard of a JUUL e-cigarette before taking part in this study were automatically coded as never users of a JUUL e-cigarette.

Participants' level of awareness of e-cigarettes/JUUL e-cigarettes before this study was determined by the question: "How much have you seen or heard about e-cigarettes/JUUL e-cigarettes before this study?" (a little, some, a lot). Awareness of the words "vaping" and "JUULing" were determined by a "yes" response to the question: "Have you ever heard the word 'vaping'/'JUULing'" before this study?"

Ever use of combustible cigarettes, e-cigarettes, and JUUL e-cigarettes. Ever use of combustible cigarettes was determined by a "yes" response to the question: "Have you ever tried cigarette smoking, even one or two puffs?" Ever use of an e-cigarette was determined by a "yes" response to the question: "Have you ever used an e-cigarette, even once or twice?" Ever use of a JUUL e-cigarette was determined by a "yes" response to the question: "Have you ever used a JUUL e-cigarette, even once or twice?" The question: "Have you ever used a JUUL e-cigarette, even once or twice?" was displayed only to participants who responded "yes" to the question: "Have you ever used an e-cigarette, even once or twice?"

Use of combustible cigarettes, e-cigarettes, and JUUL e-cigarettes in the past 30 days. Participants who had ever used [tobacco product] were asked: "When was the last time you used [tobacco product], even one or two puffs? (Please choose the first answer that fits)." Use of [tobacco product] in the past 30 days was determined by any of 3 answers to this question: "earlier today," "not today but sometime during the past 7 days," or "not during the past 7 days but sometime during the past 30 days."

Former use of combustible cigarettes, e-cigarettes, and JUUL e-cigarettes. Former users of each tobacco product were those who reported they have ever tried using [tobacco product] but have not used [tobacco product] in the past 30 days.

Frequency of use of combustible cigarettes, e-cigarettes, and JUUL e-cigarettes in the past 30 days. Participants who reported having used [tobacco product] in the past 30 days were asked: "During the past 30 days, on how many days did you [smoke a cigarette; use an e-cigarette; use a JUUL e-cigarette]?" (1-2 days; 3-5 days; 6-9 days; 10-19 days; 20-29 days; 30 days). Participants who reported use

Table 1
Prevalence of Awareness of E-cigarettes and JUUL E-cigarettes among US Adolescents by Product, Sex, and Race/Ethnicity – September-October 2018

	Sex		Race/Ethnicity				Total	
	Female	Male	White [b]	Black [b]	Hispanic	Other [b]		
Aged 15-17 Yrs	% (95% CI)	% (95% CI)	% (95% CI)	% (95% CI)	% (95% CI)	% (95% CI)	% (95% CI)	Est. no. aware [c]
Aware of…								
E-cigarettes	91.7 (88.7-94.8)	88.9 (85.3-92.4)	94.9 (92.4-97.3)	91.2 (85.4-97.0)	83.2 (77.2-89.2)	84.1 (75.4-92.7)	90.3 (88.0-92.6)	11,430,000
JUUL	44.6 (39.0-50.2)	46.3 (40.8-51.9)	56.3 (50.8-61.8)	37.4 (27.4-47.3)	29.5 (22.2-36.9)	42.0 (30.4-53.7)	45.5 (41.6-49.4)	5,760,000
E-cig Awareness								
A little	28.5 (23.5-33.6)	18.1 (13.8-22.3)	21.5 (17.0-26.1)	25.3 (16.3-34.2)	28.9 (21.6-36.1)	15.9 (7.3-24.6)	23.2 (19.9-26.5)	2,810,000
Some	40.0 (34.5-45.5)	46.3 (40.8-51.9)	45.3 (39.8-50.9)	51.6 (41.4-61.9)	32.9 (25.3-40.4)	44.9 (33.2-56.7)	43.2 (39.3-47.1)	5,470,000
A lot	20.3 (15.8-24.8)	27.0 (15.8-24.8)	27.0 (22.1-31.9)	15.4 (8.0-22.8)	21.5 (14.9-28.1)	24.6 (14.5-34.8)	23.7 (20.4-27.1)	3,000,000
JUUL Awareness								
A little	19.0 (14.6-23.4)	12.7 (9.0-16.4)	19.6 (15.2-24.0)	17.6 (9.8-25.4)	8.7 (4.2-13.3)	11.6 (4.0-19.1)	15.8 (12.9-18.7)	2,000,000
Some	16.4 (12.2-20.5)	16.5 (12.4-20.6)	19.0 (14.6-23.3)	13.2 (6.2-20.1)	12.8 (7.4-18.1)	17.4 (8.4-26.3)	16.5 (13.5-19.4)	2,080,000
A lot	9.5 (6.2-12.8)	16.8 (12.7-21.0)	17.4 (13.2-21.6)	6.6 (1.5-11.7)	8.7 (4.2-13.3)	13.0 (5.1-21.0)	13.2 (10.6-15.9)	1,670,000
Aware of Word								
Vaping	82.3 (78.0-86.6)	84.8 (80.8-88.7)	92.3 (89.3-95.2)	78.0 (69.5-86.5)	69.1 (61.7-76.5)	82.6 (73.7-91.6)	83.5 (80.6-86.5)	10,570,000
JUULing	34.4 (29.1-39.8)	36.8 (31.5-42.2)	43.4 (37.9-48.9)	25.3 (16.3-34.2)	24.8 (17.9-31.8)	37.7 (26.2-49.1)	35.6 (31.9-39.4)	4,500,000
Aged 13-14 Yrs								
Aware of…								
E-cigarettes	90.2 (86.0-94.4)	87.1 (82.4-91.7)	91.5 (87.8-95.1)	[d]	85.1 (77.9-92.3)	[d]	88.6 (85.5-91.7)	7,330,000
JUUL	35.6 (28.8-42.3)	22.9 (17.1-28.7)	30.9 (24.9-37.0)	[d]	11.7 (5.2-18.2)	[d]	29.1 (24.6-33.6)	2,400,000
E-cig Awareness								
A little	41.8 (34.8-48.7)	33.3 (26.8-39.9)	39.5 (33.0-45.9)	[d]	35.1 (25.5-44.8)	[d]	37.5 (32.7-42.2)	3,100,000
Some	33.0 (26.4-39.6)	35.8 (29.2-42.4)	34.1 (27.9-40.3)	[d]	33.0 (23.5-42.5)	[d]	34.4 (29.7-39.1)	2,840,000
A lot	15.5 (10.4-20.6)	16.9 (11.7-22.1)	17.9 (12.9-23.0)	[d]	16.0 (8.6-23.4)	[d]	16.2 (12.6-19.8)	1,340,000
JUUL Awareness								
A little	15.5 (10.4-20.6)	10.0 (5.8-14.1)	11.2 (7.1-15.4)	[d]	19.1 (11.2-27.1)	[d]	12.7 (9.4-15.9)	1,050,000
Some	12.4 (7.7-17.0)	9.0 (5.0-12.9)	13.9 (9.4-18.4)	[d]	4.3 (0.2-8.3)	[d]	10.6 (7.6-13.7)	870,000
A lot	9.3 (5.2-13.4)	3.5 (0.9-6.0)	6.3 (3.1-9.5)	[d]	6.4 (1.4-11.3)	[d]	6.3 (3.9-8.7)	520,000
Aware of Word								
Vaping	86.1 (81.2-91.0)	78.6 (72.9-84.3)	89.2 (85.2-93.3)	[d]	74.5 (65.7-83.3)	[d]	82.3 (78.5-86.0)	6,810,000
JUULing	26.8 (20.6-33.0)	15.9 (10.9-21.0)	23.8 (18.2-29.4)	[d]	17.0 (9.4-24.6)	[d]	21.3 (17.2-25.3)	1,760,000

