



## Changes in electronic cigarette use among U.S. Adults by cigarette smoking status, sociodemographics, and subjective depression, 2019–2020

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### ABSTRACT

E-cigarette use increased from 2017 to 2019 and then declined in 2020 among U.S. adults. It is important to understand whether the decline differed by smoking status and sociodemographic groups and whether daily e-cigarette use has subsequently changed. This study estimated e-cigarette use prevalence in 2019 and 2020 by analyzing the pooled National Health Interview Survey (n = 63,565) in 2022. Multivariable logistics regressions were performed to examine biannual change in current and daily e-cigarette use, overall and stratified by cigarette smoking status, sociodemographic factors, and subjective depression frequency. Among US adults, change in current e-cigarette use during 2019–2020 differed by smoking status (cigarette smoking status × year,  $p = .01$ ) and race/ethnicity (race/ethnicity × year,  $p = .03$ ). Current e-cigarette use prevalence decreased among current cigarette smokers (11.7 % to 8.0 %,  $p = 0.0001$ ) but not among former or never smokers, and among Non-Hispanic White adults (5.1 % to 4.2 %,  $p = 0.04$ ) and Non-Hispanic Black adults (3.4 % to 1.6 %,  $p = 0.0003$ ) but not among other racial and ethnic groups. Current e-cigarette use also declined among those 25–64 years old but not among young adults 18–24 years old. Daily e-cigarette use did not significantly change during 2019–2020 in the overall sample (2.3 % to 2.0 %,  $p = 0.10$ ), but declined among adults who were Non-Hispanic Black (2.4 % to 0.9 %,  $p = 0.0007$ ), aged 35–44 years, and lived below the federal poverty level. Adults with monthly depressive episodes (vs without) continued to have a higher prevalence of current (7.0 % vs 3.0 %) and daily e-cigarette use (3.6 % vs 1.6 %) in 2020. Continuous monitoring of cross-population differences in adult e-cigarette use is warranted.

Electronic cigarettes (e-cigarettes) are the second most commonly used tobacco product among U.S. adults, after cigarettes (Cornelius et al., 2020). Following several years of subtle decline in e-cigarette use prevalence, current adult e-cigarette use increased from 2.8 % in 2017 to 4.5 % in 2019 (Cornelius et al., 2020; Dai and Leventhal, 2019). The prevalence of e-cigarette use was particularly higher among current or former smokers than among never smokers (Bandi et al., 2021; Mayer et al., 2020), and the increase in e-cigarette use was predominant among 18–24 year-olds (Cornelius et al., 2020; Dai and Leventhal, 2019). The latest National Health Interview Survey (NHIS) data reported that current (some days or daily) e-cigarette use among U.S. adults declined to 3.7 % in 2020 (Cornelius et al., 2022). However, knowledge is limited about whether the decline differed across cigarette smoking status, racial and ethnic groups, and other sociodemographic (e.g., socioeconomic status [SES], poverty level, urbanicity) or mental health condition

groups (e.g., depression status). Furthermore, it remains unknown whether U.S. adult daily e-cigarette use prevalence has subsequently changed.

The focus on changes in current and daily e-cigarette use among U.S. adults is important. First, the use of e-cigarettes in 2019 had been particularly higher among White adults (vs Black adults and Hispanic adults), sexual minorities (vs non-heterosexual adults), and those with mental health conditions (vs not) (Cornelius et al., 2020). The COVID-19 pandemic also resulted in a lockdown and stay-at-home orders in many U.S. states starting March 2020. It is unclear whether the changes have resulted in widening or narrowing disparities in adult e-cigarette use. Second, e-cigarettes deliver a substantially lower level of toxicants than combustible cigarettes, presenting a harm-reduction alternative for cigarette smokers (National Academies of Sciences Engineering and Medicine, 2018). However, they are not harmless and contain varying

*Abbreviations:* CI, confidence interval; NHIS, National Health Interview Survey; NH, Non-Hispanic.

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levels of nicotine and potentially toxic constituents (e.g., carbonyl compounds and heavy metals), which pose harm to never smokers and youth (Goniewicz et al., 2018; Institute of Medicine, 2015; Marques et al., 2021; U.S. Department of Health and Human Services, 2016). Therefore, understanding changes in the use of e-cigarettes, especially among those vulnerable subpopulations, is critical to inform future tobacco regulatory policies and public health strategies.

This study analyzed pooled 2019 and 2020 NHIS data to 1) examine the biannual change in current and daily e-cigarette use prevalence among U.S. adults, 2) test the interactions of year and key sociodemographic factors, smoking status, and depression symptoms on adult e-cigarette use, and 3) identify any heterogeneous patterns in changes of e-cigarette use among subpopulations.

## 1. Methods

### 1.1. Study sample

Data were collected from the NHIS, a cross-sectional household survey conducted annually since 1957. The survey uses a multistage stratified sampling plan to provide a nationally representative sample of the noninstitutionalized U.S. civilian population and evaluates various health topics (The Centers for Disease Control and Prevention, 2022a). The NHIS was conducted in a face-to-face interview format throughout 2019 and into early 2020. During the COVID-19 pandemic, interviews shifted to telephone-only format from late March 2020 through June 2020 and predominantly telephone format thereafter (The Centers for Disease Control and Prevention, 2022b). The sample adult response rate was 48.9 % for the 2020 NHIS, which was lower than the 2019 adult response rate (59.1 %) and the typical response rates in 2014–2018 ranged from 53.0 % to 58.9 % (The Centers for Disease Control and Prevention, 2022b). Because this study did not include human subjects research and used only de-identified data, it was deemed exempt by the University of Nebraska Institutional Review Board.

