



E-cigarette use among high school students in the United States prior to the COVID-19 pandemic: Trends, correlates, and sources of acquisition

Mohammadhassan Mirbolouk^{a,1}, Ellen Boakye^{b,c,1}, Olufunmilayo Obisesan^d, Albert D. Osei^d, Omar Dzaye^b, Ngozi Osuji^b, John Erhabor^{b,c}, Andrew C. Stokes^{c,e}, Omar El-Shahawy^{c,f}, Carlos J. Rodriguez^{c,g}, Glenn A. Hirsch^{c,h}, Emelia J. Benjamin^{c,i,j}, Andrew P. DeFilippis^{c,k}, Rose Marie Robertson^{c,k}, Aruni Bhatnagar^{c,l}, Michael J. Blaha^{b,c,*}

^a Department of Internal Medicine, Yale School of Medicine, New Haven, CT, USA

^b Johns Hopkins Ciccarone Center for the Prevention of Cardiovascular Disease, Baltimore, MD, USA

^c The American Heart Association Tobacco Regulation and Addiction Center, Dallas, TX, USA

^d Department of Medicine, MedStar Union Memorial Hospital, Baltimore, MD, USA

^e Department of Global Health, Boston University School of Public Health, Boston, MA, USA

^f Department of Population Health, New York University School of Medicine, New York, NY, USA

^g Division of Cardiovascular Medicine, Albert Einstein College of Medicine, Bronx, NY, USA

^h Division of Cardiology, Department of Medicine, National Jewish Health, Denver, CO, USA

ⁱ Cardiovascular Medicine, Boston University School of Medicine, Boston, MA, USA

^j Department of Epidemiology, Boston University School of Public Health, Boston, MA, USA

^k Department of Medicine, Vanderbilt University Medical Center, Nashville, TN, USA

^l University of Louisville School of Medicine, Louisville, KY, USA

ARTICLE INFO

Keywords:

Electronic Cigarettes
Vaping
High school Students
Trends
Psychosocial Stress

ABSTRACT

Detailed description of the prevalence and sources of e-cigarettes among youth is needed to inform effective regulatory policies. We used the Youth Risk Behavior Surveillance System data (2015–2019) to assess trends in current (past-30-day-use) and frequent (≥ 10 days in past-30-days) e-cigarette use among United States high schoolers before the COVID-19 pandemic. First, we assessed trends overall and then stratified by participants' sociodemographic characteristics, use of other tobacco products, and experiences of psychosocial stress. We also evaluated past year quit attempts and the changing sources of e-cigarettes.

Our sample size was 41,021 (15,356–2015; 12,873–2017; 12,792–2019). The prevalence of current e-cigarette use increased from 24.0% (95%CI:21.9%–26.3%) in 2015 to 32.7% (30.4%–35.1%) in 2019. The proportion of current users who reported frequent use also increased significantly from 22.6% (20.4%–24.8%) to 45.4% (42.7%–48.2%). Thus, an increasing proportion of US high school students who use e-cigarettes reported frequent use, indicating greater nicotine dependence. The increase in current and frequent e-cigarette use was more pronounced in youth who reported other substance use and psychosocial stressors such as bullying. Between 2017 and 2019, there was a decline in the proportion of youth who bought e-cigarettes online (6.9% to 3.2%) or from convenience stores (22.0% to 16.6%). Conversely, there was an increase in the proportion who borrowed (34.5% to 40.1%) or purchased e-cigarettes through other people (10.7% to 18.0%), indicating that most youth are evading age-related restrictions by obtaining e-cigarettes from other people. Finally, a considerable proportion of youth tobacco users are making quit attempts; 47.6% (45.1%–50.1%) in 2019.

* Corresponding author at: Johns Hopkins Ciccarone Center for the Prevention of Cardiovascular Disease, 600 N Wolfe St, Blalock 524, Baltimore, MD 21287, USA.
E-mail addresses: mohammadhassan.mirbolouk@yale.edu (M. Mirbolouk), eboakye2@jhmi.edu (E. Boakye), olufunmilayo.h.obisesan@medstar.net (O. Obisesan), albert.d.osei@medstar.net (A.D. Osei), odzaye@jhmi.edu (O. Dzaye), nosuji1@jhmi.edu (N. Osuji), jerhabo1@jhmi.edu (J. Erhabor), acstokes@bu.edu (A.C. Stokes), Omar.ElShahawy@nyulangone.org (O. El-Shahawy), carlos.rodriguez@einsteinmed.org (C.J. Rodriguez), hirschg@njhealth.org (G.A. Hirsch), emelia@bu.edu (E.J. Benjamin), andrew.defilippis@vumc.org (A.P. DeFilippis), rosemarie.robertson@heart.org (R. Marie Robertson), aruni.bhatnagar@louisville.edu (A. Bhatnagar), mblaha1@jhmi.edu (M.J. Blaha).

¹ Co-first authors.

1. Introduction

The popularity of electronic vaping products (hereafter referred to as e-cigarettes) has surged among adolescents since their introduction into the United States (US) market in the mid-2000s (U.S. Department of Health and Human Services, 2016a). In 2016, the US Food and Drug Administration (FDA) finalized the “Deeming Rule” and extended its regulatory authority to e-cigarettes (Food and Drug Administration, 2016). Under the deeming rule, the FDA has the power to regulate e-cigarettes as tobacco products, including the implementation of age-related restrictions on their sales (Food and Drug Administration, 2016). However, despite these regulatory efforts, e-cigarette use continued to increase among adolescents and young adults (Miech et al., 2019).

More recent studies have shown a declining prevalence of e-cigarette use among US middle and high school students (Park-Lee et al., 2021; Wang et al., 2020). Despite this decline, e-cigarettes remain the most popular tobacco product among youth, with a significant proportion of youth still reporting their use (Gentzke et al., 2020). The availability of easily concealable devices such as the pod-mod e-cigarettes and youth-targeted advertisements by e-cigarette companies such as JUUL may be fueling this observation (U.S. Department of Health and Human Services, 2016b). In addition, disposable e-cigarettes such as puffbar, which were initially excluded from the federal flavor ban, are becoming more popular and may be sustaining the e-cigarette epidemic among youth (Dai and Hao, 2022; Food and Drug Administration, 2020; Wang et al., 2021).

The 2019 e-cigarette or vaping product use-associated lung injury (EVALI) epidemic, reported mostly among youth and young adults (52% of all cases) and linked to vaping tetrahydrocannabinol (THC) and vitamin E acetate, an additive used in THC-containing e-liquids, has fueled renewed concerns about e-cigarette use among youth (Centers for Disease Control and Prevention, 2020). Also, some recent studies have shown that a considerable proportion of youth who vape are making e-cigarette cessation attempts, hence the need to explore this further (Dai, 2021; Smith et al., 2021). Prevention of e-cigarette initiation, coupled with age-appropriate evidence-based e-cigarette cessation strategies, may help reduce e-cigarette use among the youth (Substance Abuse and Mental Health Services Administration (SAMHSA), n.d.). However, to develop effective preventive initiatives, it is essential to understand the distribution of e-cigarette use, consider the determinants of use, such as psychosocial stress and social influence, and the sources from where youth obtain e-cigarettes. By delineating the patterns of e-cigarette use, factors that increase susceptibility to use, and the changing sources of e-cigarettes, our findings could help inform regulatory policies to reduce youth e-cigarette use further. We hypothesized that frequent e-cigarette use, which depicts more nicotine dependence, would be increasing among youth. Additionally, the sources of e-cigarette acquisition among youth may be changing, necessitating the need for continued surveillance.

Therefore, using 2015, 2017, and 2019 (most recent survey cycle) data from one of the most extensive nationally representative health surveys—the Youth Risk Behavior Surveillance System (YRBSS) - we examined trends in current and frequent e-cigarette use prevalence among US high school students before the COVID-19 pandemic. We assessed these trends first overall and then stratified by participants’ sociodemographic characteristics, use of other tobacco products, and experiences of psychosocial stress. Finally, we also evaluated quit attempts and described for the first time how the modes of e-cigarette acquisition have changed over the last few years.

2. Materials and methods

2.1. Data source and study design

To describe the trends in e-cigarette use among US high school

students, we analyzed 2015, 2017, and 2019 national YRBSS data. Detailed information about the methodology of the YRBSS is provided elsewhere (Frieden et al., 2013). In brief, the YRBSS is a school-based biennial survey that uses a 3-stage cluster sampling design to obtain a nationally representative sample of high school students in the 9th to 12th grades of public and private schools in all 50 states and the District of Columbia (Frieden et al., 2013). The survey response rate averaged 60% in all three survey years under consideration (Frieden et al., 2016; Redfield et al., 2017; Underwood et al., 2020). Our study was exempted from review by an institutional review board since it uses publicly available deidentified YRBSS data.

The YRBSS started collecting data on e-cigarette use in 2015. Of the 15,627, 14,765, and 13,677 students who participated in the 2015, 2017, and 2019 national surveys, respectively, we included data from 15,356, 12,873, and 12,792 students who provided information on current e-cigarette use. Therefore, our sample size corresponds to approximately 93% of the 2015–2019 dataset.