Note.
Abbreviation: CI = Confidence Interval; E-cigarettes = electronic cigarettes; JUUL = JUUL e-cigarettes
a: Prevalence estimates used weighted data.
b: Blacks, whites, and others are non-Hispanic; Hispanic persons could be of any race.
c: Estimated total number of users was rounded down to the nearest 10,000 persons. Based on 2016 US census data on number of persons aged 13-14 years/15-17 years in the US population.
d: The estimate was suppressed because the sample size was <50.

Table 2
Prevalence of Use of JUUL E-cigarettes, E-cigarettes and Cigarettes among US Adolescents, by Sex and Race/Ethnicity – September-October 2018[a]

	Sex		Race/Ethnicity				Total	
	Female	Male	White [b]	Black [b]	Hispanic	Other [b]		
Aged 15-17 Yrs	% (95% CI)	% (95% CI)	% (95% CI)	% (95% CI)	% (95% CI)	% (95% CI)	% (95% CI)	Est. no. aware [c]
Ever User								
JUUL	4.3 (2.0-6.5)	10.8 (7.4-14.2)	9.6 (6.4-12.9)	5.5 (0.8-10.2)	5.4 (1.7-9.0)	5.8 (0.3-11.3)	7.6 (5.5-9.7)	960,000
E-cigarettes	12.8 (9.0-16.5)	23.8 (19.1-28.5)	22.2 (17.6-26.8)	8.8 (3.0-14.6)	17.4 (11.4-23.5)	15.9 (7.3-24.6)	18.4 (15.3-21.4)	2,320,000
Cigarettes	13.4 (9.6-17.3)	22.5 (17.9-27.2)	18.6 (14.3-23.0)	17.6 (9.8-25.4)	20.8 (14.3-27.3)	10.1 (3.0-17.3)	18.1 (15.0-21.1)	2,290,000
Used in P-30 Days								
JUUL	1.6 (0.2-3.1)	6.3 (3.7-9.0)	5.5 (2.9-8.0)	2.2 (0.0-5.2)	2.7 (0.1-5.3)	2.9 (0.0-6.9)	4.0 (2.5-5.6)	500,000
E-cigarettes	3.9 (1.8-6.1)	9.8 (6.6-13.1)	11.6 (8.0-15.1)	6.6 (1.5-11.7)	6.0 (2.2-9.9)	4.3 (0.0-9.2)	8.7 (6.5-10.9)	1,100,000
Cigarettes	3.3 (1.3-5.3)	8.3 (5.2-11.3)	5.8 (3.2-8.4)	11.0 (4.6-17.4)	4.7 (1.3-8.1)	1.4 (0.0-4.3)	5.8 4.0-7.6)	730,000
Former User								
JUUL	3.0 (1.1-4.8)	4.1 (1.9-6.3)	3.9 (1.7-6.0)	3.3 (0.0-7.0)	2.0 (0.0-4.3)	5.8 (0.3-11.3)	3.5 (2.1-5.0)	440,000
E-cigarettes	8.5 (5.4-11.7)	10.5 (7.1-13.9)	10.3 (6.9-13.7)	2.2 (0.0-5.2)	11.4 (6.3-16.5)	11.6 (4.0-19.1)	9.5 (7.2-11.8)	1,200,000
Cigarettes	10.2 (6.8-13.6)	14.6 (10.7-18.5)	12.5 (8.9-16.2)	7.7 (2.2-13.2)	16.1 (10.2-22.0)	10.1 (3.0-17.3)	12.4 (9.8-15.0)	1,570,000
Infrequent User								
JUUL	1.0 (0.0-2.1)	6.0 (3.4-8.7)	4.8 (2.4-7.2)	2.2 (0.0-5.2)	2.7 (0.1-5.3)	1.4 (0.0-4.3)	3.5 (2.1-5.0)	443,205
E-cigarettes	3.9 (1.8-6.1)	12.1 (8.5-15.7)	10.6 (7.2-14.0)	6.6 (1.5-11.7)	5.4 (1.7-9.0)	4.3 (0.0-9.2)	8.1 (5.9-10.2)	1,020,000
Cigarettes	3.0 (1.1-4.8)	7.3 (4.4-10.2)	4.8 (2.4-7.2)	11.0 (4.6-17.4)	4.0 (0.9-7.2)	1.4 (0.0-4.3)	5.2 (3.4-6.9)	650,000
Frequent User								
JUUL	0.3 (0.0-1.0)	0.3 (0.0-0.9)	0.6 (0.0-1.5)	0.0 (0.0-0.0)	0.0 (0.0-0.0)	0.0 (0.0-0.0)	0.3 (0.0-0.8)	37,989
E-cigarettes	0.3 (0.0-1.0)	1.3 (0.0-2.5)	1.0 (0.0-2.1)	0.0 (0.0-0.0)	1.3 (0.0-3.2)	0.0 (0.0-0.0)	0.8 (0.1-1.5)	101,304
Cigarettes	0.7 (0.0-1.6)	1.3 (0.0-2.5)	1.3 (0.0-2.5)	0.0 (0.0-0.0)	1.3 (0.0-3.2)	0.0 (0.0-0.0)	1.0 (0.2-1.7)	126,630

