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# Increased nicotine vaping due to the COVID-19 pandemic among US young adults: Associations with nicotine dependence, vaping frequency, and reasons for use

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## ABSTRACT

Previous research has not examined increased vaping because of the pandemic using a national sample of young adults (YAs), which is a critical gap because pandemic-related increases in vaping among YAs could have important implications for nicotine dependence, prolonged regular use, and using substances to cope with stress. We examined self-reported increased vaping attributed to the COVID-19 pandemic among YAs, and its associations with outcomes that have important implications for future nicotine use. Data came from the Monitoring the Future (MTF) Vaping Supplement. Participants were selected from a nationally representative sample of US 12th-graders who were surveyed at age 19 in fall 2020 ( $N = 1244$ ). Cross-sectional analyses of the 2020 survey included YAs who vaped nicotine in the past year (35%;  $N = 440$ ). Weighted descriptive analyses and logistic regression models examined self-reported pandemic-related increased vaping (vs. decreased vaping, or no change), and its associations with current nicotine dependence, vaping behavior, and reasons for vaping. Among YAs who vaped nicotine in the past year, 16.8% reported increased and 44.4% reported decreased vaping due to the pandemic, while 38.9% reported no change. Increased vaping (vs. decreased and/or no change) was significantly associated with nicotine dependence symptoms, current regular nicotine vaping, and vaping to relax, get high, and because of boredom. Self-reported increased vaping because of the pandemic was associated with increased risk for current nicotine dependence and frequent use. Increased vaping may have been a form of coping with pandemic-related stressors, which increases risk for future substance use problems.

## 1. Introduction

The COVID-19 pandemic and preventive measures implemented to reduce death and disease, such as school closures, statewide shutdowns of businesses, and social distancing, have been associated with a decline in the prevalence of nicotine vaping among youth (Kreslake et al., 2021). On average, nicotine vaping prevalence and frequency decreased during the pandemic (Kreslake et al., 2021; Miech et al., 2021a; Gaiha et al., 2020). Based on available data from January 2020 to June 2020 (Kreslake et al., 2021), vaping prevalence decreased among adolescents (ages 15–17) by approximately 7 percentage points (Kreslake et al., 2021), and young adults (YAs, ages 18–20) by approximately 10 percentage points (Kreslake et al., 2021). However, vaping prevalence increased among YAs between ages 21 and 24 by approximately 7 percentage points (Kreslake et al., 2021). In these overall trends, it is unclear what proportion of YAs increased or decreased vaping because of the pandemic. Currently available data include prevalence estimates in specific age ranges or sampling methods such as quota and convenience sampling of people who currently vape. Whether young adults attribute

these changes to the pandemic is unknown.

Many YAs temporarily stopped vaping, reduced vaping, or quit vaping outright (Kreslake et al., 2021; Miech et al., 2021a; Gaiha et al., 2020), while other YAs increased vaping during the pandemic (Kreslake et al., 2021). This increased vaping behavior may have important implications for future use. One national study assessed whether or not 19-year-olds (regardless of past vaping experience) reported increased vaping in response to social distancing and isolation associated with the pandemic, and approximately 9% of 19-year-olds increased vaping to cope with these aspects of the pandemic (Patrick et al., 2022). Consequently, changes in vaping behaviors during the pandemic vary as a result of pandemic-related stressors, and many YAs report increased vaping as a form of coping. Even before the pandemic, using substances as a form of coping had increased (Patrick et al., 2022) and this reason for substance use is associated with risk for increased substance use and substance use disorders in adulthood (Patrick et al., 2019; Patrick et al., 2016a; Patrick et al., 2011).