2.2. Assessment of e-Cigarette, combustible Cigarette, and other tobacco product use

Current e-cigarette use was assessed with the questions, “During the past 30 days, on how many days did you use an electronic vapor product?”. Participants who reported using e-cigarettes at least one day in the past 30 days were classified as current users. Current users who reported using e-cigarettes on ≥ 10 days were deemed frequent users as in previous studies (Han et al., 2020; Chan et al., 2022; Lee et al., 2017; McCabe et al., 2017). More frequent e-cigarette use was defined as use of e-cigarette on ≥ 20 days in the past 30-days.

Similarly, we categorized combustible cigarette use as never, former, and current based on answers to the questions “Have you ever tried cigarette smoking, even one or two puffs?” and “During the past 30 days, on how many days did you smoke cigarettes?”. Current use of other tobacco products was assessed with the questions, “During the past 30 days, on how many days did you use chewing tobacco, snuff, dip, snus, or dissolvable tobacco products, such as Copenhagen, Grizzly, Skoal, or Camel Snus?” and “During the past 30 days, on how many days did you smoke cigars, cigarillos, or little cigars?”. Participants who reported using these products on at least one day in the past 30 days were considered current users of those products.

A past-year attempt at quitting all tobacco products was assessed in the 2017 and 2019 surveys with the question, “During the past 12 months, did you ever try to quit using all tobacco products, including cigarettes, cigars, smokeless tobacco, shisha, or hookah tobacco, and electronic vapor products?”.

2.3. Sources of e-Cigarettes among current E-cigarette users

In 2017 and 2019, the sources of e-cigarettes among current e-cigarette users were assessed with the question, “During the past 30 days, how did you usually get your electronic vapor products?”. Answer choices included “I bought them in a store such as a convenience store/supermarket/discount store/gas station/vape store”, “I got them on the Internet”, “I gave someone else money to buy them for me”, “I borrowed them from someone else”, “A person who can legally buy these products gave them to me”, “I took them from a store or another person”, and “other”.

2.4. Other study measures

Participant characteristics considered in our analyses included age, sex (male, female), grade (9th, 10th, 11th, 12th), sexual orientation (heterosexual, gay/lesbian, bisexual, not sure), and race/ethnicity (American Indian/Alaskan Native/Native Hawaiian/Pacific Islander, Asian, non-Hispanic Black/African American, non-Hispanic White, Hispanic, Multi-racial). Body mass index (BMI) was calculated from self-reported weight and height and categorized as underweight, normal

weight, overweight, or obese based on age-sex percentiles. Participants reported involvement in behaviors that contribute to physical harm, and experiences leading to emotional stress were also included. These included sexual assault or rape, physical fights, traditional and cyber-bullying, threatened or injured with a weapon, consideration of suicide, marijuana use, and alcohol use.

2.5. Statistical analysis

The weighted prevalence estimates of current and frequent e-cigarette use were calculated for each year, first for the entire group, then after stratification by participants' sociodemographic characteristics, use of other tobacco products, and reported psychosocial stressors. We additionally examined trends in more frequent e-cigarette use (≥ 20 days in the past 30 days). The weighted prevalence estimate of current e-cigarette use for each year was extrapolated to the population of students enrolled in US high schools (public and private) in that year (US Census Bureau, 2015, 2018, 2019). The absolute differences (with 95 % confidence intervals) in the prevalence of current and frequent e-cigarette use between the years were estimated using the "lincom" command in Stata.

Changes in the sources of e-cigarettes between 2017 and 2019 were examined by estimating the weighted proportion of respondents who obtained their devices from the sources explored (convenience/vape shop, internet, borrowing, purchasing through others, etc.). Using combined 2017 and 2019 data and cross-sectional multivariable logistic regression models, restricting our sample to youth aged < 18 years, we examined the factors associated with underage (< 18 years) purchasing of e-cigarettes online or from convenience/vape stores and the factors related to borrowing or purchasing e-cigarettes through others.

All analyses were performed using Stata version 16 (StataCorp, College Station, TX), and the survey command "svy" command was used to account for the complex survey design of the YRBSS. We considered a two-sided alpha (α) of < 0.05 statistically significant for analyses with significance testing.

3. Results

3.1. Trends in the prevalence of E-cigarette use

The weighted prevalence of current e-cigarette use was 24.0 % (95 % CI, 21.9 %–26.3 %) in 2015, 13.2 % (11.5 %–15.1 %) in 2017, and 32.7 % (30.4 %–35.1 %) in 2019. These correspond to approximately 3.97 million, 2.22 million, and 5.36 million high school students in 2015, 2017, and 2019, respectively. The weighted prevalence of frequent e-cigarette use decreased from 5.4 % (4.7 %–6.4 %) in 2015 to 4.9 % (4.0 %–6.0 %) in 2017 before markedly increasing to 14.9 % (13.3 %–16.7 %) in 2019. Correspondingly, there was a persistent and steep increase in the proportion of current users who used e-cigarettes frequently: 22.6 % (20.4 %–24.8 %) in 2015, to 37.1 % (32.6 %–41.9 %) in 2017, and 45.4 % (42.7 %–48.2 %) in 2019 (Fig. 1). When defined as e-cigarette use in ≥ 20 days in the past 30-days, the prevalence of more frequent e-cigarette increased from 3.0 % (2.4 %–3.6 %) in 2015, to 3.3 % (2.6–4.2 %) in 2017, and 10.7 % (9.4 %–12.1 %) in 2019. Likewise, the proportion of current users who reported more frequent use increased: 12.3 % (10.6 %–14.2 %) in 2015; 25.1 % (21.3 %–29.5 %) in 2017; 32.6 % (30.0 %–35.2 %) in 2019 (Supplementary Fig. 1).

The increased prevalence of current e-cigarette use between 2015 and 2019 was observed across various sociodemographic subgroups, with the most pronounced increase seen among females (22.5 % to 33.4 %), 12th graders (28.1 % to 40.3 %), and American Indian/Alaskan Native/Native Hawaiian/Pacific Islander (29.3 % to 44.4 %) and White youth (25.0 % to 38.2 %) (Table 1). The prevalence of current e-cigarette use also increased markedly among youth who were former (35.9 % to 56.7 %) or current (69.8 % to 89.1 %) combustible cigarette smokers and current users of smokeless tobacco (66.4 % to 87.1 %), cigars/cigarillos/little cigars (67.4 % to 88.3 %), alcohol (34.2 % to 70.8 %), or marijuana (57.8 % to 78.9 %) (Table 2). The increased prevalence of current e-cigarette use was not only seen among current and former combustible cigarette smokers but also among never combustible cigarette smokers (12.2 % to 23.1 %) (Table 2). Even more striking is the 464 % relative increase in the prevalence of frequent e-cigarette use among never combustible cigarette smokers (1.4 % to 7.9 %)

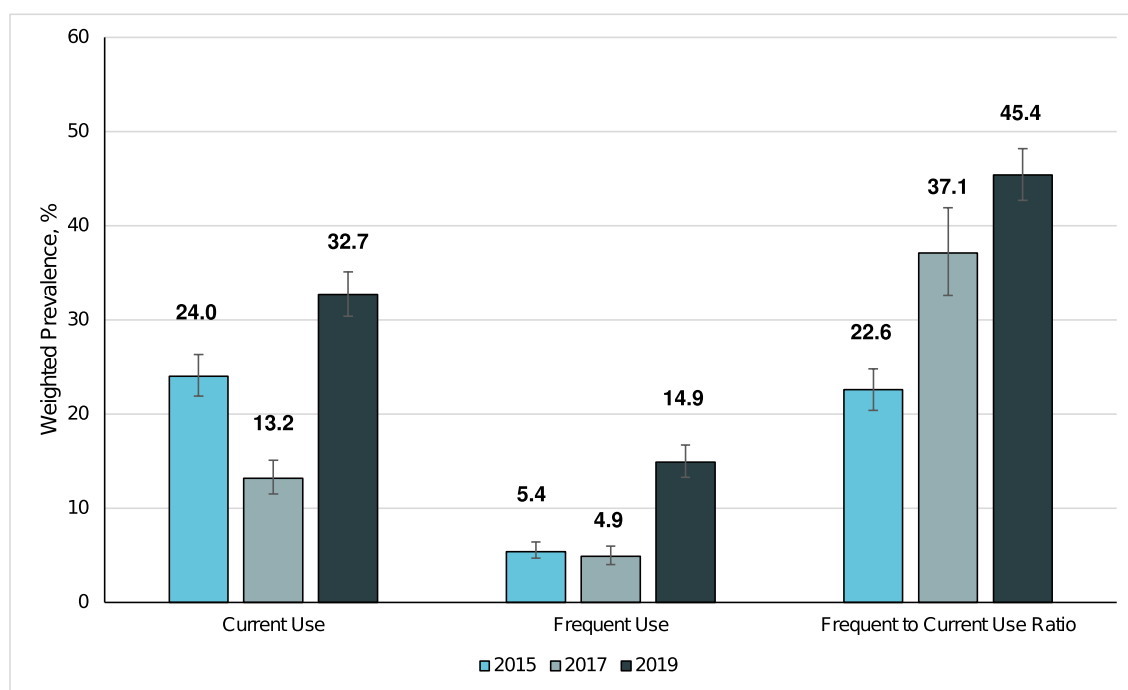


Fig. 1. Weighted Prevalence (95% Confidence Intervals) of E-Cigarette Use among High School Students in the United States, Youth Risk Behavior Surveillance System 2015, 2017, 2019.