(continued on next page)

of [tobacco product] on 1-19 of the past 30 days were coded as "infrequent users; participants who reported use of [tobacco product] on 20-30 of the past 30 days were coded as "frequent users."

First JUUL pod flavor tried. Participants who reported having ever used a JUUL e-cigarette were asked: "What was the first JUUL pod flavor you ever tried using? (Select one)" (Virginia Tobacco, Mint, Mango, Crème, Fruit, Cucumber, Classic Tobacco, Menthol).

JUUL pod flavors used in the past 30 days. Participants who reported having used a JUUL e-cigarette in the past 30 days were asked: "During the past 30 days, which flavors of JUUL refill pods have you used, even once or twice? (Select one or more)" and "During the past 30 days, which flavor of JUUL refill pod have you used the most often? (Select one)." The response options for both questions were: Virginia Tobacco, Mint, Mango, Crème, Fruit, Cucumber, Classic Tobacco, Menthol.

Lifetime and past 30-day consumption of JUUL pods. Participants who reported having ever used a JUUL e-cigarette were asked: "About how many JUUL refill pods have you used in your entire life? A

Table 2 (*continued*)
Prevalence of Use of JUUL E-cigarettes, E-cigarettes and Cigarettes among US Adolescents, by Sex and Race/Ethnicity – September-October 2018[a]

	Sex		Race/Ethnicity				Total	
	Female	Male	White [b]	Black [b]	Hispanic	Other [b]		
Aged 13-14 Yrs	% (95% CI)	% (95% CI)	% (95% CI)	% (95% CI)	% (95% CI)	% (95% CI)	% (95% CI)	Est. no. aware [c]
Ever User								
JUUL	3.1 (0.7-5.5)	0.0 (0.0-0.0)	1.3 (0.0-2.9)	[d]	2.1 (0.0-5.0)	[d]	1.5 (0.3-2.7)	120,000
E-cigarettes	10.8 (6.5-15.2)	6.0 (2.7-9.2)	6.3 (3.1-9.5)	[d]	12.8 (6.0-19.5)	[d]	8.4 (5.6-11.1)	690,000
Cigarettes	8.8 (4.8-12.7)	10.4 (6.2-14.7)	9.9 (6.0-13.8)	[d]	12.8 (6.0-19.5)	[d]	9.6 (6.7-12.5)	790,000
Used in P-30 Days								
JUUL	1.5 (0.0-3.3)	0.0 (0.0-0.0)	0.0 (0.0-0.0)	[d]	2.1 (0.0-5.0)	[d]	0.8 (0.0-1.6)	60,000
E-cigarettes	1.5 (0.0-3.3)	1.5 (0.0-3.2)	1.3 (0.0-2.9)	[d]	2.1 (0.0-5.0)	[d]	1.5 (0.3-2.7)	120,000
Cigarettes	1.5 (0.0-3.3)	1.0 (0.0-2.4)	0.9 (0.0-2.1)	[d]	2.1 (0.0-5.0)	[d]	1.3 (0.2-2.4)	100,000
Former User								
JUUL	1.5 (0.0-3.3)	0.0 (0.0-0.0)	1.3 (0.0-2.9)	[d]	0.0 (0.0-0.0)	[d]	0.8 (0.0-1.6)	60,000
E-cigarettes	8.8 (4.8-12.7)	4.5 (1.6-7.3)	4.9 (2.1-7.8)	[d]	9.6 (3.6-15.5)	[d]	6.6 (4.1-9.0)	540,000
Cigarettes	7.7 (4.0-11.5)	9.5 (5.4-13.5)	9.0 (5.2-12.7)	[d]	11.7 (5.2-18.2)	[d]	8.6 (5.8-11.4)	710,000
Infrequent User								
JUUL	1.5 (0.0-3.3)	0.0 (0.0-0.0)	0.0 (0.0-0.0)	[d]	2.1 (0.0-5.0)	[d]	0.8 (0.0-1.6)	60,000
E-cigarettes	1.5 (0.0-3.3)	1.5 (0.0-3.2)	1.3 (0.0-2.9)	[d]	0.0 (0.0-0.0)	[d]	1.5 (0.3-2.7)	120,000
Cigarettes	1.5 (0.0-3.3)	0.5 (0.0-1.5)	0.4 (0.0-1.3)	[d]	2.1 (0.0-5.0)	[d]	1.0 (0.0-2.0)	80,000
Frequent User								
JUUL	0.0 (0.0-0.0)	0.0 (0.0-0.0)	0.0 (0.0-0.0)	[d]	0.0 (0.0-0.0)	[d]	0.0 (0.0-0.0)	0
E-cigarettes	0.0 (0.0-0.0)	0.0 (0.0-0.0)	0.0 (0.0-0.0)	[d]	0.0 (0.0-0.0)	[d]	0.0 (0.0-0.0)	0
Cigarettes	0.0 (0.0-0.0)	0.5 (0.0-1.5)	0.4 (0.0-1.3)	[d]	0.0 (0.0-0.0)	[d]	0.3 (0.0-0.7)	20,000