Nicotine vaping among YAs in the U.S. had reached epidemic proportions prior to the pandemic (King et al., 2020), and this rapid uptake

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of vaping among youth and YAs changed the tobacco landscape (King et al., 2020; Cullen et al., 2018; Miech et al., 2019). Vaping increased dramatically between 2014 and 2018 (Schulenberg et al., 2021; Miech et al., 2021b), and prevalence remained high before the pandemic (1 in 5 high school students reported current nicotine vaping in 2019) (Miech et al., 2021b). Past-year nicotine vaping among YAs increased from 13% in 2017 to 24% in 2019, and past 30-day nicotine vaping increased from 6.2% in 2017 to 14.5% in 2019 (Schulenberg et al., 2021). Nicotine vaping is associated with nicotine-related effects on the brain, future cigarette use, and exposure to harmful toxins (Glantz and Bareham, 2018; Soneji et al., 2017; Rubinstein et al., 2018). Young adulthood is a particularly important age because initiation and escalation of nicotine use is becoming more prominent in young adulthood (Hair et al., 2017; Villanti et al., 2019).

Pandemic-related increases in vaping among YAs could have important implications; for instance, this increased vaping could put YAs at higher risk for nicotine dependence and prolonged regular use, and if increased vaping is associated with these outcomes, there could be cohorts of YAs who are now more addicted to nicotine and at risk for frequent nicotine use. Yet previous research has not specifically examined increased vaping among YAs who vaped in response to the pandemic using a national sample of YAs, which is a critical gap in research because previous research has either only captured vaping prevalence (past 30-day use) or research has not identified a subgroup of individuals who reported increased vaping. Similar to research on other substances (Graupensperger et al., 2021; Jaffe et al., 2021; Romm et al., 2021; Bonar et al., 2021), the available research on vaping during the COVID-19 pandemic has relied on regional datasets with limited generalizability, quota or convenience sampling, only population-level prevalence estimates, or has not examined general increased vaping because of the pandemic among YAs (Kreslake et al., 2021; Gaiha et al., 2020). Moreover, reasons for vaping (Patrick et al., 2016b) are important predictors that have not been examined during the pandemic. We hypothesize that many YAs who increased nicotine vaping did so as a form of coping with stress, which would have important implications for future nicotine use.

We examine self-reported pandemic-related increases in vaping, focusing on YAs who vaped nicotine in the past year, using data from a national sample from the Monitoring the Future project that were gathered during the COVID-19 pandemic (i.e., at age 19 during fall 2020). The project addresses how self-reported increased vaping due to the pandemic compared to self-reports of decreased vaping or no change in vaping, focusing on whether pandemic-related vaping increases were associated with nicotine dependence symptoms and current regular nicotine vaping in fall 2020. We focus on current regular use because we are interested in the degree to which YAs who increased vaping were more likely to currently vape at a high frequency compared to YAs who did not increase vaping. We then examine how increased vaping was associated with the most prominently reported reasons for nicotine vaping. The research questions (RQs) were as follows: RQ1—among YAs who vaped nicotine in 2020, what was the prevalence of self-reported increased vaping in response to the COVID-19 pandemic?; RQ2—how was self-reported increased vaping associated with nicotine dependence and current vaping frequency, adjusting for demographics and other covariates?; and RQ3—was pandemic-related vaping increase associated with specific reasons for vaping, such as to relieve stress? We hypothesize that pandemic-related increased vaping is a risk factor for nicotine dependence and regular vaping, and that increased vaping will be associated with reasons for vaping that are indicative of coping (e.g., to relieve stress).

## 2. Methods

### 2.1. Data

Data came from the Monitoring the Future (MTF) Vaping

Supplement collected from September to November 2020. Participants were selected from a nationally representative sample of US 12th-grade students participating in MTF in spring 2019 (Schulenberg et al., 2021; Bachman et al., 2015). In 2019, there were 13,713 MTF participants in 12th grade, and 7850 were eligible for the Vaping Supplement based on not being randomly selected for the MTF longitudinal study (Schulenberg et al., 2021) ( $N = 2450$ ); 3413 were ineligible because they did not provide valid contact information. There were 4358 eligible participants who were randomly selected to participate in the MTF Vaping Supplement, with an oversample of participants who reported vaping or other substance use in 12th grade. The MTF Vaping Supplement surveyed individuals about one year later (age 19.6;  $SD = 0.44$ ) in fall 2020; cross-sectional analyses reported here rely on this 2020 survey. Of the total of 1244 (28.5%) invited participants who participated, 440 participants (35%) reported past-year nicotine vaping and were included in the analysis (<3% were removed because of missing data). The study was approved by a University of Michigan Institutional Review Board, and the work was in accordance with the Code of Ethics of the World Medical Association.