Table 1

Trends in the weighted prevalence estimates of current e-cigarette use among high school students stratified by participant sociodemographic characteristics, Youth Risk Behavior Surveillance System 2015, 2017, 2019*.

Characteristic	Weighted Prevalence (95 % Confidence Intervals), %			Absolute Prevalence Difference		
	2015	2017	2019	2017 vs 2015	2019 vs 2017	2019 vs 2015
Current e-cigarette users/Participants, No.	3899/15356	1666/12873	4109/12792			
Overall	24.0 (21.9 – 26.3)	13.2 (11.5 – 15.1)	32.7 (30.4 – 35.1)	–10.8 (–13.6 – –8.0)	19.5 (16.4–22.6)	8.7 (5.4–12.0)
Age, years						
12 – 14	17.5 (14.8 – 20.6)	8.3 (6.3 – 10.9)	25.5 (22.7 – 28.6)	–9.2 (–12.9 – –5.5)	17.2 (13.5–21.0)	8.0 (4.0–12.1)
15	21.1 (18.8 – 23.7)	9.9 (8.0 – 12.3)	26.0 (23.8 – 28.4)	–11.2 (–14.5 – –7.9)	16.1 (12.9–19.3)	4.9 (1.5–8.4)
16	23.5 (21.2 – 26.1)	12.7 (10.7 – 15.0)	34.0 (30.2 – 38.0)	–10.9 (–14.1 – –7.6)	21.3 (16.8–25.9)	10.5 (5.8–15.1)
17	27.4 (24.5 – 30.4)	14.8 (12.3 – 17.7)	36.4 (33.0 – 40.0)	–12.5 (–16.4 – –8.6)	21.6 (17.1–26.2)	9.1 (4.3–13.8)
≥18	29.0 (24.9 – 33.5)	21.5 (18.9 – 24.5)	42.6 (38.6 – 46.7)	–7.5 (–12.7 – –2.3)	21.0 (16.0–26.1)	13.5 (7.6–19.5)
Sex						
Female	22.5 (20.4 – 24.8)	10.5 (8.8 – 12.5)	33.4 (30.7 – 36.3)	–12.0 (–14.8 – –9.1)	22.9 (19.4–26.3)	10.9 (7.2–14.6)
Male	25.5 (22.8 – 28.4)	15.8 (13.8 – 18.0)	31.9 (29.4 – 34.5)	–9.7 (–13.2 – –6.1)	16.1 (12.7–19.4)	6.4 (2.6–10.3)
Grade						
9th	19.5 (17.1 – 22.1)	9.5 (7.7 – 11.7)	25.0 (22.7 – 27.4)	–10.0 (–13.3 – –6.8)	15.5 (12.3–18.6)	5.4 (1.9–8.9)
10th	23.2 (20.3 – 26.3)	11.3 (9.5 – 13.4)	30.4 (27.2 – 33.8)	–11.8 (–15.5 – –8.2)	19.1 (15.2–23.0)	7.3 (2.7–11.8)
11th	25.8 (22.9 – 28.9)	14.0 (11.5 – 17.0)	35.9 (31.9 – 40.1)	–11.7 (–15.7 – –7.7)	21.9 (16.8–26.9)	10.2 (4.9–15.4)
12th	28.1 (25.0 – 31.5)	18.2 (15.8 – 20.9)	40.3 (37.2 – 43.5)	–9.9 (–14.1 – –5.7)	22.1 (17.9–26.2)	12.2 (7.6–16.8)
Sexual orientation						
Heterosexual	23.3 (21.0 – 25.8)	13.1 (11.5 – 15.0)	32.8 (30.2 – 35.4)	–10.2 (–13.1 – –7.2)	19.6 (16.4–22.9)	9.5 (5.8–13.1)
Gay/lesbian	26.0 (20.7 – 32.1)	14.5 (10.5 – 19.7)	32.6 (25.6 – 40.6)	–11.5 (–18.8 – –4.3)	18.1 (9.3–27.0)	6.6 (–2.9–16.2)
Bisexual	29.7 (25.8 – 34.0)	18.5 (15.0 – 22.6)	34.5 (30.6 – 38.7)	–11.3 (–16.8 – –5.8)	16.1 (10.4–21.7)	4.8 (–1.0–10.6)
Not sure	26.2 (20.9 – 32.4)	10.8 (7.2 – 15.9)	24.8 (20.0 – 30.5)	–15.5 (–22.9 – –8.0)	14.0 (7.0–21.1)	–0.01.4 (–9.3–6.5)
Race/Ethnicity						
American Indian/Alaskan Native/Native Hawaiian/ Pacific Islander	29.3 (20.8 – 39.7)	16.3 (8.5 – 29.2)	44.4 (35.7 – 53.5)	–13.0 (–27.1–1.1)	28.1 (14.5–41.7)	15.1 (1.8–28.3)
Asian	14.5 (10.5 – 19.7)	3.7 (2.4 – 5.5)	13.0 (9.7 – 17.1)	–10.8 (–15.6 – –6.0)	9.3 (5.3–13.3)	–1.5 (–7.5–4.5)
African American	18.0 (14.8 – 21.7)	8.5 (6.2 – 11.4)	19.6 (16.0 – 23.7)	–9.5 (–13.7 – –5.3)	11.1 (6.5–15.8)	1.6 (–3.8–7.1)
White	25.0 (22.0 – 28.3)	15.6 (13.2 – 18.2)	38.2 (36.0 – 40.5)	–9.5 (–13.5 – –5.4)	22.7 (19.3–26.1)	13.2 (9.3–17.1)
Hispanic	24.8 (21.2 – 28.9)	10.4 (7.3 – 14.8)	27.7 (23.7 – 32.1)	–14.4 (–19.4 – –9.4)	17.3 (11.7–22.8)	2.9 (–3.0–8.7)
Multi-Racial	26.9 (24.5 – 29.4)	12.4 (10.3 – 14.8)	33.1 (29.6 – 36.8)	–14.5 (–17.9 – –11.2)	20.7 (16.2–25.2)	6.2 (1.8–10.6)
BMI						
Underweight	19.8 (15.0 – 25.7)	11.7 (8.1 – 16.4)	24.9 (18.5 – 32.6)	–8.2 (–14.8 – –1.5)	13.2 (5.1–21.4)	5.1 (–3.9–14.1)
Normal Weight	23.2 (20.8 – 25.8)	12.7 (11.0 – 14.7)	33.3 (30.8 – 35.9)	–10.4 (–13.5 – –7.4)	20.6 (17.4–23.8)	10.2 (6.5–13.8)
Overweight	27.6 (23.6 – 32.1)	13.2 (10.7 – 16.2)	34.4 (30.0 – 39.1)	–14.4 (–19.6 – –9.2)	21.2 (15.7–26.6)	6.8 (0.4–13.2)
Obese	24.5 (21.7 – 27.5)	14.5 (12.0 – 17.4)	31.0 (27.9 – 34.3)	–10.0 (–13.9 – –6.1)	16.5 (12.3–20.8)	6.5 (2.1–11.0)

*Values are prevalence estimates presented as percentages (%) with 95% Confidence Intervals (CI).

(Supplementary Table 2).

Among respondents who reported current use of at least one tobacco product, the prevalence of current e-cigarette use was 79.1 % (75.5 %–82.4 %) in 2015, remained relatively stable at 73.6 % (68.7 %–78.0 %) in 2017, but significantly increased to 96.6 % (95.5 %–97.5 %) in 2019 (Supplementary Fig. 2). We present the trends in frequent e-cigarette use prevalence from 2015 to 2019 stratified by respondents’ characteristics in Supplementary Tables 1-3.

3.2. Trends in use of other tobacco products and past year quit attempts

Between 2015 and 2019, current use prevalence of other tobacco products significantly decreased. Current combustible cigarette use decreased from 10.8 % (9.0 %–12.4 %) to 5.9 % (4.8 %–7.1 %). Similarly, the prevalence of chewing tobacco and cigars decreased from 7.3 % (6.0 %–8.9 %) to 3.8 % (3.2 %–4.6 %) and 10.3 % (9.0 %–11.8 %) to 5.7 % (4.8 %–6.7 %), respectively (Fig. 2).

In 2017 and 2019, approximately 41.4 % (39.0 %–43.9 %) and 47.6

Table 2

Trends in the prevalence of current e-cigarette use among high school students stratified by use of other tobacco products and substances, Youth Risk Behavior Surveillance System 2015, 2017, 2019*.