Note.
Abbreviation: CI = Confidence Interval; E-cigarettes = electronic cigarettes; JUUL = JUUL e-cigarettes
a: Prevalence estimates used weighted data.
b: Blacks, whites, and others are non-Hispanic; Hispanic persons could be of any race.
c: Estimated total number of users was rounded down to the nearest 10,000 persons. Based on 2016 US census data on number of persons aged 13-14 years/15-17 years in the US population.
d: The estimate was suppressed because the sample size was <50.

pack usually has 4 JUUL pods in it. Your best guess is fine." (1 or more puffs but not a whole pod; 1 to 2 pods (about ½-pack total); 3 to 4 pods (about ½-pack to 1 pack); 5 to 12 pods (more than 1 pack but less than 3 packs); 13 to 19 pods (more than 2-½ packs but less than 5 packs); 20 or more pods (5 packs or more)).

For each flavor that participants reported they used in the past 30 days, we asked: "During the past 30 days, about how many [flavor name] flavored JUUL refill pods have you used? A pack usually has 4 JUUL refill pods in it. Your best guess is fine." (1 or more puffs but not a whole pod; 1 to 2 pods (about ½-pack total); 3 to 4 pods (about ½-pack

to 1 pack); 5 to 12 pods (more than 1 pack but less than 3 packs); 13 to 19 pods (more than 2-½ packs but less than 5 packs); 20 or more pods (5 packs or more)).

Lower and upper bound estimates of the number of packs of JUULpods consumed by US adolescents in the past 30 days were calculated by multiplying the lower/upper bounds of each response option (eg, option 4: lower bound = 5 pods, upper bound = 12 pods) by the number of participants who chose that option. The products of these calculations were then summed to give a lower and upper bound estimate of the total number of pods consumed by participants in the past 30 days. These lower and upper bound estimates were then divided by 4 to give estimates of the total number of packs of JUULpods consumed, which were then divided by the number of participants who reported use of a JUUL e-cigarette in the past 30 days to give lower and upper bound estimates of the number of packs of JUULpods consumed per participant in the past 30 days. Using data from the 2016 US Census, these estimates were then multiplied by the number of 13-17-year-olds in the US population to give lower and upper bound estimates of the number of packs of JUULpods consumed by US adolescents aged 13-17 years in the past 30 days.

Data Analysis

Population-weighted proportions and 95% confidence intervals are reported for levels of use of each tobacco product, stratified by age group (13-14 years unweighted N = 407 vs 15-17 years unweighted N = 610). The number of persons aware of each tobacco product, and the number of users of each tobacco product was estimated by multiplying the number of individuals aged 13-14 years old and 15-17 years old in the US population according to 2016 US census data by the point prevalence estimate of awareness and use of each tobacco product within each age group. Estimates of the number of persons aware of each tobacco product and users of each tobacco product were rounded down to the nearest 10,000 persons. All prevalence estimates used weighted data.

RESULTS

Prevalence of Awareness

Approximately 90.3% of adolescents aged 15-17 years (estimated 11,430,000 persons) and 88.6% of adolescents aged 13-14 years (estimated 7,330,000 persons) had ever seen or heard of e-cigarettes before this study (Table 1). In contrast, 45.5% of adolescents aged 15-17 years (estimated 5,760,000 persons) and 29.1% of adolescents aged 13-14 years (estimated 2,400,000 persons) had ever seen or heard of a brand of e-cigarette called "JUUL" before this study. Among adolescents aged 15-17 years, awareness of JUUL e-cigarettes was comparable between males (46.3%) and females (44.6%), highest among those identifying as non-Hispanic white (56.3%) and lowest among those identifying as Hispanic (29.5%).

Approximately 23.7% of adolescents aged 15-17 years had seen or heard "a lot" about e-cigarettes, and 13.2% had seen or heard "a lot" about JUUL e-cigarettes specifically. Male (16.8%) and non-Hispanic Whites (17.4%) were the most likely to have heard or seen 'a lot' about JUUL e-cigarettes. Among adolescents aged 13-14 years, awareness of e-cigarettes was comparable between males (87.1%) and females (90.2%). Females were more likely to have ever seen or heard of JUUL e-cigarettes (35.6%) and more likely to have heard "a lot" about JUUL e-cigarettes (9.3%).