### 1.2. Measures

#### 1.2.1. Tobacco use status

Current e-cigarette use was assessed by two separate questions “Have you ever used an e-cigarette or other electronic vaping product, even just one time, in your entire life?” and “Do you NOW use e-cigarettes or other electronic vaping products every day, some days, or not at all?” Those who responded “Yes” to the first question and “every day” or “some days” to the second question were classified as current e-cigarette users. Those who reported using e-cigarettes every day were classified as daily e-cigarette users (Cornelius et al., 2020; Dai and Leventhal, 2019).

Combustible cigarette smoking status is coded as a trichotomous level variable, including never (<100 cigarettes smoked lifetime), former (smoked  $\geq$  100 cigarettes and not currently smoking), and current ( $\geq$ 100 cigarettes and now smoking some days or every day) (Cornelius et al., 2020).

#### 1.2.2. Other measures

Self-reported sociodemographic factors included age (18–24, 25–34, 35–44, 45–64, and >65 years), sex (male or female), race and ethnicity (non-Hispanic [NH] White, NH Black, Hispanic/Latino, or NH others), sexual orientation status (heterosexual, gay/lesbian, bisexual, other), poverty ratio (<1.0, 1.0–3.9, and  $\geq$ 4.0) (Dai and Leventhal, 2019), education (less than high school, high school or GED, some college, and college or above), and urbanicity (metropolitan [large central metro, large fringe metro, medium and small metro] or non-metropolitan). (The Centers for Disease Control and Prevention, National Health Interview Survey, 2020) The poverty ratio provided in the NHIS was derived from family’s income relative to the federal poverty threshold (100 %, 138 %, 200 %, 250 % and 400 %), which takes the family size into account (The Centers for Disease Control and Prevention, National Health Interview

Survey, 2020).

The frequency of subjective depression was measured by the question, “How often do you feel depressed? Would you say daily, weekly, monthly, a few times a year, or never?” Those who responded “Daily”, “Weekly”, and “Monthly” were coded as “ $\geq$ monthly” and those who responded “A few times a year” and “No.” were coded as “a few times a year or never.” in the main analysis. The raw categories were assessed in the sensitivity analysis.

### 1.3. Statistics analysis

Weighted estimates of self-reported current e-cigarette use (yes/no) and daily e-cigarette use (yes/no) were calculated using the Taylor series variance estimation (Fuller, 1975), overall and stratified by cigarette smoking status, sociodemographic factors, and subjective depression frequency. For both e-cigarette use prevalence outcomes, logistic regressions tested unadjusted year  $\times$  covariate omnibus interactions in the overall sample to assess any group differences in e-cigarette use, and multivariable logistic regressions were performed to examine the association of year with e-cigarette use, overall and separately in subsamples stratified by each covariate’s respective status. Statistical analysis was performed in SAS 9.4 (Cary, NC) with p-values < 0.05 (two tailed) as the significance threshold.

## 2. Results

The pooled 2019–2020 NHIS sample ( $n = 63,565$ ) was 11.7 % young adults aged 18–24 years old, 51.7 % female, 63.1 % non-Hispanic (NH) White adults, 11.7 % NH Black adults, and 16.6 % Hispanic adults, 10.6 % living with poverty ratio <1.0, and 22.6 % former and 13.2 % current cigarette smokers. As shown in Table 1, the unweighted sample characteristics were largely consistent across two years except for the poverty ratio  $\geq$ 4.0 increasing from 40.8 % in 2019 to 45.1 % in 2020. The sample percentage with monthly depressive symptoms did not change between these two years (16.7 % in 2019 and 17.0 % in 2020,  $p = 0.09$ ).

The biannual changes in current e-cigarette use are presented in Table 2. Among U.S. adults overall, current e-cigarette use prevalence declined from 4.5 % (95 %CI, 4.1 %–4.8 %) in 2019 to 3.7 % (95 %CI, 3.4 %–4.0 %) in 2020 (difference =  $-0.8$  % [95 %CI,  $-1.2$  % to  $-0.3$  %],  $p = 0.006$ ). The change in current e-cigarette use from 2019 to 2020 differed by smoking status with significant interactions of cigarette smoking status  $\times$  year ( $p = 0.01$ ) and race/ethnicity  $\times$  year ( $p = 0.03$ ). Current e-cigarette use prevalence decreased from 2019 to 2020 among current cigarette smokers (11.7 % to 8.0 %, difference =  $-3.8$  % [95 %CI,  $-5.6$  % to  $-2.0$  %],  $p = 0.0001$ ) but not among former (7.8 % to 7.0 %,  $p = 0.14$ ) or never smokers (1.7 % to 1.7 %,  $p = 0.98$ ), among NH White adults (5.1 % to 4.2 %, difference =  $-0.9$  % [95 %CI,  $-1.5$  % to  $-0.3$  %],  $p = 0.04$ ) and NH Black adults (3.4 % to 1.6 %, difference =  $-1.8$  % [95 %CI,  $-2.8$  % to  $-0.8$  %],  $p = 0.0003$ ) but not among Hispanic adults (2.8 % to 2.8 %,  $p = 0.88$ ) or other racial/ethnic groups (4.3 % to 4.4 %,  $p = 0.83$ ). Current e-cigarette use also substantially decreased among those living under the federal poverty level (5.3 % to 3.3 %, difference =  $-2.0$  % [95 %CI,  $-3.3$  % to  $-0.7$  %],  $p = .002$ ), and the decline was also observed in both males and females, adults aged 25–64 years old, heterosexual adults, those residing in metropolitan areas, and those reporting depression “never” or “a few times a year”. However, the prevalence of current e-cigarette use did not change among those aged 18–20 years old (8.1 % in 2019 vs 8.4 % in 2020,  $p = 0.72$ ) and those aged 21–24 years old (10.1 % in 2019 vs 10.0 % in 2020,  $p = 0.81$ ). Subjects with monthly depressive episodes had a higher prevalence of e-cigarette use than those without in both 2019 (8.2 % vs 3.7 %) and 2020 (7.0 % vs 3.0 %).