### 2.2. Measures

#### 2.2.1. Exposure

Respondents who reported nicotine vaping in the past 12 months in 2020 were asked, "How has the COVID-19 pandemic impacted how much you vape?" Response options were: "I did not change how I vaped," "I did not vape at all," "I vaped less," or "I vaped more." This measure was recoded to capture pandemic-related vaping change as: increased vaping ("I vaped more"), decreased vaping ("I did not vape at all," "I vaped less"), or no change ("I did not change how I vaped").

#### 2.2.2. Outcomes

We examined three outcomes for our three research questions. The Hooked on Nicotine Checklist tailored to nicotine vaping (Case et al., 2018) was used to assess six symptoms of nicotine dependence using the following yes/no questions: "Have you ever felt like you really needed to vape?"; "Do you ever have a strong urge to vape?"; "When you have not vaped, do you find it difficult to concentrate?"; "When you have not vaped, do you feel more irritable?"; "When you have not vaped, do you feel nervous, restless or anxious?"; "Do you typically vape within 30 minutes of waking up in the morning?". We measured nicotine dependence via a count measure (0 to 6 symptoms), which offers strong psychometric properties (Case et al., 2018; Wheeler et al., 2004).

To assess current nicotine vaping, the survey asked, "On how many days (if any) have you vaped nicotine...during the last 30 days?" Any current nicotine vaping was defined as any vaping in the past 30 days (1 = yes, 0 = no), and regular nicotine vaping was defined as vaping more than 5 days in the past 30 (1 = more than 5 days, 0 = 5 or fewer days/no days) (Amato et al., 2016).

To assess reasons for nicotine vaping (Miech et al., 2021b; Patrick et al., 2016b), the survey asked, "What have been the most important reasons for vaping?" with the following answer choices (respondents could select all that applied): (1) To help me quit regular cigarettes (quit cigs); (2) Because regular cigarette use is not permitted (cigs not allowed); (3) Because it was more convenient than smoking (more convenient than smoking); (4) To experiment—to see what it's like (experimentation); (5) To relax or relieve tension (to relax/relieve tension); (6) To lose or control my weight (control weight); (7) To feel good or get high (get high); (8) Because it looks cool (looks cool); (9) To have a good time with my friends (good time with friends); (10) Because of boredom, nothing else to do (boredom); (11) Because it tastes good (taste); (12) Because I am "hooked"—I have to have it (hooked). Each reason was examined as a separate dichotomous outcome.

#### 2.2.3. Covariates

We assessed whether participants had ever made a vaping cessation

attempt in past; whether participants owned their own vaping device; and combustible cigarette use in past 30 days (all three: 1 = yes, 0 = no) (Pearson et al., 2018). We also assessed perceived vaping risk via a two-item scale ( $\alpha = 0.83$ ; range = 0 to 4); higher scores indicated higher perceived risk (Schulenberg et al., 2021; Miech et al., 2021b). The two items asked, “How much do you think people risk harming themselves (physically or in other ways) if they vape an e-liquid with nicotine occasionally?” and “How much do you think people risk harming themselves (physically or in other ways) if they vape an e-liquid with nicotine regularly?”. Previous research indicates perceived risk of nicotine vaping is an important predictor of current use (Cuccia et al., 2021), and consequently, we included this measure as a control as it could influence the relationship between increased vaping and all outcomes.

We included perceptions of friends’ disapproval of vaping since vaping-related norms are associated with current nicotine vaping (Katz et al., 2020; Wyman et al., 2021). This covariate captured how participants perceived their close friends felt about the respondent vaping occasionally and vaping every day. We generated a continuous scale of two variables ( $\alpha = 0.81$ ; range = 1 to 3), with higher scores indicating more disapproval (Schulenberg et al., 2021; Miech et al., 2021b). We included sex (male = 1, female = 0), race/ethnicity (non-Hispanic White = 1, all other = 0), and student status (full-time in 4-year college = 1, all other = 0) as demographic covariates.