Approximately 83.5% of adolescents aged 15-17 years and 82.3% of adolescents aged 13-14 years had ever heard the word "vaping." In contrast, 35.6% of adolescents aged 15-17 years and 21.3% of adolescents aged 13-14 years had ever heard of the word "JUULing."

Prevalence of Use

Among adolescents aged 15-17 years, 7.6% had ever used a JUUL e-cigarette; 4.0% had used a JUUL e-cigarette in the past 30 days; 3.5% were former users of a JUUL e-cigarette; 3.5% had used a JUUL e-cigarette on 1-19 of the past 30 days; and 0.3% had used a JUUL e-cigarette on 20-30 of the past 30 days (Table 2). By comparison, 18.4% had ever used an e-cigarette (any brand); 8.7% had used an e-cigarette in the past 30 days; 9.5% were former users of e-cigarettes; 8.1% had used an e-cigarette on 1-19 of the past 30 days; and 0.8% had used an e-cigarette on 20-30 of the past 30 days.

Among adolescents aged 13-14 years, 1.5% had ever used a JUUL e-cigarette; 0.8% had used a JUUL e-cigarette in the past 30 days; 0.8% were

Table 3
Use of JUUL Pod Flavors among Ever Users of a JUUL E-cigarette, Past 30-day Users of a JUUL E-cigarette and All Adolescents Aged 15-17 Years

	15-17 yrs Ever Used a JUUL (unweighted N = 48) %	15-17 yrs Used JUUL in Past 30 Days (unweighted N = 25) %	All 15-17 years (unweighted N = 610) %
JUUL Pods Used in Lifetime			
1 or more puffs but never a whole pod	39.9	22.3	3.0
1 to 2 pods (about ½-pack total)	6.4	2.2	0.5
3 to 4 pods (about ½-pack to 1 pack)	21.6	24.4	1.6
5 to 12 pods (more than 1 pack but less than 3 packs)	15.0	18.5	1.1
13 to 19 pods (more than 2-½ packs but less than 5 packs)	7.7	14.7	0.6
20 or more pods (5 packs or more)	9.3	17.9	0.7
First JUUL Pod Flavor Used			
Virginia Tobacco	0.7	1.4	0.1
Mint/ Cool Mint	16.7	13.3	1.3
Mango	29.4	49.1	2.2
Crème/ Crème Brulee	5.8	11.2	0.4
Fruit/ Fruit Medley	26.4	15.1	2.0
Cucumber/ Cool Cucumber	1.3	0.0	0.1
Classic Tobacco	2.0	0.0	0.2
Menthol/ Classic Menthol	2.5	0.0	0.2
Don't Remember	15.1	9.9	1.1
JUUL Pod Flavors Used in Past 30 Days			
Virginia Tobacco	-	2.0	0.1
Mint/ Cool Mint	-	41.1	1.6
Mango	-	59.5	2.3
Crème/ Crème Brulee	-	21.1	0.8
Fruit/ Fruit Medley	-	35.6	1.4
Cucumber/ Cool Cucumber	-	3.7	0.1
Classic Tobacco	-	10.0	0.4
Menthol/ Classic Menthol	-	9.3	0.4
JUUL Pod Flavor Used Most Often in Past 30 Days (choose one)			
Virginia Tobacco	-	2.0	0.1
Mint/ Cool Mint	-	12.0	0.5
Mango	-	47.3	1.8
Crème/ Crème Brulee	-	7.7	0.3
Fruit/ Fruit Medley	-	27.6	1.0
Cucumber/ Cool Cucumber	-	0.0	0.0
Classic Tobacco	-	3.4	0.1
Menthol/ Classic Menthol	-	0.0	0.0

Table 4
Total Number of JUUL Pods Consumed in the Past 30 Days by US Adolescents, by JUUL Pod Flavor

Aged 15-17 years	**Virginia Tobacco**	**Mint**	**Mango**	**Crème**	**Fruit**	**Cucumber**	**Classic Tobacco**	**Menthol**	**Total**
JUUL Pods Used in Past 30 Days									
1 or more puffs but not a whole pod	0	4	7	2	3	1	2	1	-
1 to 2 pods (about ½-pack total)	0	3	5	0	0	0	0	0	-
3 to 4 pods (about ½-pack to 1 pack)	0	2	0	1	5	0	0	0	-
5 to 12 pods (more than 1 pack but less than 3 packs)	0	1	2	2	1	0	1	1	-
13 to 19 pods (more than 2-½ packs but less than 5 packs)	0	0	0	0	0	0	0	0	-
20 or more pods (5 packs or more)	0	0	0	0	0	0	0	0	-
Lower estimate of total number (packs) of pods consumed in past 30 days	0	11	15	13	20	0	5	5	69 (17.25)
Upper estimate of total number (packs) of pods consumed in past 30 days	0	30	37	34	35	1	14	13	164 (41)
Aged 13-14 years	**Virginia Tobacco**	**Mint**	**Mango**	**Crème**	**Fruit**	**Cucumber**	**Classic Tobacco**	**Menthol**	**Total**
JUUL Pods Used in Past 30 Days									
1 or more puffs but not a whole pod	0	1	0	1	1	0	0	1	-
1 to 2 pods (about ½-pack total)	1	2	1	1	0	0	0	0	-
3 to 4 pods (about ½-pack to 1 pack)	0	0	0	0	0	0	0	0	-
5 to 12 pods (more than 1 pack but less than 3 packs)	0	0	0	0	1	0	0	0	-
13 to 19 pods (more than 2-½ packs but less than 5 packs)	0	0	0	0	0	0	0	0	-
20 or more pods (5 packs or more)	0	0	0	0	0	0	0	0	-
Lower estimate of number (packs) of pods consumed in past 30 days	1	2	1	1	5	0	0	0	11 (2.75)
Upper estimate of number (packs) of pods consumed in past 30 days	2	5	2	3	13	0	0	0	25 (6.25)