As shown in Table 3, daily e-cigarette use did not change from 2019 to 2020 in the overall sample (2.3 % to 2.0 %,  $p = 0.10$ ), and differed by race/ethnicity (race/ethnicity  $\times$  year,  $p = .03$ ) with a significant

**Table 1**  
Sample characteristics of the 2019 and 2020 NHIS, n = 63,565.

	2019		2020		P-value <sup>a</sup>
	n	% (95 % CI)	n	% (95 % CI)	
Overall	31,997		31,568		
Age Groups (years)					<0.001
18–20	818	2.6 (2.4 to 2.7)	585	1.9 (1.7 to 2.0)	
21–24	1347	4.2 (4.0 to 4.4)	1122	3.6 (3.4 to 3.8)	
25–34	4,893	15.3 (14.9 to 15.7)	4,333	13.8 (13.4 to 14.1)	
35–44	4,966	15.6 (15.2 to 16.0)	4,844	15.4 (15 to 15.8)	
45–64	10,597	33.2 (32.7 to 33.7)	10,589	33.6 (33.1 to 34.1)	
65+	9,295	29.1 (28.6 to 29.6)	10,025	31.8 (31.3 to 32.3)	
Sex					0.90
Male	14,733	46.0 (45.5 to 46.6)	14,521	46.0 (45.5 to 46.6)	
Female	17,261	54.0 (53.4 to 54.5)	17,045	54.0 (53.4 to 54.5)	
Race/Ethnicity <sup>b</sup>					<0.001
White, NH	21,915	68.5 (68.0 to 69.0)	22,090	70.0 (69.5 to 70.5)	
Black NH	3,483	10.9 (10.5 to 11.2)	3,201	10.1 (9.8 to 10.5)	
Hispanic	4,152	13.0 (12.6 to 13.3)	3,833	12.1 (11.8 to 12.5)	
Others	2,447	7.6 (7.4 to 7.9)	2,444	7.7 (7.4 to 8.0)	
Sexual Orientation					<0.001
Heterosexual	29,818	93.2 (92.9 to 93.5)	29,361	93 (92.7 to 93.3)	
Gay/Lesbian	452	1.4 (1.3 to 1.5)	571	1.8 (1.7 to 2.0)	
Bisexual	413	1.3 (1.2 to 1.4)	407	1.3 (1.2 to 1.4)	
Others	1,314	4.1 (3.9 to 4.3)	1,229	3.9 (3.7 to 4.1)	
Poverty Ratio <sup>c</sup>					<0.001
<1.0	3,548	11.1 (10.7 to 11.4)	2,824	8.9 (8.6 to 9.3)	
1.0–3.9	15,394	48.1 (47.6 to 48.7)	14,520	46 (45.4 to 46.5)	
≥4.0	13,055	40.8 (40.3 to 41.3)	14,224	45.1 (44.5 to 45.6)	
Education					<0.001
Less than High School	2,954	9.2 (8.9 to 9.5)	2,462	7.8 (7.5 to 8.1)	
High School or GED	8,201	25.6 (25.1 to 26.1)	7,486	23.7 (23.3 to 24.2)	
Some College	9,386	29.3 (28.8 to 29.8)	9,106	28.8 (28.3 to 29.3)	
College Degree or Above	11,277	35.2 (34.7 to 35.8)	12,365	39.2 (38.6 to 39.7)	
Urbanicity <sup>d</sup>					0.004
Metropolitan	26,916		26,817		

**Table 1 (continued)**

	2019		2020		P-value <sup>a</sup>
	n	% (95 % CI)	n	% (95 % CI)	
		84.1 (83.7 to 84.5)		84.9 (84.6 to 85.3)	
Nonmetropolitan	5,081	15.9 (15.5 to 16.3)	4,751	15.1 (14.7 to 15.4)	
Subjective Depression Frequency <sup>e</sup>					0.39
Never/a few times a year	26,113	83.3 (82.9 to 83.7)	25,785	83.0 (82.6 to 83.4)	
At least monthly	5,248	16.7 (16.3 to 17.1)	5,278	17.0 (16.6 to 17.4)	

<sup>a</sup> : P-values were from  $\chi^2$  test to compare demographic distributions between 2019 and 2020.