Characteristic	Weighted Prevalence (95 % Confidence Intervals), %			Absolute Prevalence Difference		
	2015	2017	2019	2017 vs 2015	2019 vs 2017	2019 vs 2015
Combustible cigarette use						
Never	12.2 (10.6–14.0)	3.5 (2.8–4.3)	23.1 (21.2–25.2)	–8.7 (-10.5 - –6.9)	19.7 (17.6–21.8)	10.9 (8.3–13.5)
Former	35.9 (32.7–39.1)	21.1 (17.4 – 25.3)	56.7 (51.6–61.5)	–14.7 (-19.9 - –9.6)	35.5 (29.1–41.9)	20.8 (14.7–26.9)
Current	69.8 (65.4–73.9)	69.7 (63.8–75.0)	89.1 (85.3–92.1)	–0.1 (-7.3–7.0)	19.4 (12.9–26.0)	19.3 (13.8–24.8)
Use of chewing tobacco, snuff, dip, snus, or dissolvable tobacco products in the past 30 days						
No	20.9 (19.0–22.9)	9.8 (8.5–11.4)	30.4 (28.3–32.7)	–11.0 (-13.4 - –8.6)	20.6 (17.8–23.3)	9.6 (6.6–12.6)
Yes	66.4 (60.5–71.8)	68.3 (62.2–73.8)	87.1 (80.9–91.5)	1.9 (-6.3–10.1)	18.8 (11.0–26.6)	20.7 (13.0–28.4)
Use of cigars, cigarillos, or little cigars in the past 30 days						
No	19.2 (17.3–21.2)	8.1 (6.8–9.5)	29.2 (27.1–31.4)	–11.1 (-13.4 - –8.8)	21.1 (18.5–23.8)	10.0 (7.1–13.0)
Yes	67.4 (62.5–71.8)	69.9 (65.4–74.1)	88.3 (84.5–91.3)	2.5 (-4.0–9.0)	18.4 (12.9–23.9)	21.0 (15.2–26.7)
At least one drink of alcohol in the past 30 days						
No	5.9 (4.9–7.1)	3.1 (2.5 – 3.8)	15.5 (14.0–17.2)	–2.8 (-4.1 - –1.6)	12.5 (10.7–14.2)	9.6 (7.7–11.5)
Yes	34.2 (31.7–36.9)	37.4 (33.5 – 41.5)	70.8 (67.6–73.8)	3.1 (-1.7–7.9)	33.4 (28.2–38.7)	36.6 (32.4–40.7)
Use marijuana use in past 30 days						
No	14.5 (12.7 – 16.4)	6.3 (5.1 – 7.7)	19.9 (17.8 – 22.1)	–8.2 (-10.4 - –5.9)	13.6 (11.1–16.2)	5.5 (2.6–8.4)
Yes	57.8 (54.2 – 61.3)	43.9 (39.4 – 48.6)	78.9 (75.7 – 81.8)	–13.9 (-19.8 - –7.9)	35.0 (29.2–40.8)	21.1 (16.1–26.1)

*Values are prevalence estimates presented as percentages (%) with 95% Confidence Intervals (CI).

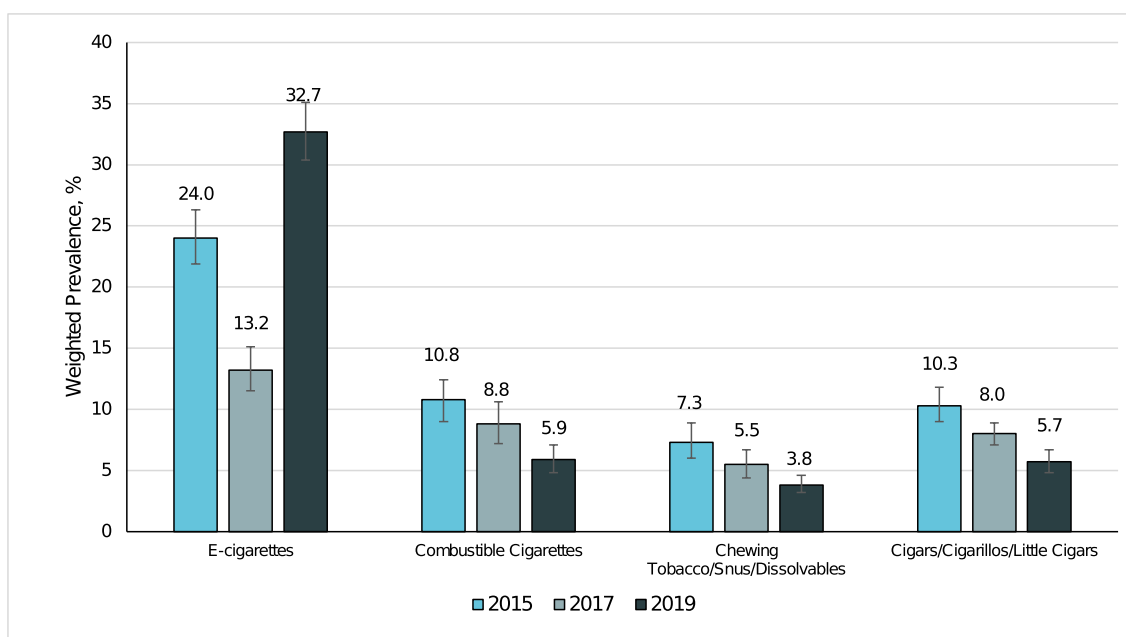


Fig. 2. Weighted Prevalence (95% Confidence Intervals) of Current Use of Different Tobacco Products among High School Students in the United States, Youth Risk Behavior Surveillance System 2015, 2017, 2019.

(45.2 %–50.1 %) of youth who used any tobacco product in the past 12 months, respectively reported making past year quit attempts.

3.3. Psychosocial stress and E-cigarette use

Compared to respondents who did not report psychosocial stressors, those who reported being sexually assaulted, threatened, bullied, or missing out of school because they felt unsafe had a higher prevalence of current and frequent e-cigarette use (Table 3 and Supplementary Table 3). For example, about 58.5 % (51.5 % – 65.1 %) of respondents who reported ever being sexually assaulted or raped reported current e-cigarette use, compared to 31.3 % (29.0 % – 33.7 %) of those who did not report sexual assault or rape. Similarly, current e-cigarette use

prevalence among respondents who experienced cyberbullying was 50.1 % (46.9 %–53.4 %) compared to 29.4 % (27.1 %–31.8 %) among those who did not report cyberbullying (Table 3). The prevalence of current e-cigarette use was also higher among respondents who reported risky sexual behaviors, including those who had two or more sexual partners in the past three months (71.6 % [65.5 % – 77.0 %]) compared to those who had not never had sex (19.1 % [17.3 %–21.0 %]). Also, the increase in e-cigarette use prevalence between 2015 and 2019 was greater among those who reported psychosocial stressors or risky sexual behaviors than those who did not (Table 3 and Supplementary Table 3).

Table 3

Trends in the prevalence of e-cigarette use among high school students stratified by psychosocial factors, Youth Risk Behavior Surveillance System 2015, 2017, 2019.

