

UC San Diego

UC San Diego Previously Published Works

Title

Daily E-cigarette Use and the Surge in JUUL Sales: 2017–2019

Permalink

<https://escholarship.org/uc/item/99t6k0z6>

Journal

Pediatrics, 149(6)

ISSN

0031-4005

Authors

Pierce, John P

Zhang, Jasen

Alexander, Laura E Crotty

et al.

Publication Date

2022-06-01

DOI

10.1542/peds.2021-055379

Copyright Information

This work is made available under the terms of a Creative Commons Attribution-NonCommercial-NoDerivatives License, available at

<https://creativecommons.org/licenses/by-nc-nd/4.0/>

Peer reviewed

Daily E-cigarette Use and the Surge in JUUL Sales: 2017–2019

John P. Pierce, PhD,^{a,b} Jasen Zhang, MS,^a Laura E. Crotty Alexander, MD,^{c,e} Eric C. Leas, PhD,^a Sheila Kealey, MPH,^b Martha M. White, MS,^b David R. Strong, PhD,^{a,b} Dennis R. Trinidad, PhD,^a Sara B. McMenamin, PhD,^a Ruifeng Chen, MS,^a Tarik Benmarhnia, PhD,^d Karen Messer, PhD^{a,b}

abstract

OBJECTIVES: To identify how the 2017 rapid surge in sales of JUUL e-cigarettes affected usage among US youth and young adults.

METHODS: Annual surveys in the Population Assessment of Tobacco and Health Study assess tobacco use by product and brand among the US population. We identified 2 cohorts aged 14 to 34 years, 1 with baseline survey in 2014 before the rapid surge of JUUL and the other in 2017 as the surge in JUUL sales was occurring. For 5 age groups, we compared 2-year incidence of first tobacco use and of new-onset daily tobacco use by product, and report levels of dependence.

RESULTS: Sociodemographic variables and rates of experimentation with any tobacco product were similar between cohorts. Among baseline nondaily tobacco users, only those aged 14 to 17 years had an increase in the 2-year incidence of new daily tobacco use (2014 cohort = 4.8%, 95% confidence interval 4.3, 5.5 vs 2017 cohort = 6.3%, 95% confidence interval 5.8–7.0) to rates approaching those in the 1990s. In 2019, three-quarters of new daily tobacco users aged 14 to 17 vaped daily and had e-cigarette dependence scores similar to daily cigarette smokers and older adult e-cigarette vapers. We estimate that about 600 000 Americans aged <21 years used JUUL products daily in 2019, a rate 2.5 times those aged 25 to 34 years.

CONCLUSIONS: The surge in US JUUL sales was associated with a sharp rise in daily e-cigarette vaping and daily tobacco use among US youth, not young adults.



^aHerbert Wertheim School of Public Health and Human Longevity Science, ^bMoore's Cancer Center, ^cSchool of Medicine, Division of Pulmonary Critical Care & Sleep, and ^dScripps Institution of Oceanography, University of California San Diego, San Diego, California; and ^eSection of Pulmonary Critical Care, Veterans Administration San Diego Healthcare System, San Diego, California

Drs Pierce and Messer conceptualized and designed the study, supervised the analyses, drafted the initial manuscript, and reviewed and revised the manuscript; Mr Zhang, Mr Chen and Ms White conducted the main analyses, including drafting the figures and tables, assisted in the interpretation of the results, and reviewed and helped revise the manuscript; Drs Crotty Alexander, Leas, Strong, Trinidad, McMenamin, and Benmarhnia and Ms Kealey helped with the conceptualization and design of the study, reviewed and commented on the presentation and interpretations of the data, and critically reviewed the manuscript for important intellectual content; and all authors approved the final manuscript as submitted and agree to be accountable for all aspects of the work.

DOI: <https://doi.org/10.1542/peds.2021-055379>

Accepted for publication Feb 17, 2022

Address correspondence to John P. Pierce, PhD, Herbert Wertheim School of Public Health and Human Longevity Science, Moore's Cancer Center, University of California San Diego, La Jolla, CA 92093. E-mail: jppierce@ucsd.edu

PEDIATRICS (ISSN Numbers: Print, 0031-4005; Online, 1098-4275).