<sup>b</sup> : Race and Hispanic ethnicity were self-reported and Hispanic persons could be of any race.

<sup>c</sup> : The poverty ratio was calculated by dividing family income by the poverty threshold from the Census Bureau in the previous calendar year.

<sup>d</sup> : Metropolitan (large central metro, large fringe metro, medium and small metro) vs non-metropolitan.

<sup>e</sup> : Measured by the question “How often depressed?” with “Yes” including those who responded “Daily”, “Weekly”, and “Monthly”, and “No” including those who responded “A few times a year” and “No”.

decrease among NH Black adults (2.4 % to 0.9 %, difference = -1.5 % [95 %CI, -2.4 % to -0.6 %],  $p = 0.0007$ ) but not among other racial/ethnic groups. Daily e-cigarette use also declined among current smokers (7.8 % to 5.7 %, difference = -2.1 % [95 %CI, -3.6 % to -0.6 %],  $p = .02$ ), adults aged 35–44 years old (2.6 % to 1.7 %, difference = -0.9 % [95 %CI, -1.6 % to -0.3 %],  $p = 0.01$ ) and those under the poverty ratio (3.4 % to 1.9 %, difference = -1.5 % [95 %CI, -2.5 % to -0.5 %],  $p = 0.01$ ). Subjects with monthly depressive episodes had a higher prevalence of daily e-cigarette use than those without (4.5 % vs 1.9 % in 2019 and 3.6 % vs 1.6 % in 2020).

Sensitivity analyses (Appendix Tables 1-3) reported sample distribution and changes in current e-cigarette use by subjective depression frequency (daily, weekly, monthly, a few times a year and never). E-cigarette use tended to be higher among those with more frequent depression symptoms (daily/weekly/daily vs a few times a year vs never) and the changes in e-cigarettes were not significant between 2019 and 2020 by subjective depression frequency.

### 3. Discussion

This study found an 18 % decline in current e-cigarette use prevalence among U.S. adults (4.5 % to 3.7 %) from 2019 to 2020, and the changes in adult e-cigarette use were heterogeneous across cigarette smoking status and sociodemographic groups. The decline in e-cigarette use may be attributable to several factors. First, the study period overlapped with the COVID-19 pandemic that first arrived in the United States in January 2020 with the widespread pandemic-related shutdown occurring in mid-March 2020. Many U.S. states issued stay-at-home orders and some U.S. retailers, including vape shops or smoke shops, closed during the initial pandemic outbreak (Berg et al., 2021). E-cigarette users may have decreased or stopped their use because of difficulty in obtaining their usual products due to business closures or perceived negative outcomes from COVID-19 (Gaiha et al., 2020; Kalkhoran et al., 2021). Furthermore, people of color and low-income workers have been disproportionately harmed by the economic effects of the COVID-19 pandemic (U.S. Department of Health and Human Services, 2021). These subpopulations (e.g., non-Hispanic Black adults, and those living in poverty) also exhibited more pronounced declines in e-cigarette use

**Table 2**  
U.S. E-cigarette Use Prevalence, 2019–2020, by Cigarette Smoking Statuses, Sociodemographics, and Subjective Depression (N = 63,565).