Characteristics	Weighted Prevalence (95 % Confidence Intervals), %			Absolute Prevalence Difference		
	2015	2017	2019	2017 vs 2015	2019 vs 2017	2019 vs 2015
Missing out of school in the past 30 days because of feeling unsafe						
No	23.0 (20.9 – 25.2)	12.2 (10.5–14.2)	31.4 (29.1–33.8)	-10.7 (-13.6 - -7.9)	19.2 (16.1–22.2)	8.4 (5.1–11.7)
Yes	42.3 (35.0 – 50.0)	24.2 (20.4–28.6)	48.0 (43.0–53.0)	-18.1 (-26.9 - -9.3)	23.7 (17.1–30.3)	5.6 (-3.5–14.8)
Ever been sexually assaulted or raped						
No	22.3 (20.3 – 24.5)	12.1 (10.6–13.8)	31.3 (29.0–33.7)	-10.2 (-12.9 - -7.5)	19.2 (16.3–22.1)	9.0 (5.7–12.3)
Yes	45.7 (40.4 – 51.1)	30.4 (26.2–35.0)	58.5 (51.5–65.1)	-15.3 (-22.3 - -8.2)	28.0 (19.6–36.5)	12.8 (4.0–21.5)
Threatened or injured with a weapon on school property in the past 12 months						
No	23.0 (20.9 – 25.2)	12.1 (10.5 – 13.9)	30.9 (28.6 – 33.2)	-10.8 (-13.6 - -8.1)	18.7 (15.8–21.7)	7.9 (4.6–11.2)
Yes	41.8 (37.3 – 46.6)	31.2 (26.3 – 36.5)	56.3 (52.0 – 60.4)	11.2 (-17.6 - -3.7)	25.1 (18.4–31.8)	14.4 (8.0–20.8)
Physical fight in the past 12 months						
No	18.9 (17.0 – 21.0)	8.6 (7.3 – 10.1)	28.2 (26.0–30.5)	-10.3 (-12.7 - -7.9)	19.6 (16.9–22.3)	9.3 (6.2–12.5)
Yes	40.9 (37.8 – 44.1)	27.2 (23.9 – 30.9)	50.3 (46.2–54.4)	-13.7 (-18.4 - -8.9)	23.1 (17.5–28.7)	9.4 (4.2–14.7)
Bullied on school property in past 12 months						
No	22.6 (20.5–24.8)	12.1 (10.5–13.9)	30.0 (27.5–32.5)	-10.4 (-13.2 - -7.7)	17.8 (14.7–21.0)	7.4 (4.0–10.8)
Yes	29.4 (26.3 – 32.8)	17.5 (14.9 – 20.5)	43.5 (40.1 – 46.9)	-11.9 (-16.3 - -7.6)	26.0 (21.5–30.4)	14.0 (9.2–18.9)
Cyberbullied in past 12 months						
No	21.8 (19.7–24.0)	11.7 (10.1–13.5)	29.4 (27.1–31.8)	-10.1 (-12.8 - -7.4)	17.7 (14.7–20.7)	7.6 (4.4–10.8)
Yes	35.9 (32.5 – 39.5)	22.0 (19.0 – 25.3)	50.1 (46.9 – 53.4)	-13.9 (-18.7 - -9.1)	28.2 (23.6–32.7)	14.3 (9.3–19.2)
Seriously consider suicide in the past 12 months						
No	21.6 (19.5–23.8)	11.5 (10.0–13.3)	29.2 (26.9–31.6)	-10.1 (-12.8 - -7.4)	17.7 (14.7–20.7)	7.7 (4.4–10.9)
Yes	35.4 (32.3 – 38.6)	21.1 (17.8 – 24.9)	47.6 (44.4 – 50.8)	-14.2 (-19.0 - -9.5)	26.4 (21.6–31.3)	12.2 (7.6–16.8)
Number of people with which you had sexual intercourse in the past 3 months						
Never had sex	12.9 (11.5–14.4)	4.9 (4.0 – 5.9)	19.1 (17.3–21.0)	-8.0 (-9.8 - -6.3)	14.2 (12.2–16.3)	6.2 (3.9–8.6)
None during the past 3 months	34.2 (31.1 – 37.5)	22.3 (17.9 – 27.4)	49.7 (44.4 – 55.0)	-11.9 (-17.7 - -6.1)	27.3 (20.2–34.5)	15.4 (9.1–21.7)
One	36.8 (32.6 – 41.4)	25.3 (22.3 – 28.6)	54.3 (50.5 – 58.0)	-11.5 (-17.0 - -6.1)	28.9 (23.9–34.0)	17.4 (11.5–23.4)
Two or more	55.9 (50.5–61.0)	44.0 (37.1 – 51.1)	71.6 (65.5 – 77.0)	-11.8 (-20.8 - -2.9)	27.6 (18.2–37.0)	15.8 (7.9–23.6)
Plan about weight						
Lose weight	25.6 (23.3 – 28.1)	12.6 (10.5 – 14.7)	35.1 (32.3–38.1)	-13.1 (-16.3 - -9.9)	22.7 (19.1–26.3)	9.5 (5.7–13.4)
Gain weight	27.5 (25.0 – 30.2)	18.4 (15.7 – 21.4)	36.9 (33.2–40.7)	-9.1 (-12.9 - -5.4)	18.5 (13.7–23.2)	9.3 (4.5–14.2)
Stay the same	20.7 (18.0 – 23.6)	11.4 (9.4–13.8)	31.0 (27.7–34.6)	-9.3 (-12.7 - -5.8)	19.6 (15.6–23.7)	10.4 (5.8–15.0)
No plan	19.2 (16.0 – 23.0)	10.2 (8.0–13.0)	26.5 (23.1–30.1)	-9.0 (-13.3 - -4.7)	16.2 (11.8–20.7)	7.2 (2.2–12.2)
Grades in school, mostly						
A	14.1 (11.4–17.2)	7.6 (6.2–9.3)	26.3 (23.6–29.2)	-6.4 (-9.8 - -3.1)	18.6 (15.4–21.9)	12.2 (8.1–16.3)
B	25.0 (22.9–27.3)	13.5 (11.3–16.0)	33.9 (31.1–36.8)	-11.6 (-14.8 - -8.3)	20.4 (16.7–24.2)	8.9 (5.0–12.7)
C	33.3 (30.9–35.8)	19.1 (15.7–23.0)	41.0 (37.2–44.9)	-14.2 (-18.7 - -9.8)	21.9 (16.5–27.3)	7.7 (3.0–12.3)
D or Fs	44.7 (38.1–51.4)	27.2 (22.7–32.2)	51.4 (45.4–57.4)	-17.5 (-25.8 - -9.3)	24.2 (16.4–32.1)	6.7 (-2.5–15.9)
Other/ not sure	27.5 (22.5–33.2)	17.8 (13.2–23.5)	31.4 (25.0–38.6)	-9.8 (-16.5 - -3.1)	13.7 (4.9–22.4)	3.9 (-4.9–12.7)
Level of English speaking						
Not well or not very well	33.8 (23.9–45.4)	22.9 (14.8 – 33.9)	39.0 (28.8–50.3)	-10.9 (-25.4–3.6)	16.1 (1.2–30.9)	5.2 (-10.5–20.9)
very well or well	24.0 (21.7–26.4)	12.9 (11.1–14.9)	33.4 (30.9–36.0)	-11.1 (-14.1 - -8.1)	20.5 (17.2–23.7)	9.4 (5.8–13.0)

*Values are prevalence estimates presented as percentages (%) with 95% Confidence Intervals (CI).

3.4. Sources of E-cigarettes

Between 2017 and 2019, there was a decrease in the proportion of current e-cigarette users who purchased e-cigarettes from the internet (6.9 % to 3.2 %) or convenience/vape stores (22.0 % to 16.6 %). Conversely, there was an increase in the proportion of users who borrowed devices (34.5 % to 40.1 %) or purchased through other people (10.7 % to 18.0 %). Of note, a majority of frequent e-cigarette users purchased e-cigarettes from convenience/vape stores (26.9 %) or purchased from others (28.8 %), while most occasional e-cigarette users borrowed their devices (61.6 %).

In cross-sectional analyses adjusting for grade and race/ethnicity,

males (OR:1.88; 95 %CI:1.42–2.49) and current combustible cigarette smokers (OR:1.85; 95 %CI:1.35–2.53) had higher odds of underage purchasing of e-cigarettes from convenience/vape stores compared to females and non-current combustible cigarette smokers, respectively. Similarly, males (OR:2.46; 95 %CI:1.57–3.85) and current combustible cigarette smokers (OR:1.82; 95 %CI:1.11–2.96) had higher odds of purchasing e-cigarettes online compared to females and non-current combustible cigarette smokers, respectively (**Supplementary Table 4**).

4. Discussion

Using a large nationally representative sample of US high schoolers,

we found that between 2015 and 2019, while the prevalence of combustible cigarette and other tobacco product use declined, current and frequent e-cigarette use prevalence increased. Additionally, we found that the increase in e-cigarette use prevalence was higher among youth who reported other substance use and experiences of psychosocial stress. Also, a considerable proportion of youth who reported tobacco product use admitted to making past-year quit attempts. More importantly, the sources of e-cigarettes among youth have changed, with an increasing proportion of youth borrowing or purchasing e-cigarettes through other persons.

Although our estimates of current e-cigarette use prevalence are slightly higher than those reported by the National Youth Tobacco Survey (NYTS:2015–16.0 %;2017–11.7 %;2019–27.5 %), the observed trends are similar, with current e-cigarette use decreasing between 2015 and 2017 and subsequently increased in 2019 (Cullen et al., 2018, 2019; Singh et al., 2019; Wang et al., 2018). The decrease from 2015 to 2017 may be due to increasing awareness of the potential health effects of e-cigarettes during that time and the finalization of the “Deeming Rule” in 2016, which prohibited e-cigarette sales to youth < 18 years (Food and Drug Administration, 2016), and the reported decrease in e-cigarette advertising expenditure between 2014 and 2018 (Ali et al., 2020). Reasons for the increase between 2017 and 2019 remain unclear but may relate to introduction of pod-mods with various youth-appealing flavors and designs that are easier to conceal than other more bulky models and aggressive marketing and increase in e-cigarette advertising expenditure in 2018 (Ali et al., 2020; King et al., 2018). Nevertheless, over the same period, use of other tobacco products such as combustible cigarettes, chewing tobacco, and cigars declined significantly, as demonstrated in another study using the Monitoring the Future (MTF) survey data (Meza et al., 2020).