### 2.3. Analytic strategy

For RQ1, we used weighted descriptive analyses. We used cross-tabs and mean comparisons that employed design-adjusted F-tests and adjusted Wald tests for RQ2; these analyses assessed differences in prevalence of outcomes and covariates across pandemic-related vaping change. For RQ2, we also used multivariable negative binomial regression to assess the count outcome of nicotine dependence symptoms and logistic regression to assess the binary outcome of current regular vaping, adjusting for covariates. For RQ3, we used cross-tabs and mean comparisons that employed design-adjusted F-tests and adjusted Wald tests, as well as multivariable logistic regression, to assess reasons for use. Weights were used to adjust for the complex survey design of the MTF study, oversampling of vapers, and survey nonresponse.

For all regression analyses, an additional model was examined that included all variables in the main regression models plus longitudinal data from age 18 (i.e., 1 = vaped in past year in fall 2019, 0 = did not); it is important to note these analyses only included the subsample for whom age-18 vaping data were available ( $N = 299$ ).

## 3. Results

### 3.1. Pandemic-related increased vaping and bivariate differences

Shown in Tables 1, 16.8% of YAs who vaped in the past year at age 19 (in fall 2020) reported pandemic-related increased vaping. Reported decreased vaping due to the pandemic was most prevalent (44.4%), followed by no change in vaping (38.9%). Nicotine dependence was highest among YAs who reported pandemic-related increased vaping, as were the prevalence estimates for any and regular past 30-day vaping (Table 1). They also had a higher prevalence of owning a vaping device. Those with increased vaping had the lowest prevalence of ever trying to quit vaping, but the difference was not significant ( $p = 0.082$ ). Cigarette use was highest among YAs who reported no change. YAs who reported decreased vaping reported highest level of friends’ disapproval of vaping, lowest prevalence of current vaping, and highest prevalence of a past quit attempt (Table 1).

### 3.2. Regression results for nicotine dependence and current vaping frequency

Negative binomial and logistic regression analyses for RQ2 are shown in Table 2. YAs who reported no change and decreased vaping (vs. increased vaping) had fewer nicotine dependence symptoms (respectively, IRR = 0.67, 95% CI = 0.49, 0.93; IRR = 0.63, 95% CI = 0.45, 0.86), adjusting for covariates. For covariates, a previous vaping cessation attempt and owning a vaping device were significantly and positively associated with nicotine dependence. Past 30-day cigarette use was significantly and positively associated with nicotine dependence.

YAs who reported no change and decreased vaping (vs. increased vaping) had lower odds of regular nicotine vaping (respectively, OR = 0.35, 95% CI = 0.15, 0.80; OR = 0.11, 95% CI = 0.05, 0.25), adjusting for covariates. Owning a vaping device was significantly and positively related to regular vaping. Friend’s disapproval of vaping was negatively associated with regular current nicotine vaping.

Sensitivity analyses including past-year nicotine vaping at age 18 showed that past-year nicotine vaping in spring 2019 was significantly and positively associated with all outcomes in fall 2020. In regression analyses, the difference between increased vaping and no change became nonsignificant for nicotine dependence, but remained significant for increased versus decreased vaping (IRR = 0.67, 95% CI = 0.46, 0.98). All conclusions were unchanged for regular current nicotine vaping.

**Table 1**  
Weighted Statistics for Past-year Young Adult Vapers and Differences Across COVID-related Vaping Behavior Change.