	Current E-cigarette Use Weighted % (95 % CI) <sup>a</sup>		Interaction with year		Change in Current E-cigarette Use, Stratified	
	2019 (n = 31,997)	2020 (n = 31,568) <sup>b</sup>	p-value <sup>c</sup>	2020 vs 2019 <sup>d</sup>	AOR (95 % CI) <sup>e</sup>	Adjusted p-value <sup>e</sup>
Overall	4.5 (4.1 to 4.8)	3.7 (3.4 to 4.0)		−0.8 (−1.2 to −0.3)	0.8 (0.7 to 0.9)	0.006
Cigarette Smoking Status <sup>f</sup>			0.01			
Never	1.7 (1.4 to 1.9)	1.7 (1.4 to 2.0)		0.1 (−0.3 to 0.4)	1.0 (0.8 to 1.3)	0.86
Former	7.8 (7.0 to 8.6)	7.1 (6.2 to 7.9)		−0.7 (−1.9 to 0.4)	0.9 (0.7 to 1.0)	0.14
Current	11.7 (10.4 to 13)	8.0 (6.7 to 9.2)		−3.8 (−5.6 to −2.0)	0.7 (0.5 to 0.8)	0.0001
Age Groups (years)			0.51			
18–20	8.1 (6.1 to 10.1)	8.4 (5.6 to 11.3)		0.3 (−3.2 to 3.8)	1.1 (0.7 to 1.8)	0.72
21–24	10.1 (8.2 to 12.1)	10 (7.8 to 12.3)		−0.1 (−3.1 to 2.9)	1.0 (0.7 to 1.5)	0.81
25–34	7.4 (6.5 to 8.4)	6.1 (5.2 to 7.0)		−1.3 (−2.6 to −0.1)	0.8 (0.6 to 1.0)	0.03
35–44	5.3 (4.5 to 6.1)	4.1 (3.4 to 4.8)		−1.2 (−2.2 to −0.2)	0.8 (0.6 to 1.0)	0.04
45–64	3.0 (2.6 to 3.4)	2.2 (1.9 to 2.6)		−0.8 (−1.4 to −0.3)	0.7 (0.6 to 0.9)	0.01
65+	0.8 (0.6 to 1.0)	0.6 (0.4 to 0.8)		−0.2 (−0.4 to 0.1)	0.8 (0.5 to 1.1)	0.16
Sex			0.10			
Male	5.5 (5.0 to 6.0)	4.6 (4.1 to 5.1)		−0.8 (−1.5 to −0.1)	0.9 (0.7 to 1.0)	0.04
Female	3.5 (3.1 to 3.9)	2.8 (2.4 to 3.2)		−0.7 (−1.2 to −0.1)	0.8 (0.7 to 1.0)	0.048
Race/Ethnicity <sup>g</sup>			0.03			
White, NH	5.1 (4.7 to 5.5)	4.2 (3.8 to 4.6)		−0.9 (−1.5 to −0.3)	0.9 (0.7 to 1.0)	0.04
Black NH	3.4 (2.6 to 4.2)	1.6 (1.0 to 2.2)		−1.8 (−2.8 to −0.8)	0.4 (0.3 to 0.7)	0.0003
Hispanic	2.8 (2.2 to 3.4)	2.8 (2.1 to 3.5)		0.0 (−0.9 to 0.9)	1.0 (0.7 to 1.4)	0.88
Others	4.3 (3.1 to 5.4)	4.4 (3.3 to 5.5)		0.2 (−1.4 to 1.7)	1.0 (0.6 to 1.4)	0.83
Sexual Orientation			0.66			
Heterosexual	4.2 (3.9 to 4.5)	3.5 (3.2 to 3.8)		−0.7 (−1.2 to −0.3)	0.9 (0.8 to 1.0)	0.02
Gay/Lesbian	6.4 (3.3 to 9.6)	6.7 (4.0 to 9.4)		0.3 (−3.8 to 4.4)	1.0 (0.5 to 2.2)	0.91
Bisexual	16.2 (11.8 to 20.6)	10.8 (6.9 to 14.7)		−5.4 (−11.3 to 0.4)	0.6 (0.3 to 1.0)	0.06
Others	5.7 (3.1 to 8.3)	5.0 (2.7 to 7.2)		−0.7 (−4.2 to 2.8)	0.9 (0.5 to 1.9)	0.81
Poverty Ratio <sup>h</sup>			0.16			
<1.0	5.3 (4.3 to 6.2)	3.3 (2.4 to 4.1)		−2.0 (−3.3 to −0.7)	0.6 (0.4 to 0.8)	0.002
1.0–3.9	4.7 (4.2 to 5.1)	4.0 (3.6 to 4.5)		−0.6 (−1.3 to 0.0)	0.9 (0.8 to 1.1)	0.32
≥4.0	3.9 (3.5 to 4.4)	3.4 (3.0 to 3.8)		−0.5 (−1.2 to 0.1)	0.8 (0.7 to 1.0)	0.06
Education			0.66			
Less than High School	3.5 (2.6 to 4.4)	3.0 (1.9 to 4.2)		−0.5 (−1.9 to 1.0)	0.8 (0.5 to 1.3)	0.41
High School or GED	5.3 (4.7 to 5.9)	4.4 (3.8 to 5.1)		−0.9 (−1.8 to 0.0)	0.9 (0.7 to 1.1)	0.18
Some College	5.8 (5.2 to 6.4)	4.8 (4.2 to 5.4)		−1.0 (−1.9 to −0.2)	0.9 (0.7 to 1.0)	0.09
College Degree or Above	2.6 (2.3 to 3.0)	2.2 (1.9 to 2.6)		−0.4 (−0.9 to 0.1)	0.8 (0.6 to 1.0)	0.06
Urbanicity <sup>i</sup>			0.36			
Metropolitan	4.5 (4.2 to 4.8)	3.7 (3.3 to 4.0)		−0.8 (−1.3 to −0.4)	0.8 (0.7 to 0.9)	0.005
Nonmetropolitan	4.2 (3.4 to 4.9)	3.9 (3.0 to 4.9)		−0.2 (−1.4 to 1.0)	0.9 (0.6 to 1.2)	0.43
Subjective Depression frequency <sup>j</sup>			0.82			
Never/a few times a year	3.7 (3.4 to 4.0)	3.0 (2.7 to 3.3)		−0.7 (−1.1 to −0.2)	0.8 (0.7 to 1.0)	0.01
At least monthly	8.2 (7.3 to 9.2)	7.0 (6.0 to 8.0)		−1.3 (−2.7 to 0.2)	0.9 (0.7 to 1.1)	0.16

Abbreviations, CI: Confidence Interval, NH: Non-Hispanic, Q: Quarter.

<sup>a</sup> : Weighted estimates from National Health Interview Survey years 2019 (N = 31,997) and 2020 (N = 31,568). Current e-cigarette use classified for respondents who reported now using e-cigarettes every day or some days.

<sup>b</sup> : Due to the COVID-19 pandemic, the 2020 NHIS shifted from in-person interviewing to all-telephone interviewing from late March to June. During the 3rd and 4th quarters of 2020, most respondents were interviewed by telephone and small subsets were interviewed in person. E-cigarette use prevalence did not differ across quarters of 2020 (Q1: 3.8 % (95 %CI [3.2–4.3]), Q2: 3.6 % (95 %CI [2.9–4.3]), Q3: 3.6 % (95 %CI [3.0–4.1]), Q4: 3.9 % (95 %CI [3.3–4.5]); p =.86).