E-cigarette use among youth remains a significant public health problem due to the potential for subsequent initiation of combustible cigarette use –the “gateway effect” (Berry et al., 2019; Soneji et al., 2017). However, in our study, the rise in e-cigarette use did not coincide with increased combustible cigarette use, similar to findings from other studies (Creamer et al., 2020; Sun et al., 2021). Thus, the downward trend in combustible cigarette use may not be compatible with the “gateway effect” of e-cigarettes (Chapman et al., 2019). Nevertheless, the increase in e-cigarette use was much larger than the decline in use of other tobacco products, suggesting that e-cigarettes are not just an alternative tobacco product for those already susceptible to addictive behaviors but also e-cigarettes are recruiting individuals to nicotine addiction, who otherwise would have remained nicotine abstinent. In addition, the prevalence of current e-cigarette use increased significantly among youth who had never smoked combustible cigarettes and among those who did not report current use of other tobacco products such as smokeless tobacco, cigars, little cigars, and cigarillos, similar to findings among young adults (Bandi et al., 2021). Data from the National Health Interview Survey showed that among young adults who had never smoked combustible cigarettes, the prevalence of current e-cigarette use increased by about 174 % between 2014 and 2018 (Bandi et al., 2021). Thus, a substantial and growing number of youth who use e-cigarettes have never smoked combustible cigarettes or used other tobacco products and would possibly not be exposed to nicotine if e-cigarettes were unavailable to the youth. Therefore, reducing e-cigarette use among the youth could substantially minimize nicotine exposure and addiction in this population.

Of greater concern, an increasing proportion of current e-cigarette users reported frequent use. The NYTS also showed that in 2019, 34.2 % of high school students who were current e-cigarette users reported frequent use (≥ 20 days in the past 30 days) (Cullen et al., 2019). Similarly, a study using 2019 MTF survey data reported that approximately 46.1 % of 12th-grade current e-cigarette users reported frequent use. In comparison with experimental use, frequent e-cigarette use among the youth is significantly associated with higher substance-related risk behaviors (McCabe et al., 2017). Moreover, increased

frequency of vaping is associated with more frequent and heavy smoking at follow-up (Leventhal et al., 2016). Thus, frequent e-cigarette use represents a problematic pattern of use, as it increases the risk of nicotine addiction, subsequent combustible cigarette and other tobacco product use, and abuse of other substances.

Mental health and experiences of emotionally stressful events are associated with e-cigarette and other tobacco product use among the youth (Riehm et al., 2019). Youth who reported experiences of psychosocial stress were more likely to report current and frequent e-cigarette use than those who did not report such stressors. As shown by a recent study, students may be using e-cigarettes to cope with stressful experiences (Jha & Kraguljac, 2021). Interventions aimed at assisting youth tobacco users in quitting can complement prevention efforts in reducing tobacco use among youth. Recent evidence shows that a significant proportion of youth e-cigarette users, particularly those with increased harm perception, report intentions to quit and past-year quit attempts (Dai, 2021; Smith et al., 2021). Similarly, in our current study, a significant proportion of youth who use tobacco products reported making past year quit attempts, similar to that reported in another recent study (Dai, 2021; Smith et al., 2021; Wang, 2019). Emerging evidence suggests that vaping cessation text messaging programs may effectively help e-cigarette cessation among young adults (Graham et al., 2021). Such programs can be tested among youth to assess their effectiveness in aiding quit attempts. Additionally, clinicians who interact with youth should universally inquire about tobacco product use, counsel on health effects, discourage use, and offer resources and support to help them quit (Owens et al., 2020; Selph et al., 2020).

Finally, understanding the changing sources of e-cigarettes among youth is necessary to inform regulatory approaches limiting youth access to e-cigarettes. Among youth, social sources such as friends continue to be the most popular source of e-cigarettes (Baker et al., 2019; Kong et al., 2017; Wang et al., 2021). The results from our study indicate that most youth borrow or purchase e-cigarettes through other persons, therefore circumventing age-related restrictions on e-cigarette sales. Additionally, despite declines in the proportion of youth who obtain e-cigarettes online or from convenience/vape stores, an appreciable number, particularly males and those who concurrently smoke combustible cigarettes, are still able to purchase e-cigarettes from these sources (Baker et al., 2019). Additionally, a recent study found that during the coronavirus disease 2019 pandemic, most underage youth accessed e-cigarettes from online sources (Gaiha et al., 2020). Therefore, increased efforts are warranted to enforce age-related restrictions on e-cigarette sales, both online and from brick-and-mortar stores, and develop interventions to discourage the social sharing of e-cigarettes.

The findings of our study have important public health implications. First, our results identify salient participant characteristics that may increase vulnerability to e-cigarette use, such as psychosocial stress experienced at school. School-based interventions aimed at stress reduction and helping students cope with stressful experiences in healthier ways could potentially decrease e-cigarette use. Secondly, we also show that a considerable number of youths are making quitting attempts. These findings highlight the urgent need to develop age-appropriate cessation strategies. Most current tobacco cessation approaches have been designed for and tested with adult users, and there are few, if any, validated youth-based approaches to tobacco cessation. More youth-friendly cessation methods such as “*This is Quitting*” are needed (This is Quitting, n.d). Finally, some youth still purchase e-cigarettes from convenience/vape stores. Others borrow or purchase e-cigarettes through other people to get around policies restricting underage purchases. Hence, there is an imminent need for more public awareness and stricter enforcement of existing age-related restriction policies and new interventions to limit e-cigarette acquisition through non-commercial and social sources. Also, with the lifting of stay-at-home orders that accompanied the COVID-19 pandemic, future studies are needed to examine how the sources of e-cigarettes, particularly among underage youth, have changed.

4.1. Strengths and limitations

For our study, we analyzed data from the YRBSS survey, which comprehensively assesses tobacco product use among the youth, including the sources of e-cigarettes and past year quit attempts. Because these data were collected before the onset of the COVID-19, the interpretation of the results was more straightforward as they were not confounded by the social upheaval caused by the pandemic. Nevertheless, our findings should be interpreted with caution, as there are some limitations. For example, all the data were self-reported with the potential for recall bias and misclassification. Additionally, data on other factors that may influence youth e-cigarette use, such as peer or parental tobacco use, harm perception, impulsivity, and marketing influence, were not available and hence not explored. Finally, the impact of the EVALI outbreak, which was first reported in July 2019, and COVID-19, first reported in December 2019, on e-cigarette use among the youth could not be assessed (Leas et al., 2021; Timeline of WHO's response to COVID-19., n.d). Thus, future studies are needed to shed more light on the impact of EVALI and COVID-19 on e-cigarette use among youth.

5. Conclusions

Youth e-cigarette use remains a significant public health problem with a concerning emerging pattern of more frequent use. Also, with the increasing proportion of youth tobacco users making quit attempts, age-appropriate cessation programs need to be assessed and made available to aid cessation efforts. Finally, the sources of e-cigarettes among youth are changing; continued surveillance is therefore required to inform effective and timely policies.

CRediT authorship contribution statement

Mohammadhassan Mirbolouk: Conceptualization, Methodology, Formal analysis, Writing – original draft. **Ellen Boakye:** Conceptualization, Methodology, Formal analysis, Writing – original draft. **Olu-funmilayo Obisesan:** Methodology, Writing – review & editing. **Albert D. Osei:** Methodology, Writing – review & editing. **Omar Dzaye:** Writing – review & editing, Visualization. **Ngozi Osuji:** Writing – review & editing. **John Erhabor:** Writing – review & editing. **Andrew C. Stokes:** Conceptualization, Writing – review & editing. **Omar El-Shahawy:** Conceptualization, Writing – review & editing. **Carlos J. Rodriguez:** Writing – review & editing. **Glenn A. Hirsch:** Writing – review & editing, Supervision. **Emelia J. Benjamin:** Writing – review & editing, Supervision. **Andrew P. DeFilippis:** Conceptualization, Writing – review & editing. **Rose Marie Robertson:** Conceptualization, Writing – review & editing, Funding acquisition. **Aruni Bhatnagar:** Conceptualization, Writing – review & editing, Funding acquisition. **Michael J. Blaha:** Conceptualization, Methodology, Writing – review & editing, Supervision, Funding acquisition.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data used in the study is publicly available deidentified Youth Risk Behavior Surveillance System Data

Acknowledgements

This work was supported, in part, by grants from the National Heart, Lung, and Blood Institute of the National Institutes of Health (NIH) and the Food and Drug Administration (FDA) Center for Tobacco Products

(CTP) [P50HL120163 and U54HL120163] and NHLBI 1K01HL154130-01. The funding institutions played no role in study design, in the collection, analysis, and interpretation of data, in the writing of the report, and in the decision to submit the paper for publication. This paper's content is solely the authors' responsibility and does not necessarily represent the official views of the NIH or the FDA.

Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.pmedr.2022.101925>.