Copyright © 2022 by the American Academy of Pediatrics

WHAT'S KNOWN ON THE SUBJECT: The marketing of tobacco products, including e-cigarettes, is linked to increased initiation and some evidence of dependence in adolescents. The rapid increase in JUUL sales in 2017 has been associated with a major increase in vaping among high school students.

WHAT THIS STUDY ADDS: The surge in JUUL sales was associated with increased new daily e-cigarette use among 14- to 17-year-olds, with dependence levels similar to new daily cigarette smokers. In 2019, 600 000 US youth aged <21 years were daily JUUL users.

To cite: Pierce JP, Zhang J, Crotty Alexander LE, et al. Daily E-cigarette Use and the Surge in JUUL Sales: 2017–2019. *Pediatrics*. 2022;149(6):e2021055379

E-cigarettes have had few marketing restrictions in the United States, and in 2013 to 2014, one-third of adolescent never tobacco users were receptive to e-cigarette advertising and had become susceptible to try e-cigarettes.¹ By 2014, e-cigarettes (nicotine concentration 1%–3%) were the most commonly used tobacco product among US adolescents.² Nicotine users can quickly develop drug dependence, which is characterized by daily use that involves craving and tolerance with loss of control.³ As nicotine tolerance develops, the initial tobacco product may not provide desired nicotine levels, resulting in switching to a different tobacco product, as occurred with low-nicotine e-cigarettes where the majority of experimenters switched to daily cigarette smoking.^{4,5}

In 2015, JUUL Laboratories Inc disrupted the US e-cigarette market when they introduced nicotine salt technology (effectively doubling e-cigarette nicotine concentration to 5%), and youth-appealing flavors.^{6,7} In 2017, JUUL products led a 40% surge in US e-cigarette sales.^{8,9} Vaping in high schools grew dramatically,^{10,11} whereas cigarette smoking further declined.¹² Other e-cigarette brands quickly developed their own high-nicotine products in what has been described as a nicotine arms race.⁶ When discussing the rise in adolescent vaping between 2017 and 2019, the US Secretary for Health and Human Services stated: “The United States has never seen an epidemic of substance use arise as quickly as our current epidemic of youth use of e-cigarettes.”¹³

Thus, studies to date have considered prevalence of product use primarily in school settings and identified a surge in teen vaping. In this article, we use longitudinal data from the nationally representative Population Assessment of Tobacco

and Health (PATH) Study to estimate the incidence of experimentation and daily use of tobacco products including e-cigarettes. We focus on the participants aged 12 to 34 years surveyed in 2017 (2017 cohort) who were reinterviewed in 2019, a time frame corresponding to the surge in JUUL sales. We compare this cohort to same-age PATH participants surveyed in 2014 (2014 cohort) who were reinterviewed in 2016, before the surge in JUUL sales. Across cohorts, we compare the age-specific incidence of both ever-use and daily use for both cigarettes and e-cigarettes. Then we compare tobacco dependence among new daily users in 2019. We test the hypotheses that the surge in e-cigarette use would result in more new daily vapers, particularly in the youngest age groups, and that they would have dependence scores similar to older-adult new e-cigarette vapers and new daily cigarette smokers.

METHODS

Data source: The PATH Study is a large, nationally representative cohort of the US noninstitutionalized population aged 12-plus years.¹⁴ The study started with a screener survey of an address-based sample of US households, and then oversampled tobacco users, adolescents, young adults (aged 18–24 years), and African Americans. Separate adolescent (aged 12–17 years) and adult (aged 18-plus years) questionnaires in English and Spanish were used. At the first survey wave in 2013 to 2014 (labeled 2014 in this paper), 32 320 adults and 13 651 adolescents completed surveys. The cohort was reinterviewed each year through 2017, when a refreshment sample was recruited to reset the cohort size, adding 6064 adults and 5435 adolescents. Survey wave 5 was completed in 2019. The

response rate for 2-year follow-up of the 2014 cohort was 78.2%, and for the 2017 cohort, it was 85.6%. Our population of interest consists of PATH respondents in each cohort who were aged 14 to 34 years (2014 cohort = 24 409; 2017 cohort = 20 161). We use restricted-use data available from the National Addiction and HIV Data Archive.¹⁵

Tobacco use measures: PATH respondents were shown images for each tobacco product and asked if they had ever used the product even 1 or 2 puffs/times. Adult daily use was assessed from the question, “Do you now [smoke/use product] every day, some days, or not at all?” On the adolescent questionnaire, respondents were asked “on how many of the last 30 days” they had used each tobacco product. We classified reported use on all 30 days as daily use. To obtain the e-cigarette brand used by daily vapers, on each survey, respondents were asked, “What brand of electronic nicotine product do you own?” with open-ended responses coded.