<sup>c</sup> : p-value from unadjusted logistic regression model omnibus interaction test.

<sup>d</sup> : Unadjusted difference of 2020 estimate minus 2019 estimate.

<sup>e</sup> : Multivariable logistic regression model included pooled 2019 and 2020 data with year (2020 vs 2019) and all variables in this Table as simultaneous regressors.

<sup>f</sup> : Combustible cigarette smoking was classified into never (<100 cigarettes smoked lifetime), former (smoked ≥ 100 cigarettes lifetime and not currently smoking), or current (smoked ≥ 100 cigarette lifetime and currently smoking every day or some days) statuses.

<sup>g</sup> : Race and Hispanic ethnicity were self-reported and Hispanic persons could be of any race.

<sup>h</sup> : Ratio of family income to the federal poverty threshold.

<sup>i</sup> : Metropolitan (large central metro, large fringe metro, medium and small metro) vs non-metropolitan.

<sup>j</sup> : Measured by the question “How often depressed?” with “Yes” including those who responded “Daily”, “Weekly”, and “Monthly”, and “No” including those who responded “A few times a year” and “No”.

from 2019 to 2020 in this study. Future studies should examine whether economic insecurity might contribute to the decline in e-cigarette use.

Second, consistent with our finding of a decline in current e-cigarette use, the Federal Trade Commission (FTC) reported that total e-cigarette sales declined from \$2.703 billion in 2019 to \$2.24 billion in 2020. There were also significant shifts in sales toward flavored disposable e-cigarettes and menthol e-cigarette cartridges in 2020 (Federal Trade Commission, 2022). These changes coincided with evolving e-cigarette products in the market and shifting tobacco regulatory policies during the study period. For instance, JUUL, the most popular e-cigarette brand

in 2019, stopped online sales of its sweet and fruity e-cigarette products in late 2019 (Jennifer Maloney). The U.S. FDA also issued a guidance prioritizing enforcement against sales of cartridge-based e-cigarettes in flavors other than tobacco and menthol in February 2020 (The Food and Drug Administration, 2020). Last, there was widespread media coverage after the multistate outbreak of e-cigarette or vaping product-use-associated lung injury (EVALI) in 2019 (Leas et al., 2020), which was linked to tetrahydrocannabinol (THC)-containing e-cigarette products, specifically strongly linked to Vitamin E acetate (Blount et al., 2020). The raised awareness of potential vaping risks may have also

**Table 3**

Daily E-cigarette Use Prevalence, 2019–2020, by Cigarette Smoking Statuses, Sociodemographics, and Subjective Depression (N = 63,565).