Variables	COVID-related vaping behavior change:			Total	p
	% (95% CI)	No change 38.9 (32.7, 45.5)	Decreased vaping 44.4 (38.4, 50.6)		
Past 30-day nicotine vaping	85.2 (78.4, 90.2)	47.6 (39.3, 56.2)	95.3 (87.3, 98.3)	<0.001	70.2 (64.5, 75.4)
Current regular nicotine vaping	55.3 (44.3, 65.8)	20.1 (14.8, 26.6)	74.7 (63.2, 83.5)	<0.001	42.9 (36.7, 49.4)
Ever attempt vaping cessation	58.0 (46.4, 68.8)	68.2 (59.7, 75.6)	49.9 (36.7, 63.1)	0.082	61.2 (54.8, 67.1)
Own vaping device type (vs. do not own)	60.6 (49.7, 70.5)	33.6 (25.3, 43.0)	67.9 (53.6, 79.5)	<0.001	49.8 (43.6, 56.1)
Currently smoke cigarettes	16.1 (8.5, 28.3)	5.6 (3.2, 9.5)	13.8 (7.4, 24.2)	0.028	11.0 (7.4, 16.2)
Male sex (vs. female)	62.8 (52.3, 72.2)	55.8 (47.6, 63.7)	53.2 (40.1, 65.9)	0.413	58.1 (52.2, 63.7)
Non-Hispanic white (vs. all other)	72.0 (62.0, 80.3)	62.5 (53.5, 70.7)	60.7 (47.0, 73.0)	0.230	65.9 (59.8, 71.5)
Current student 4-year college/university (vs. other)	36.2 (27.0, 46.9)	47.6 (39.2, 56.1)	40.6 (28.9, 53.4)	0.202	42.0 (36.2, 48.0)
		Mean (95% CI)			
Nicotine dependence symptoms (0 to 6)	2.0 (1.4, 2.5)	1.4 (1.0, 1.7)	2.6 (2.0, 3.2)	0.002	1.8 (1.5, 2.1)
Vaping risk perception scale	2.6 (2.4, 2.8)	2.8 (2.7, 3.0)	2.6 (2.3, 2.9)	0.053	2.7 (2.6, 2.8)
Friend vaping perception scale	1.2 (1.1, 1.3)	1.4 (1.3, 1.5)	1.2 (1.1, 1.3)	0.002	1.3 (1.3, 1.4)

Notes. Past-year vapers  $N = 440$

**Table 2**

Negative Binomial and Logistic Regression Results for COVID-related Vaping Behavior Change and Vaping Outcomes among Past-year Young Adult Vapers.

Variables	Outcomes		Nicotine dependence		Current regular nicotine vaping	
			IRR (95% CI)		AOR (95% CI)	
COVID-related vaping behavior change						
Increased vaping (reference)						
No change			<b>0.67</b>	<b>(0.49, 0.93)</b>	<b>0.35</b>	<b>(0.15, 0.80)</b>
Decreased vaping			<b>0.63</b>	<b>(0.45, 0.86)</b>	<b>0.11</b>	<b>(0.05, 0.25)</b>
Ever attempt vaping cessation			<b>2.47</b>	<b>(1.81, 3.38)</b>	0.95	(0.51, 1.77)
Own vaping device type			<b>2.74</b>	<b>(2.03, 3.69)</b>	<b>8.09</b>	<b>(4.46, 14.67)</b>
Vaping risk perception scale			0.93	(0.80, 1.09)	0.97	(0.64, 1.46)
Friend vaping perception scale			0.82	(0.63, 1.07)	<b>0.36</b>	<b>(0.18, 0.72)</b>
Currently smoke cigarettes			<b>1.58</b>	<b>(1.13, 2.20)</b>	1.63	(0.64, 4.10)
Male sex (vs. female)			0.94	(0.74, 1.20)	1.03	(0.58, 1.82)
Non-Hispanic white (vs. all other)			1.26	(0.96, 1.66)	1.83	(0.98, 3.42)
Current student 4-year college/university (vs. other)			0.80	(0.61, 1.05)	0.81	(0.44, 1.48)

Notes. Past-year vapers N = 440; Negative binomial regression was used for nicotine dependence count outcome and logistic regression was used for the binary regular nicotine vaping outcome. Bolded odds ratios indicates statistical significance (p < .05).

3.3. Reasons for vaping

Prevalence of each reason for nicotine vaping and differences across vaping-related behavior change are shown in Table 3. Among YAs who vaped in the past year, the most prevalent reason for vaping was to relax/relieve tensions (54.2%). Other prevalent reasons for nicotine vaping were experimentation (44.0%) and boredom (39.0%). The least prevalent reason for nicotine vaping was cigarettes were not allowed to be used (<1%); to control weight (4.1%) and to quit cigarettes (6.3%), and they were the only reasons with a prevalence of <10%. All prevalence estimates for the total sample are presented in the right-hand column of Table 3.