References

- Ali, F. R. M., Marynak, K. L., Kim, Y., Binns, S., Emery, S. L., Gomez, Y., & King, B. A., 2020. E-cigarette advertising expenditures in the USA, 2014–2018. *Tob. Control*, 29 (e1), e124–e126. doi:10.1136/TOBACCOCONTROL-2019-055424.
- Baker, H.M., Kowitz, S.D., Meernik, C., Heck, C., Martin, J., Goldstein, A.O., Ranney, L., 2019. Youth source of acquisition for E-Cigarettes. *Prev. Med. Reports* 16, 101011. <https://doi.org/10.1016/j.pmedr.2019.101011>.
- Bandi, P., Cahn, Z., Goding Sauer, A., Douglas, C.E., Drope, J., Jemal, A., Fedewa, S.A., 2021. Trends in E-Cigarette Use by Age Group and Combustible Cigarette Smoking Histories, U.S. Adults, 2014–2018. *Am. J. Prevent. Med.* 60 (2), 151–158. <https://doi.org/10.1016/j.amepre.2020.07.026>.
- Berry, K.M., Fetterman, J.L., Benjamin, E.J., Bhatnagar, A., Barrington-Trimis, J.L., Leventhal, A.M., Stokes, A., 2019. Association of Electronic Cigarette Use With Subsequent Initiation of Tobacco Cigarettes in US Youths. *JAMA Netw. Open* 2 (2), e187794–e. <https://doi.org/10.1001/JAMANETWORKOPEN.2018.7794>.
- Centers for Disease Control and Prevention. (2020). *Outbreak of Lung Injury Associated with the Use of E-Cigarette, or Vaping, Products | Electronic Cigarettes | Smoking & Tobacco Use | CDC*. https://www.cdc.gov/tobacco/basic_information/e-cigarettes/severe-lung-disease.html.
- Chan, G.C.K., Gartner, C., Lim, C., Sun, T., Hall, W., Connor, J., Stjepanović, D., Leung, J., 2022. Association between the implementation of tobacco control policies and adolescent vaping in 44 lower-middle, upper-middle, and high-income countries. *Addiction* 117 (8), 2296–2305. <https://doi.org/10.1111/ADD.15892>.
- Chapman, S., Bareham, D., Maziak, W., 2019. The gateway effect of E-cigarettes: reflections on main criticisms. *Nicotine Tob. Res.* 21 (5), 695. <https://doi.org/10.1093/NTR/NTY067>.
- Creamer, M.L.R., Everett Jones, S., Gentzke, A.S., Jamal, A., King, B.A., 2020. Tobacco Product Use Among High School Students — Youth Risk Behavior Survey, United States, 2019. *MMWR Suppl.* 69 (1), 56. <https://doi.org/10.15585/MMWR.SU6901A7>.
- Cullen, K.A., Ambrose, B.K., Gentzke, A.S., Apelberg, B.J., Jamal, A., King, B.A., 2018. 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.* 67 (45), 1276–1277. <https://doi.org/10.15585/mmwr.mm6745a5>.
- Cullen, K.A., Gentzke, A.S., Sawdey, M.D., Chang, J.T., Anic, G.M., Wang, T.W., Creamer, M.L.R., Jamal, A., Ambrose, B.K., King, B.A., 2019. e-Cigarette Use among Youth in the United States, 2019. *JAMA - J. Am. Med. Assoc.* 322 (21), 2095–2103. <https://doi.org/10.1001/jama.2019.18387>.
- Dai, H., 2021. Prevalence and factors associated with youth vaping cessation intention and quit attempts. *Pediatrics* 148 (3). <https://doi.org/10.1542/PEDS.2021-050164/181069>.
- Dai, H., Hao, J., 2022. Online popularity of JUUL and Puff Bars in the USA: 2019–2020. *Tob. Control*. 31 (1), 7–10. <https://doi.org/10.1136/TOBACCOCONTROL-2020-055727>.
- Food and Drug Administration, D. of H. and H. S. (2016). Deeming Tobacco Products to be Subject to the Federal Food, Drug, and Cosmetic Act, as Amended by the Family Smoking Prevention and Tobacco Control Act; Restrictions on the Sale and Distribution of Tobacco Products and Required Warning Statements for Tobacco Products. Final Rule. <https://www.govinfo.gov/content/pkg/FR-2016-05-10/pdf/2016-10685.pdf>.
- Food and Drug Administration, 2020. FDA finalizes enforcement policy on unauthorized flavored cartridge-based e-cigarettes that appeal to children, including fruit and mint | FDA. <https://www.fda.gov/news-events/press-announcements/fda-finalizes-enforcement-policy-unauthorized-flavored-cartridge-based-e-cigarettes-appeal-children>.
- Frieden, T. R., Harold Jaffe, D. W., Cardo, D. M., Moolenaar, R. L., Leahy, M. A., Martinroe, J. C., Spriggs, S. R., Starr, T. M., Doan, Q. M., King, P. H., Roper, W. L., Hill, C., Matthew Boulton, C. L., Arbor, A., Virginia Caine, M. A., Barbara Ellis, I. A., Jonathan Fielding, G. E., Jones, T. F., Rima Khabbaz, T. F., ... William Schaffner, P., 2013. Methodology of the Youth Risk Behavior Surveillance System-2013 Morbidity and Mortality Weekly Report Centers for Disease Control and Prevention MMWR Editorial and Production Staff MMWR Editorial Board. *Recomm. Reports*, 62.
- Frieden, T. R., Jaffe, H. W., Rasmussen, S. A., Leahy, M. A., Martinroe, J. C., Spriggs, S. R., Yang, M., Yang, T., Doan, Q. M., King, P. H., Starr, T. M., Jones, T. F., Boulton, M. L., Caine, V. A., Daniel, K. L., Fielding, J. E., Fleming, D. W., Halperin, W. E., Holmes, K. K., ... Schaffner, W., 2016. Morbidity and Mortality Weekly Report Centers for Disease Control and Prevention MMWR Editorial and Production Staff (Serials) MMWR Editorial Board.