former users of a JUUL e-cigarette; 0.8% had used a JUUL e-cigarette on 1-19 of the past 30 days; and 0.0% had used a JUUL e-cigarette on 20-30 of the past 30 days. By comparison, 8.4% had ever used an e-cigarette (any brand); 1.5% had used an e-cigarette in the past 30 days; 6.6% were former users of e-cigarettes; 1.5% had used an e-cigarette on 1-19 of the past 30 days; and 0.0% had used an e-cigarette on 20-30 of the past 30 days.

Use of JUUL Pod Flavors

Among adolescents aged 15-17 years who had used a JUUL e-cigarette in the past 30 days (weighted point estimate = 4.0%), 49.1% reported Mango as the first JUUL pod flavor they ever tried; 59.5% had used Mango-flavored JUUL pods in the past 30 days, and 41.1% had used Mint-flavored JUUL pods in the past 30 days (Table 3). Mango was the most commonly reported "flavor used most often"

in the past 30 days (47.3%), followed by Fruit (27.6%) and Mint (12.0%). Overall, 2.2% of adolescents aged 15-17 years had ever used a JUUL e-cigarette *and* started with Mango-flavored JUUL pods, and 2.3% of adolescents aged 15-17 years had used Mango-flavored JUUL pods in the past 30 days. The number of adolescents aged 13-14 years reporting use a JUUL e-cigarette in the past 30 days was too low to estimate the prevalence of first use and past 30-day use of each JUUL pod flavor.

Consumption of JUUL Pods

Among adolescents aged 15-17 years, 0.7% had used 20 or more JUUL pods in their lifetime (Table 3). Each adolescent aged 15-17 years who had used a JUUL e-cigarette in the past 30 days was estimated to have consumed between 0.69 to 1.64 packs of JUUL pods (each pack contains 4 pods) in the past 30 days. At the population level, between 349,499 packs and 830,693 packs of JUUL pods were estimated to have been consumed by US adolescents aged 15-17 years in the past 30 days (Table 4).

Among adolescents aged 13-14 years, 0.0% had used 5 or more JUUL pods in their lifetime. Each adolescent aged 13-14 years who had used a JUUL e-cigarette in the past 30 days was estimated to have consumed between 0.69 to 1.56 packs of JUUL pods (each pack containing 4 pods) in the past 30 days (Table 4). At the population level, between 45,513 packs and 103,438 packs of JUUL pods were estimated to have been consumed by US adolescents aged 13-14 years in the past 30 days. In total, between 395,011 packs and 934,130 packs of JUUL pods were estimated to have been consumed by US adolescents aged 13-17 years in the past 30 days.

DISCUSSION

This study is among the first to report nationally representative estimates of the prevalence of youth awareness and use of JUUL e-cigarettes among adolescents aged 13-17-years in the US. In September-October 2018, about 45 in 100 adolescents aged 15-17 years and 29 in 100 adolescents aged 13-14 years were estimated to have been aware of the JUUL brand of e-cigarette. Approximately 4 in 100 adolescents aged 15-17 years and one in 100 adolescents aged 13-14 years were estimated to have used a JUUL e-cigarette in the past 30 days. In both age groups, frequent use of a JUUL e-cigarette was rare and past 30-day cigarette smoking was more prevalent than past 30-day JUUL use. Overall, close to half of all past 30-day e-cigarette use in this sample involved use of a JUUL e-cigarette. These estimates provide US public health policymakers with a reliable quantitative snapshot of the prevalence of youth awareness and use of JUUL e-cigarettes nationwide in September-October 2018. Relatedly, these estimates highlight the potential for error in attempting to size the prevalence of JUUL use in the general US youth population on the basis of convenience samples of anecdotal and media reports.

Present estimates of the prevalence of awareness of JUUL e-cigarettes among adolescents aged 15-17 years are substantially higher than the estimated prevalence of JUUL awareness (21%) reported by Willet et al[18] in early 2018. The greater awareness of JUUL e-cigarettes in the present sample may be due to the fact that a year had passed since collection of data by Willet et al, during which there had been a substantial increase in news coverage and social media discussion about the JUUL e-cigarette, including displays of images of the JUUL device and packaging. It is conceivable that the youth population's heightened awareness of the JUUL e-cigarette youths' was attributable to a past-year increased exposure to opinions and imagery related to JUUL products, much of which was generated by users and by organizations intending to dissuade youth from using e-cigarettes.