Table 3 shows that there were 2 reasons that were statistically significantly different between YAs who reported increased vaping versus those who decreased vaping or reported no change: boredom and to control weight. Specifically, YAs who reported increased vaping were more likely to report that they vaped to control weight and out of boredom.

Logistic regression results presented in Table 4 showed that slightly different results emerged after adjusting for covariates. Compared to increased vaping, YAs who reported no change and decreased vaping had lower odds of vaping to get high (respectively, AOR = 0.36, 95% CI = 0.16, 0.80; AOR = 0.42, 95% CI = 0.19, 0.95). Compared to increased vaping, YAs who reported no change had lower odds of vaping to relax/relieve tension (AOR = 0.32; 95% CI = 0.14, 0.72), boredom (AOR = 0.29; 95% CI = 0.14, 0.59), and control weight (AOR = 0.21; 95% CI = 0.06, 0.74). Sensitivity analyses that adjusted for fall 2019 vaping showed that the difference in odds of vaping to control weight between

increased vaping versus no change became nonsignificant (AOR = 0.26; 95% CI = 0.06, 1.30). All other associations remained similar.

**Table 4**

Logistic Regression Results for COVID-related Vaping Behavior Change and Reasons for Vaping Outcomes among Past-year Young Adult Vapers.

Outcomes	No Change (vs. increased)		Decreased (vs. increased)	
	AOR (95% CI)		AOR (95% CI)	
<i>Reasons for vaping</i>				
To relax/relieve tension	<b>0.32</b>	<b>(0.14, 0.72)</b>	0.52	(0.24, 1.14)
Experimentation	1.46	(0.73, 2.95)	1.35	(0.66, 2.75)
Boredom	<b>0.29</b>	<b>(0.14, 0.59)</b>	0.61	(0.30, 1.24)
Taste	0.68	(0.33, 1.41)	0.95	(0.46, 1.95)
Have good time with friends	1.12	(0.54, 2.35)	1.17	(0.54, 2.52)
Get high	<b>0.36</b>	<b>(0.16, 0.80)</b>	<b>0.42</b>	<b>(0.19, 0.95)</b>
More convenient than smoking	0.52	(0.19, 1.39)	0.59	(0.22, 1.57)
Hooked	0.58	(0.25, 1.35)	0.39	(0.14, 1.10)
Looks cool	0.96	(0.30, 3.07)	1.15	(0.37, 3.58)
Quit cigs	1.39	(0.31, 6.32)	2.31	(0.49, 11.01)
Control weight	<b>0.21</b>	<b>(0.06, 0.74)</b>	0.55	(0.19, 1.58)
Cigs not allowed	0.17	(0.01, 2.24)	0.50	(0.08, 3.03)

Notes. Past-year vapers N = 440; each reason was used as the outcome and analyzed in a separate regression; all models controlled for all covariates in Table 2. Bolded odds ratios indicates statistical significance (p < .05).

**Table 3**

Weighted Statistics for Reasons for Vaping after COVID-19 Onset (2020) among Past-year Young Adult Vapers and Differences Across COVID-related Vaping Behavior Change.