	Daily E-cigarette Use, Weighted % and 95 % CI <sup>a</sup>		Interaction with year p-value <sup>b</sup>	Change in Daily E-cigarette Use		
	2019 (n = 31,997)	2020 (n = 31,568)		2020 vs 2019 <sup>c</sup>	AOR (95 % CI) <sup>d</sup>	Adjusted p-value <sup>d</sup>
Overall	2.3 (2.1 to 2.6)	2.0 (1.7 to 2.2)		−0.4 (−0.7 to −0.1)	0.9 (0.8 to 1.0)	0.10
Cigarette Smoking Status <sup>e</sup>			0.09			
Never	1.1 (1.0 to 1.3)	1.2 (1.0 to 1.5)		0.1 (−0.2 to 0.4)	1.1 (0.8 to 1.4)	0.73
Former	2.2 (1.8 to 2.7)	2.1 (1.6 to 2.5)		−0.2 (−0.8 to 0.4)	0.9 (0.7 to 1.2)	0.44
Current	7.8 (6.8 to 8.8)	5.7 (4.6 to 6.8)		−2.1 (−3.6 to −0.6)	0.7 (0.6 to 0.9)	0.02
Age Groups (years)			0.25			
18–20	5.1 (3.5 to 6.8)	5.2 (3.0 to 7.4)		0.0 (−2.7 to 2.8)	1.0 (0.6 to 1.8)	0.91
21–24	5.4 (4.0 to 6.9)	6.3 (4.6 to 7.9)		0.8 (−1.4 to 3.0)	1.2 (0.8 to 1.8)	0.38
25–34	4.1 (3.5 to 4.8)	3.4 (2.8 to 4.0)		−0.7 (−1.6 to 0.2)	0.8 (0.6 to 1.1)	0.12
35–44	2.6 (2.1 to 3.2)	1.7 (1.3 to 2.1)		−0.9 (−1.6 to −0.3)	0.6 (0.5 to 0.9)	0.01
45–64	1.4 (1.2 to 1.7)	1.1 (0.8 to 1.4)		−0.3 (−0.7 to 0.0)	0.8 (0.6 to 1.1)	0.25
65+	0.4 (0.2 to 0.5)	0.3 (0.1 to 0.4)		−0.1 (−0.3 to 0.1)	0.7 (0.4 to 1.2)	0.18
Sex			0.53			
Male	2.8 (2.4 to 3.1)	2.4 (2.1 to 2.8)		−0.4 (−0.9 to 0.2)	0.9 (0.7 to 1.1)	0.29
Female	1.9 (1.6 to 2.2)	1.5 (1.3 to 1.8)		−0.4 (−0.8 to 0.0)	0.9 (0.7 to 1.1)	0.19
Race/Ethnicity <sup>f</sup>			0.03			
White, NH	2.5 (2.2 to 2.7)	2.1 (1.8 to 2.4)		−0.4 (−0.8 to 0.0)	0.9 (0.8 to 1.1)	0.36
Black NH	2.4 (1.7 to 3.1)	0.9 (0.4 to 1.4)		−1.5 (−2.4 to −0.6)	0.4 (0.2 to 0.7)	0.0007
Hispanic	1.8 (1.4 to 2.3)	1.9 (1.3 to 2.5)		0.1 (−0.7 to 0.9)	1.0 (0.7 to 1.6)	0.83
Others	2.3 (1.4 to 3.1)	2.5 (1.8 to 3.3)		0.3 (−0.9 to 1.4)	1.1 (0.6 to 1.7)	0.84
Sexual Orientation			0.68			
Heterosexual	2.2 (2.0 to 2.4)	1.8 (1.6 to 2.0)		−0.4 (−0.7 to −0.1)	0.9 (0.7 to 1.0)	0.11
Gay/Lesbian	4.1 (1.2 to 7.0)	5.2 (2.7 to 7.7)		1.1 (−2.8 to 4.9)	1.4 (0.5 to 3.6)	0.54
Bisexual	10 (6.4 to 13.7)	7.5 (3.9 to 11.0)		−2.6 (−7.6 to 2.6)	0.7 (0.4 to 1.4)	0.34
Others	2.7 (1.2 to 4.3)	2.9 (1.1 to 4.7)		0.2 (−2.2 to 2.6)	1.2 (0.5 to 2.9)	0.75
Poverty Ratio <sup>g</sup>			0.11			
<1.0	3.4 (2.7 to 4.2)	1.9 (1.2 to 2.6)		−1.5 (−2.5 to −0.5)	0.6 (0.4 to 0.9)	0.01
1.0–3.9	2.5 (2.2 to 2.9)	2.2 (1.8 to 2.5)		−0.3 (−0.8 to 0.2)	0.9 (0.8 to 1.2)	0.60
≥4.0	1.8 (1.5 to 2.1)	1.7 (1.4 to 2.0)		−0.1 (−0.5 to 0.4)	0.9 (0.7 to 1.2)	0.53
Education			0.58			
Less than High School	1.8 (1.2 to 2.4)	1.5 (0.7 to 2.3)		−0.3 (−1.2 to 0.7)	0.8 (0.4 to 1.5)	0.49
High School	2.8 (2.3 to 3.2)	2.2 (1.7 to 2.6)		−0.6 (−1.3 to 0.0)	0.8 (0.6 to 1.1)	0.23
Some College	3.1 (2.6 to 3.6)	2.5 (2.1 to 3.0)		−0.5 (−1.2 to 0.1)	0.9 (0.7 to 1.1)	0.34
College	1.4 (1.2 to 1.7)	1.4 (1.1 to 1.7)		0.0 (−0.4 to 0.4)	1.0 (0.7 to 1.3)	0.92
Urbanicity <sup>h</sup>			0.74			
Metropolitan	2.4 (2.1 to 2.6)	2 (1.7 to 2.2)		−0.4 (−0.7 to −0.1)	0.9 (0.7 to 1.0)	0.13
Nonmetropolitan	2.2 (1.7 to 2.7)	2 (1.3 to 2.7)		−0.2 (−1.1 to 0.7)	0.8 (0.5 to 1.3)	0.35
Subjective Depression Frequency <sup>i</sup>			0.71			
Never/a few times a year	1.9 (1.7 to 2.1)	1.6 (1.4 to 1.9)		−0.3 (−0.6 to 0.0)	0.9 (0.8 to 1.1)	0.28
At least monthly	4.5 (3.7 to 5.3)	3.6 (2.9 to 4.3)		−0.9 (−2.0 to 0.2)	0.8 (0.6 to 1.1)	0.19

Abbreviations, CI: Confidence Interval, NH: Non-Hispanic.

<sup>a</sup> : Weighted estimates from National Health Interview Survey years 2019 (N = 31,997) and 2020 (N = 31,568). Daily e-cigarette use classified for respondents who reported now using e-cigarettes every day.<sup>b</sup> : p-value from unadjusted logistic regression model omnibus interaction test.<sup>c</sup> : Unadjusted difference of 2020 estimate minus 2019 estimate.<sup>d</sup> : Multivariable logistic regression model included pooled 2019 and 2020 data with year (2020 vs 2019) and all variables in this Table as simultaneous regressors.  
<sup>e</sup> : Combustible cigarette smoking was classified into never (<100 cigarettes smoked lifetime), former (smoked ≥ 100 cigarettes lifetime and not currently smoking), or current (smoked ≥ 100 cigarette lifetime and currently smoking every day or some days) statuses.<sup>f</sup> : Race and Hispanic ethnicity were self-reported and Hispanic persons could be of any race.<sup>g</sup> : Ratio of family income to the federal poverty threshold.<sup>h</sup> : Metropolitan (large central metro, large fringe metro, medium and small metro) vs non-metropolitan.<sup>i</sup> : Measured by the question “How often depressed?” with “Yes” including those who responded “Daily”, “Weekly”, and “Monthly”, and “No” including those who responded “A few times a year” and “No”.

contributed to the observed decrease in e-cigarette use among U.S. adults. Indeed, using Nielsen Scantrack sales data from convenience stores and mass market channels, Liber *et al.* (Liber *et al.*, 2021) reported a 10.6 % decline in e-cigarette sales related to the EVALI outbreak. Future studies should investigate how these factors (e.g., the COVID-19 pandemic, changing vaping policies and e-market) may jointly contribute to the changes in adult e-cigarette use and whether the effects are different across vulnerable subpopulations.