Present estimates of the prevalence of use of JUUL e-cigarettes among adolescents aged 15-17 years, however, are consistent with those reported by Vallone et al,[19] whose estimates also were derived from data collected through an online survey of a national probability sample of adolescents in 2018. Specifically, Vallone et al[19] estimated ever use of a JUUL e-cigarette at 9.5% (compared to 7.6% in our study) and past 30-day use at 6.1% (compared to 4.0% in our study). Present estimates of the prevalence of past 30-day use of any e-cigarette/ENDS (11% vs 8.7% in our study) and conventional cigarettes (7% vs 5.6% in our study) among 15-17-year-olds also were comparable to those reported by Vallone et al.[19]

However, our estimates of past 30-day e-cigarette use and previously by Vallone et al[19] are substantially lower compared to those reported from the 2018 National Youth Tobacco Survey.[4] In 2018, 20.8%

of high school students (compared to 8.7% of 15-17-year-olds in our study) and 4.9% of middle school students (compared to 1.5% of 13-14-year-olds in our study) were estimated to have used an e-cigarette in the past 30 days. As e-cigarette use by youth was assessed in our study by the same or similar questions as those asked in the 2017 NYTS, differences in prevalence estimates may be attributable, in part, to differences in data collection methods and/or differences in the composition of probabilistic samples drawn from Internet research panels and schools. Whereas the NYTS is a paper-and-pencil survey instrument that is completed in school classrooms by students who are able to view and respond to all questions, the present survey was completed online by adolescents, in the privacy of their home, with the electronic survey instrument routing them to questions that were applicable to them on the basis of answers or combinations of answers given to a previous question or combination of questions. The similarity of estimates we report to those reported from 2 other online surveys of probabilistic samples of US youth drawn from Internet research panels appears to suggest that tobacco use patterns, or reporting biases, may vary between Internet-based and school-based samples of youth. Additionally, a direct comparison of present estimates of youth e-cigarette to those derived from the 2017 NYTS is also difficult due to these studies' assessments of slightly different age ranges; whereas our study included the perceptions and intentions of adolescents aged 13-17 years, as is common in research on youth tobacco use, the NYTS also included adolescents aged 12 and 18, with the latter possibly being of legal age to purchase tobacco products, depending on where they lived.

Consistent with guidance received from the FDA Center for Tobacco Products as part of a pre-study meeting, questions relating to use of e-cigarettes and JUUL e-cigarettes in our survey instrument were programmed to display only to participants who indicated they had heard of or seen e-cigarettes/JUUL e-cigarettes before taking part in this study. These routing restrictions were deemed appropriate to prevent raising awareness of and interest in using e-cigarettes/JUUL e-cigarettes among participants who were not previously aware of these products, especially in the absence of a reliable estimate of the prevalence of awareness of JUUL e-cigarettes among adolescents. A similar routing control was applied in the survey instrument administered online by Vallone et al,[19] but such a restriction is not applied, and indeed cannot be applied in the paper-and-pencil-based NYTS.

The estimates obtained in this study should not be considered as definitive evidence, but as one piece of evidence to be considered alongside complimentary and competing snapshot estimates of the same tobacco use behaviors captured within a similar timeframe. These estimates also must be interpreted in the context of several methodological considerations and limitations. Present estimates are limited by a reliance on accurate, honest self-reporting of behaviors from youth. Although they were asked to complete and submit the survey in private and were assured that their answers would not be disclosed to their parents or to anyone else, they may have been reluctant nonetheless to report underage use of tobacco products. Such limitations of self-reporting are also true for classroom-based surveys, however, where other social pressures and biases to under- or over-report behaviors may be more influential. Additionally, no pre-testing of adolescents' comprehension of survey items was conducted. However, such pre-testing was not deemed to be necessary given that all items and response options used in the present survey had been copied or closely adapted from the 2017 NYTS and the Youth Interview Form of the PATH Study, both of which were developed on the basis of extensive cognitive testing with adolescents and are well-established as comprehensible to an 8th grade reading level.

Adolescents' awareness of the JUUL e-cigarette was assessed in this survey without displaying any images of the JUUL e-cigarette. The decision not to display an image of the JUUL e-cigarette to adolescents as part of the survey instrument was based on non-binding advice that was offered to the study authors by the FDA Center for Tobacco Products as part of a meeting to discuss the design of this study. From the discussion at this meeting, we deemed that although showing an image of the JUUL e-cigarette would likely have increased clarity for adolescents about the specific brand of e-cigarette under consideration, showing an image of the JUUL e-cigarette also carried a risk of making a proportion of youth aware of the JUUL e-cigarette for the first time, and increasing their curiosity to try using the JUUL e-cigarette. Given that the level of youth awareness of the JUUL e-cigarette was unknown – and so part of

the rationale for this study – the ethical risks of potentially contributing to youth awareness, curiosity, and use of a JUUL e-cigarette was ultimately judged to outweigh the potential benefits of increased precision in measurement. In light of the finding that more than half of adolescents aged 15-17 years had never seen or heard of a JUUL e-cigarette before taking part in this study, the decision not to show an image of the JUUL e-cigarette may have been for the greater public health good. In accordance with guidance on the scientific assessment of modified risk tobacco products (MRTPs), researchers should continue to weigh the potential ethical risks of displaying images of specific branded tobacco products to youth against the potential measurement benefits of showing such images on a case-by-case basis and seek advice from the FDA and institutional review boards on this issue before commencing studies.

Although this study provides useful estimates of the prevalence of youth use of the JUUL e-cigarette, it does not provide any information as to why adolescents start and continue using a JUUL e-cigarette, both instead of, in place of, and in addition to conventional cigarettes and other brands of e-cigarette, or indeed, why former users stopped using a JUUL e-cigarette. Anecdotally, youth users have reported the appeal of the flavor variety offered in JUULpods, the small size and shape of the device that makes it easy to conceal, and the delivery of a satisfying nicotine 'hit' as reasons for their use of a JUUL e-cigarette. However, formal quantitative and qualitative assessments of adolescents' reasons for using the JUUL e-cigarette are needed to inform educational and regulatory measures that may more effectively reduce the appeal and availability of JUUL e-cigarettes to youth.