Variables	COVID-related vaping behavior change:		No change		Decreased vaping		Increased vaping		Total
					% (95% CI)			p	
<i>Reasons for nicotine vaping (in descending order for overall prevalence)</i>									
To relax/relieve tension	51.9	(40.7, 62.9)	49.8	(41.3, 58.3)	71.1	(56.7, 82.3)	0.052	54.2	(48.0, 60.3)
Experimentation	43.6	(33.0, 54.8)	48.6	(40.1, 57.1)	33.1	(22.6, 45.6)	0.195	44.0	(38.0, 50.2)
Boredom	<b>29.2</b>	<b>(20.5, 39.7)</b>	<b>42.3</b>	<b>(34.0, 51.0)</b>	<b>53.2</b>	<b>(39.6, 66.4)</b>	0.015	39.0	(33.2, 45.1)
Taste	28.0	(19.1, 39.1)	31.8	(24.5, 40.2)	35.0	(23.6, 48.3)	0.666	30.9	(25.5, 36.8)
Have good time with friends	27.0	(18.5, 37.5)	33.5	(26.0, 41.9)	24.9	(16.0, 36.6)	0.393	29.5	(24.4, 35.3)
Get high	24.1	(15.5, 35.4)	28.0	(20.4, 37.1)	42.8	(30.0, 56.6)	0.092	29.0	(23.4, 35.2)
More convenient than smoking	18.1	(9.2, 32.5)	10.1	(5.3, 18.5)	27.4	(16.9, 41.1)	0.080	16.1	(11.2, 22.7)
Hooked	18.5	(10.4, 30.7)	9.5	(5.0, 17.2)	25.0	(15.3, 38.1)	0.061	15.6	(11.1, 21.4)
Looks cool	8.4	(3.9, 16.9)	14.2	(9.6, 20.7)	7.7	(3.2, 17.6)	0.261	10.9	(7.7, 15.0)
Quit cigs	8.8	(2.5, 2.6)	3.5	(1.6, 7.8)	7.6	(2.1, 23.9)	0.436	6.3	(2.9, 12.9)
Control weight	<b>2.0</b>	<b>(0.8, 4.5)</b>	<b>4.5</b>	<b>(2.7, 7.7)</b>	<b>8.1</b>	<b>(3.8, 16.4)</b>	0.033	4.1	(2.8, 6.1)
Cigs not allowed	0.0	(0.0, 2.6)	0.1	(0.0, 4.9)	2.1	(0.7, 6.4)	0.310	0.8	(0.3, 2.1)

Notes. Past-year vapers N = 440; bolded indicates difference across groups is statistically significant.



#### 4. Discussion

Many YAs reported decreased vaping because of the pandemic. However, there is a smaller group of YAs who reported increased vaping due to the pandemic and are at heightened risk for a range of deleterious vaping-related outcomes. Specifically, YAs who reported increased vaping as result of the pandemic showed greater risk for nicotine dependence and current frequent use in fall 2020. In addition, three quarters of YAs who reported pandemic-related vaping increase also indicated that they vape nicotine in order to relax or relieve tension (i.e., as a form of coping with stress).

Previous research has shown that nicotine vaping on average declined during the pandemic (Kreslake et al., 2021; Miech et al., 2021a), and our analyses support this finding. At the same time, the current results highlight that there is a subset of YAs who reported increased vaping because of the pandemic. As anticipated, this group is at increased risk for not only nicotine dependence, but frequent use and reasons for use that have implications for future substance use problems. Therefore, addressing vaping among YAs who increased vaping due to the pandemic should be a priority for intervention efforts.

Owning a vaping device was strongly associated with outcomes in the analysis, supporting previous research showing that reduced vaping among adolescents and YAs could have been impacted by access to a vaping device (Kreslake et al., 2021; Miech et al., 2021a). However, YAs who increased vaping during the pandemic were still at risk for current nicotine vaping regardless of whether they owned a vaping device. It is possible that a lack of device ownership could have played a role in why some YAs vaped less or not at all during the pandemic.

YAs who reported increased vaping were more likely to report that they vape nicotine for reasons related to dealing with stress/relaxing, pleasure, and because they were bored. To relax/relieve tension was the only reason for nicotine vaping with a prevalence over 50% among all YAs who reported past-year nicotine vaping. These results are potentially disconcerting because using substances to cope with stress among young people is a critical public health issue due to its association with risk for substance use disorders (Patrick et al., 2019; Patrick et al., 2016a). Before the pandemic began, research had demonstrated that 18-year-olds tend to vape because they are experimenting, or they like the taste or get pleasure from it (Patrick et al., 2016b; Ambrose et al., 2015), not because they are trying to quit or reduce cigarette use (Lippert, 2015; Kong et al., 2015). Our results support this previous research and demonstrate that the reasons for nicotine vaping of relaxation/relieving stress, getting high, and boredom had higher prevalence among YA who reported past-year nicotine vaping and pandemic-related vaping increase.