Previously-reported young adult current e-cigarette use rose from 2017 (5.2 %) to 2018 (7.6 %) (Dai and Leventhal, 2019), continued to escalate into 2019 (9.3 %) (Cornelius *et al.*, 2020) and then leveled off by 2020 (9.4 %), according to the current findings. Stratified analyses further show an insignificant change in e-cigarette use among young adults aged 18–20 years old though the federal law increased the

minimum legal sales age for tobacco from 18 to 21 in December 2019 (The Food and Drug Administration, 2022). According to prior literature (Berg *et al.*, 2021; Gaiha *et al.*, 2020), this happened potentially because many underage young adults continued to obtain their vaping products through stockpiling of products or from the online purchase or retail channel non-compliance with the underage sale laws. Evidence-based strategies, including age verification (Gaiha *et al.*, 2020) and vaping cessation program (Graham *et al.*, 2021), are needed to reduce e-cigarette use among young adults. For instance, a recent randomized control trial showed the promising results with 39 % higher odds of abstinence rate from *This is Quitting*, a vaping cessation text message program, than the control group among young adult e-cigarette users (Graham *et al.*, 2021). Consistent with prior literature (Cummins *et al.*, 2014; Obisesan *et al.*, 2019; Park *et al.*, 2017), this study reported higher e-cigarette use

among those with monthly depressive symptoms than those without such conditions. E-cigarettes often contain nicotine, which can negatively impact emotional regulation and amplify stress sensitivity (Cummins et al., 2014; Obisesan et al., 2019; Park et al., 2017). Though current e-cigarette use declined during 2019–2020 for the overall population in this study, the change in e-cigarette use was not significant among those with subjective depression symptoms (at least monthly). Future studies should assess the long-term health effects of e-cigarette use on those with mental illness and the development of clinical interventions and tobacco control policies for e-cigarette use needs to take this priority population into account.

Daily e-cigarette users represent an important group in tobacco use research. Frequent e-cigarette use in young people might increase nicotine addiction and elevate the risk of future combustible cigarette smoking and other substance use (National Academies of Sciences Engineering and Medicine, 2018). Although the effectiveness of e-cigarette use in population cigarette smoking cessation is still inconclusive (U.S. Department of Health and Human Services, 2020), both cross-sectional and longitudinal studies have provided evidence that daily use of e-cigarettes was associated with an increased smoking cessation rate among combustible cigarette smokers (Berry et al., 2019; Wang et al., 2021; Zhu et al., 2017). This study found no changes in daily e-cigarette use from 2019 to 2020 among U.S. adults overall and among young adults aged 18–24 years. Although the long-term health effects of e-cigarette use remain unknown (U.S. Department of Health and Human Services, 2016), a growing body of literature suggests that daily e-cigarette use may increase the success of smoking cessation (Johnson et al., 2019; Kasza et al., 2021; Wang et al., 2021; Zhu et al., 2017). The decline in daily e-cigarette use among current smokers and subpopulations with disproportionately low smoking cessation (e.g., Black adults and those in poverty (Leventhal et al., 2021)) warrants further investigation of its potential impacts on smoking-related health disparities.

This study has some limitations. First, e-cigarette use and smoking status were self-reported and thus subject to recall bias. Second, the NHIS interview format changed during the COVID-19 pandemic and might affect prevalence estimates, although we found similar e-cigarette use prevalence across 2020 (Table 2 footnote). Third, the 2020 response rate (48.9 %) was lower than in 2019 (59.1 %), though sample weighting is designed to account for nonresponse bias. Fourth, former smokers who quit smoking before e-cigarettes might have distinct vaping patterns than former smokers who use e-cigarettes to quit smoking. Since the NHIS cross-sectional data did not collect information on the sequence of smoking cessation and initiation of e-cigarettes, this study analyzed former smokers as one group. Future studies should analyze e-cigarette use behaviors among distinct former smoker groups. Finally, NHIS estimates are not generalizable to institutionalized, imprisoned, or military populations.

Despite these limitations, this study provided the latest evidence on the disparities in U.S. adult e-cigarette use during the COVID-19 pandemic. There was a decline in current e-cigarette use but no change in overall daily e-cigarette use from 2019 to 2020. The decline was pronounced among current smokers, Black adults, and those in poverty, but not among young adults. Continuous monitoring of adult e-cigarette use is warranted.

#### 4. Data availability statement

The NHIS data are publicly available and can be downloaded here: <https://www.cdc.gov/nchs/nhis/data-questionnaires-documentation.htm>.

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#### 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

The data are publicly available

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