- Gaiha, S.M., Lempert, L.K., Halpern-Felsher, B., 2020. Underage Youth and Young Adult e-Cigarette Use and Access Before and During the Coronavirus Disease 2019 Pandemic. *JAMA Netw. Open* 3 (12). <https://doi.org/10.1001/JAMANETWORKOPEN.2020.27572> e2027572–e2027572.
- Gentzke, A.S., Wang, T.W., Jamal, A., Park-Lee, E., Ren, C., Cullen, K.A., Neff, L., 2020. Tobacco Product Use Among Middle and High School Students — United States, 2020. *Morb. Mortal. Wkly. Rep.* 69 (50), 1881. <https://doi.org/10.15585/MMWR.MM6950A1>.
- Graham, A.L., Amato, M.S., Cha, S., Jacobs, M.A., Bottcher, M.M., Papandonatos, G.D., 2021. Effectiveness of a Vaping Cessation Text Message Program Among Young Adult e-Cigarette Users: A Randomized Clinical Trial. *JAMA Intern. Med.* 181 (7), 923–930. <https://doi.org/10.1001/JAMAINTERNMED.2021.1793>.
- Han, Y.Y., Rossier, F., Forno, E., Celedón, J.C., 2020. Electronic vapor products, marijuana use, smoking, and asthma in US adolescents. *J. Allergy Clin. Immunol.* 145 (3), 1025–1028.e6. <https://doi.org/10.1016/j.jaci.2019.12.001>.
- Jha, V., & Kraguljac, A., 2021. Focus: Preventive Medicine: Assessing the Social Influences, Self-Esteem, and Stress of HighSchool Students Who Vape. *Yale J. Biol. Med.*, 94(1), 95. <https://pubmed.ncbi.nlm.nih.gov/35995953/>.
- King, B.A., Gammon, D.G., Marynak, K.L., Rogers, T., 2018. Electronic Cigarette Sales in the United States, 2013–2017. *JAMA* 320 (13), 1379–1380. <https://doi.org/10.1001/jama.2018.10488>.
- Kong, G., Morean, M.E., Cavallo, D.A., Camenga, D.R., Krishnan-Sarin, S., 2017. Sources of electronic cigarette acquisition among adolescents in Connecticut. *Tob. Regul. Sci.* 3 (1), 10. <https://doi.org/10.18001/TRS.3.1.2>.
- Leas, E.C., Nobles, A.L., Caputi, T.L., Dredze, M., Zhu, S.-H., Cohen, J.E., Ayers, J.W., 2021. News coverage of the E-cigarette, or Vaping, product use Associated Lung Injury (EVALI) outbreak and internet searches for vaping cessation. *Tob. Control.* 30 (5), 578–582. <https://doi.org/10.1136/TOBACCOCONTROL-2020-055755>.
- Lee, J.A., Lee, S., Cho, H.J., 2017. The relation between frequency of E-cigarette use and frequency and intensity of cigarette smoking among South Korean adolescents. *Int. J. Environ. Res. Public Health* 14 (3). <https://doi.org/10.3390/ijerph14030305>.
- Leventhal, A.M., Stone, M.D., Andrabi, N., Barrington-Trimis, J., Strong, D.R., Sussman, S., Audrain-McGovern, J., 2016. Association of e-Cigarette Vaping and Progression to Heavier Patterns of Cigarette Smoking. *JAMA* 316 (18), 1918–1920. <https://doi.org/10.1001/JAMA.2016.14649>.
- McCabe, S.E., West, B., Veliz, P., Boyd, C.J., 2017. E-cigarette use, cigarette smoking, dual use and problem behaviors among U.S. adolescents: Results from a national survey. *J. Adolesc. Health* 61 (2), 155. <https://doi.org/10.1016/j.jadohealth.2017.02.004>.
- Meza, R., Jimenez-Mendoza, E., Levy, D.T., 2020. Trends in Tobacco Use Among Adolescents by Grade, Sex, and Race, 1991–2019. *JAMA Netw. Open* 3 (12), e2027465–e. <https://doi.org/10.1001/JAMANETWORKOPEN.2020.27465>.
- Miech, R., Johnston, L., O'Malley, P.M., Bachman, J.G., Patrick, M.E., 2019. Trends in Adolescent Vaping, 2017–2019. *N. Engl. J. Med.* 381 (15), 1490–1491. <https://doi.org/10.1056/NEJMC1910739>.
- Owens, D.K., Davidson, K.W., Krist, A.H., Barry, M.J., Cabana, M., Caughey, A.B., Curry, S.J., Donahue, K., Doubeni, C.A., Epling, J.W., Kubik, M., Ogedegbe, G., Pbert, L., Silverstein, M., Simon, M.A., Tseng, C.W., Wong, J.B., 2020. Primary Care Interventions for Prevention and Cessation of Tobacco Use in Children and Adolescents: US Preventive Services Task Force Recommendation Statement. *JAMA - J. Am. Med. Assoc.* 323 (16), 1590–1598. <https://doi.org/10.1001/JAMA.2020.4679>.
- Park-Lee, E., Ren, C., Sawdey, M.D., Gentzke, A.S., Cornelius, M., Jamal, A., Cullen, K.A., 2021. Notes from the Field: E-Cigarette Use Among Middle and High School Students — National Youth Tobacco Survey, United States, 2021. *MMWR. Morb. Mortal. Wkly. Rep.* 70 (39), 1387–1389. <https://doi.org/10.15585/MMWR.MM7039A4>.
- Redfield, R. R., Kent, C. K., Leahy, M. A., Martinroe, J. C., Spriggs, S. R., Yang, T., Doan, Q. M., King, P. H., Starr, T. M., Yang, M., Jones, T. F., Boulton, M. K., Caine, V. A., Daniel, K. L., Fielding, J. E., Fleming, D. W., Halperin, W. E., Holmes, K. K., Ikeda, R., ... Schaffner, W., 2017. Morbidity and Mortality Weekly Report Centers for Disease Control and Prevention MMWR Editorial and Production Staff (Serials) MMWR Editorial Board.
- Riehm, K.E., Young, A.S., Feder, K.A., Krawczyk, N., Tornmohlen, K.N., Pacek, L.R., Mojtabei, R., Crum, R.M., 2019. Mental Health Problems and Initiation of E-cigarette and Combustible Cigarette Use. *Pediatrics* 144 (1). <https://doi.org/10.1542/PEDS.2018-2935>.
- Substance Abuse and Mental Health Services Administration (SAMHSA). (n.d.). *EVIDENCE-BASED RESOURCE GUIDE SERIES Reducing Vaping Among Youth and Young Adults Reducing Vaping Among Youth and Young Adults Acknowledgments I Reducing Vaping Among Youth and Young Adults Acknowledgments*. doi:10.1001/jama.2019.18387.
- Selph, S., Patnode, C., Bailey, S.R., Pappas, M., Stoner, R., Chou, R., 2020. Primary Care-Relevant Interventions for Tobacco and Nicotine Use Prevention and Cessation in Children and Adolescents: Updated Evidence Report and Systematic Review for the US Preventive Services Task Force. *JAMA - J. Am. Med. Assoc.* 323 (16), 1599–1608. <https://doi.org/10.1001/JAMA.2020.3332>.
- Singh, T., Arrazola, R.A., Corey, C.G., Husten, C.G., Neff, L.J., Homa, D.M., King, B.A., 2019. Tobacco Use Among Middle and High School Students — United States, 2011–2015. *MMWR. Morb. Mortal. Wkly. Rep.* 65 (14), 361–367. <https://doi.org/10.15585/MMWR.MM6514A1>.
- Smith, T.T., Nahhas, G.J., Carpenter, M.J., Squeglia, L.M., Diaz, V.A., Leventhal, A.M., Dahne, J., 2021. Intention to Quit Vaping Among United States Adolescents. *JAMA Pediatr.* 175 (1), 97–99. <https://doi.org/10.1001/JAMAPEDIATRICS.2020.2348>.
- Soneji, S., Barrington-Trimis, J.L., Wills, T.A., Leventhal, A.M., Unger, J.B., Gibson, L.A., Yang, JaeWon, Primack, B.A., Andrews, J.A., Miech, R.A., Spindle, T.R., Dick, D.M., Eissenberg, T., Hornik, R.C., Dang, R., Sargent, J.D., 2017. Association Between Initial Use of e-Cigarettes and Subsequent Cigarette Smoking Among Adolescents and Young Adults: A Systematic Review and Meta-analysis. *JAMA Pediatr.* 171 (8), 788–797. <https://doi.org/10.1001/jamapediatrics.2017.1488>.
- Sun, T., Lim, C.C.W., Stjepanović, D., Leung, J., Connor, J.P., Gartner, C., Hall, W.D., Chan, G.C.K., 2021. Has increased youth e-cigarette use in the USA, between 2014 and 2020, changed conventional smoking behaviors, future intentions to smoke and perceived smoking harms? *Addict. Behav.* 123, 107073 <https://doi.org/10.1016/j.addbeh.2021.107073>.
- This is Quitting.* (n.d.). Retrieved May 30, 2022, from <https://truthinitiative.org/thisisquitting>.
- Timeline of WHO's response to COVID-19.* (n.d.). Retrieved August 10, 2021, from https://www.who.int/emergencies/diseases/novel-coronavirus-2019/interactive-timeline?gclid=CjwKCAjwgb6lBhAREiwAgMYKkRok_Fly5yCmT0h_bxpLCEyIATIVdD94cl4rX3ycZ6Jm45C0sSGL8dBoCYxQAvD_BwE#event-0.
- U.S. Department of Health and Human Services, 2016. Chapter 1. Introduction, Conclusions, and Historical Background Relative to E-Cigarettes (in E-Cigarette Use Among Youth and Young Adults: A Report of the Surgeon General). https://www.ncbi.nlm.nih.gov/books/NBK538680/pdf/Bookshelf_NBK538680.pdf.
- U.S. Department of Health and Human Services, 2016. *E-Cigarette Use Among Youth and Young Adults: A Report of the Surgeon General*. U.S. Department 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. <https://www.ncbi.nlm.nih.gov/books/NBK538687/>.
- Underwood, J.M., Brener, N., Thornton, J., Harris, W.A., Bryan, L.N., Shanklin, S.L., Deputy, N., Roberts, A.M., Queen, B., Chyen, D., Whittle, L., Lim, C., Yamakawa, Y., Leon-Nguyen, M., Kilmer, G., Smith-Grant, J., Demissie, Z., Jones, S.E., Clayton, H., Dittus, P., 2020. Overview and Methods for the Youth Risk Behavior Surveillance System — United States, 2019. *MMWR Suppl.* 69 (1), 1–10. <https://doi.org/10.15585/MMWR.SU6901A1>.
- US Census Bureau, 2015. School Enrollment in the United States: October 2015 - Detailed Tables. <https://www.census.gov/data/tables/2015/demo/school-enrollment/2015-cps.html>.
- US Census Bureau, 2018. More Than 76 Million Students Enrolled in U.S. Schools. <https://www.census.gov/newsroom/press-releases/2018/school-enrollment.html>.
- US Census Bureau, 2019. Census Bureau Reports Nearly 77 Million Students Enrolled in U.S. Schools. <https://www.census.gov/newsroom/press-releases/2019/school-enrollment.html>.
- Wang, T.W., 2019. Tobacco Product Use and Associated Factors Among Middle and High School Students — United States, 2019. *MMWR. Surveill. Summ.* 68 (12) <https://doi.org/10.15585/MMWR.SS6812A1>.
- Wang, T.W., Gentzke, A., Sharapova, S., Cullen, K.A., Ambrose, B.K., Jamal, A., 2018. Tobacco Product Use Among Middle and High School Students — United States, 2011–2017. *Morb. Mortal. Wkly. Rep.* 67 (22), 629. <https://doi.org/10.15585/MMWR.MM6722A3>.
- Wang, T.W., Neff, L.J., Park-Lee, E., Ren, C., Cullen, K.A., King, B.A., 2020. E-cigarette Use Among Middle and High School Students — United States, 2020. *MMWR. Morb. Mortal. Wkly. Rep.* 69 (37), 1310–1312. <https://doi.org/10.15585/MMWR.MM6937E1>.
- Wang, T.W., Gentzke, A.S., Neff, L.J., Glidden, E.V., Jamal, A., Park-Lee, E., Ren, C., Cullen, K.A., King, B.A., Hacker, K.A., 2021. Characteristics of e-Cigarette Use Behaviors Among US Youth, 2020. *JAMA Netw. Open* 4 (6). <https://doi.org/10.1001/JAMANETWORKOPEN.2021.11336> e2111336–e2111336.