All of the reasons for nicotine vaping that were higher among YAs who reported increased vaping could be theoretically linked to the COVID-19 pandemic, including increased isolation, stress, and economic hardships for many YAs (Horigian et al., 2021; Mehus et al., 2021; Charles et al., 2021). In a previous study, 9% of all YAs vaped more to cope with social distancing and isolation. This increased vaping was also associated with pandemic-related stressors. In the current analysis, among YAs who reported nicotine vaping in past year, a broader question asked about vaping-related change without reference to specific aspects of the pandemic. Consequently, current results indicate YAs who vaped nicotine in the past year reported increased vaping because of the pandemic generally and potentially for multiple reasons, including to relax and boredom.

It is important to note that pre-pandemic vaping behavior was associated with nicotine dependence in all analyses. Generally, our results held after accounting for pre-pandemic vaping behavior, which implies that previous vaping behavior before the pandemic did not completely explain associations between pandemic-related increased vaping and outcomes. Despite being able to adjust for pre-pandemic vaping behavior, it was not possible to disentangle the causal effects that the pandemic had on vaping, but our self-report measure directly

assessed whether participants *perceived* the pandemic to have caused their vaping behavior changes. It is apparent that a subset of YAs attributes their increased vaping to the pandemic, and their current vaping patterns put them at risk for more deleterious outcomes. It is critical to consider interventions to reduce risks for nicotine dependence and negative consequences of heavy nicotine vaping among YAs, and particularly YAs at risk for increased vaping during the pandemic. Moreover, identifying how the pandemic has impacted substance use, such as nicotine vaping, should remain a priority for future research.

##### 4.1. Limitations

This study had limitations that should be noted. We relied on a self-reported measure of pandemic-related vaping changes. This measure captured respondents' interpretation of how the pandemic influenced their vaping behavior, although those perceptions may be inaccurate. We conducted analyses in an attempt to rule out the possibility that previous vaping behavior influenced the relationship between pandemic-related vaping increase and measures such as nicotine dependence. However, it is possible that nicotine dependence symptoms predated the pandemic. Due to data limitations (e.g., no previous measure of nicotine dependence), we cannot make causal claims about pandemic-related increased vaping. Furthermore, although the analytic sample only included YAs who reported past-year nicotine vaping, respondents could have been considering their vaping of nicotine, cannabis, or both products in responding to the question about pandemic-related change. Future research should seek to differentiate vaping of nicotine and cannabis, as well as their overlap. Moreover, future research should also consider whether increased vaping found here was a naturally occurring change that could have happened even without the pandemic and whether YAs increase vaping at age 19 to cope with general stressors not specifically connected to the pandemic.

#### 5. Conclusion

YAs who vaped nicotine in the past 12 months and reported increasing their vaping due to the pandemic had higher levels of nicotine dependence and greater odds of current frequent nicotine vaping in fall 2020. YAs who increased vaping also reported reasons for vaping that potentially pose a risk for future development of substance use disorders and negative consequences in adulthood. Future research should continue to examine YAs who increased vaping during the early stages of the pandemic (examined here) and later and ongoing phases. Tracking how the pandemic may have contributed to increased vaping among YAs who vape nicotine, and how this increased vaping is related to future use and other issues such as mental health, is an important priority for public health research and intervention.

##### Declaration of interests

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.

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No financial disclosures were reported by the authors of this paper.

##### CRedit authorship contribution statement

**Michael J. Parks:** Conceptualization, Methodology, Software, Validation, Formal analysis, Investigation, Data curation, Writing – original draft, Writing – review & editing, Visualization. **Nancy L. Fleischer:** Validation, Methodology, Writing – original draft, Writing – review & editing, Visualization. **Megan E. Patrick:** Conceptualization, Methodology, Validation, Investigation, Resources, Writing – review &

editing, Supervision, Project administration, Funding acquisition.

## Declaration of Competing Interest

The authors report no conflicts of interest.

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