In our study, we did not assess youth awareness of any other specific brand of e-cigarettes, and so no conclusions can be drawn about whether JUUL was the most recognizable e-cigarette brand among youth, or whether youth are comparably aware of other e-cigarette brands. Relatedly, no information was collected on the factors that have contributed to youth awareness of the JUUL brand of e-cigarette. Lastly, our study also did not identify demographic and tobacco use factors by which awareness and use of the JUUL e-cigarette varied among youth. Examining the extent to which significant variation in awareness and use of the JUUL e-cigarette exists, for example, among regions of the US, among metropolitan versus rural areas, by socioeconomic status, and among use of other tobacco products, will be important next steps.

Readers also should be mindful that, in the present fast-changing landscape of youth tobacco use, as a result of the marketing of an increasing array of pod-based e-cigarettes and e-liquid flavors, present estimates of youth awareness and use of JUUL e-cigarettes may become outdated, but will nonetheless serve as good baseline measures against which future trends and the impact of regulations and legislation that affect the accessibility, affordability, and appeal of JUUL products to youth can be assessed. For example, the present estimates of JUUL awareness and use were obtained approximately one month prior to an announcement from JUUL Labs Inc on November 13, 2018 that the company was immediately stopping sales of its mango-, crème-, fruit- and cucumber-flavored pods to the over 90,000 US retail stores that currently sell JUUL's flavored pods, including convenience stores and specialty vape stores. This voluntary action was reportedly taken by JUUL Labs Inc in response to concern expressed by the FDA about the role of non-tobacco flavors in increasing the appeal of vaping to youth, and in anticipation that the FDA would pursue further statutory action to reduce youth access and appeal of e-cigarettes, ie, action affecting all flavored ENDS products (other than tobacco, mint and menthol flavors or non-flavored products) sold in age-restricted, in-person locations, and, if sold online, under heightened practices for age verification. Present estimates can inform future assessments of the impact of these voluntary and proposed statutory actions aimed at preventing and reducing youth use of JUUL e-cigarettes.

Conclusions

Based on national probability data obtained from a cross-sectional online survey conducted in September-October 2018, the prevalence of past 30-day use of a JUUL e-cigarette was estimated at 4.0% among adolescents aged 15-17 years and 0.8% among adolescents aged 13-14 years. These estimates were attributable, in large part, to more than half of adolescents aged 15-17 years and two-thirds of adolescents aged 13-14 years having never heard of, nor seen a brand of e-cigarette called JUUL. These estimates may be limited to online

modes of data collection and to the time period in which the data were collected.

These estimates should give some cause for concern. The use of nicotine-containing e-cigarettes is not harmless to users of any age and poses unique health and addiction risks during adolescence. Therefore, no level of e-cigarette use by youth is acceptable from a public health perspective. Furthermore, regular assessment of the youth population's use of JUUL e-cigarettes is necessary to determine the trajectory of youth use of JUUL e-cigarettes. The present findings reinforce the need for regulatory actions that are more effective in limiting youth access to e-cigarettes, for continual monitoring of changes in the prevalence and frequency of e-cigarette use among adolescents, and for a better understanding of adolescents' routes into and out of e-cigarette use. Expanding and improving surveillance, research, and evaluation of the youth population, including collection of data on use behaviors, attitudes, and beliefs related to JUUL e-cigarettes is critically important to public health efforts to characterize use of JUUL e-cigarettes use among youth, the impact of JUUL e-cigarette use on youth use of other tobacco products, and youth sub-populations that are especially at-risk for initiating and continuing use of JUUL e-cigarettes.

Human Subject Approval Statement

This study was approved by Advarra Institutional Review Board (Approval no. 00029560, September 14, 2018).

Availability of Data and Materials

The raw data collected in this study and the survey instrument were submitted by the authors to the FDA Center for Tobacco Products on 6 November 2018. The raw data collected in this study has not and will not be shared with JUUL Labs Inc. The Parent Inform Consent Form, Youth Assent Form and survey instrument used in this study are available as supplementary material online.

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Funding for this study was provided by JUUL Labs Inc., the manufacturer of the JUUL brand of e-cigarettes. This study was conducted by study authors entirely independently from JUUL Labs Inc. No person from JUUL Labs Inc. had any input to or control over the study design, contents of the survey instrument, sample recruitment, data analysis, interpretation of data, or decision to report findings. The authors alone are responsible for the contents, production and decision to report this study.

Conflict of Interests Disclosure Statement

In the past 12 months, the employer of CR and NM, the Centre for Substance Use Research (CSUR), has received funding from JUUL Labs Inc. to independently design and conduct research on the impact of JUUL vapor products on tobacco use behaviors, perceptions and intentions among adults and adolescents in the United States, Canada and the United Kingdom. In the past three years, the Centre for Substance Use Research has also received funding from other e-cigarette manufacturers, including Fontem Ventures, Nicoventures and Philip Morris International, to independently conduct research on tobacco harm reduction, specifically, on factors that increase and decrease smokers' interest in and likelihood of completely substituting e-cigarettes for combustible cigarettes.

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Authors' contributions

CR and NM conceived of the study. CR developed the survey instrument and conducted the data analyses. CR and NM wrote the manuscript. Both authors read and approved the final manuscript.

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