Dependence scores: The PATH Study uses the Wisconsin Inventory of Smoking Dependence Motives framework³ and, in random order, queries 7 domains on both the adolescent and the adult questionnaires separately for cigarettes and e-cigarettes: “I find myself reaching for [product] without thinking about;” “I frequently crave [product];” “My [product] use is out of control;” “I usually want to use [product] right after I wake up;” “Using [product] really helps me feel better if I’ve been feeling down;” “Using [product] helps me think better;” “I would feel alone without my [product].” The 5-point response scale ranged from 1 = “Not true of me at all” to 5 = “Extremely true of me.” Scores were added across the questions giving a range of 7 to 35,

where 7 indicated no evidence of dependence.

Statistical analyses: All analyses were conducted in R (version 4.1.1). We used available single-wave weights for data from an individual survey and longitudinal weights for data involving multiple waves (such as incidence estimates).¹⁴ Variance estimates for confidence intervals (CIs) were calculated considering both population weights and replicate weights, with the latter constructed from a balanced repeated replications procedure with Fay adjustment ($\rho = 0.3$).¹⁶ Sample characteristics were explored using weighted proportions with 95% confidence limits.

We stratified each cohort by baseline age group (ages 14–17, 18–21, 22–25, 26–29, and 30–34). Within each age group, we calculated the prevalence of ever-use and daily use of any tobacco, cigarettes, and e-cigarettes. Then, for each cohort, we calculated the 2-year incidence of ever-use, among those who were baseline never tobacco users. We also calculated the rate of progression (over 2 years) to daily tobacco use, daily cigarette smoking, and daily

e-cigarette vaping, among baseline nondaily ever tobacco users. We use nonoverlapping 95% CIs to identify significant differences in the above statistics.

RESULTS

Characteristics of the 2014 and 2017 Cohorts

There were no differences between the weighted estimates from the 2 cohorts on sex or race/ethnicity distribution at baseline (Table 1). The 2017 cohort had fewer respondents aged 14 to 17 years (14.9%, 95% CI: 14.6%–15.1%) than the 2014 cohort (18.5%, 95% CI: 18.3%–18.7%), but there were no other age group differences across the cohorts. The 2017 cohort had fewer never tobacco users (34.1% 95% CI: 32.4%–35.8%) than the 2014 cohort (38.9%, 95% CI: 37.3%–40.4%), and correspondingly more ever, but not daily, tobacco users (50.2%, 95% CI: 48.6%–51.9%), than the 2014 cohort (44.5%, 95% CI: 43.2%–45.8%). Approximately 16% in each cohort were current daily tobacco users. We examined e-cigarette use, and none of the 2014 cohort were daily JUUL e-cigarette users in 2016 (survey wave 3).

New Ever-Use of Cigarettes and E-Cigarettes Among Baseline Never-Users

In the 2014 cohort, the proportion of baseline never-users who tried cigarette smoking over the following 2 years was similar for those aged 14 to 17 years and 18 to 21 years, at 10% (Fig 1A). Estimates for older age groups were imprecise (with large confidence limits) but were less than half that of the 14- to 21-year-old age groups. In the 2017 cohort, among those aged 14 to 17 years, the proportion who tried cigarette smoking was 33% lower than the 2014 cohort at 6.7% (95% CI: 6.0%–7.4%) and, for those aged 18 to 21 years, it was 49% lower at 5.3% (95% CI: 4.3%–6.5%).

First use of e-cigarettes was highest among the youngest age group (14–17 years) for each cohort, at 22.0% (95% CI: 20.9%–23.1%) in the 2014 cohort and 24.7% (95% CI: 23.5%–25.9%) in the 2017 cohort, an increase of 12.3% (Fig 1B). Compared with those aged 14 to 17 years, first experimentation with e-cigarettes was much lower among those aged 18 to 21 years at 15.8% (95% CI: 13.4%–18.5%) in

TABLE 1 Baseline Characteristics for the 2014 and 2017 Cohorts in the PATH Study

Variables	Categories	2014 Cohort Baseline			2017 Cohort Baseline		
		Sample (n)	Wtd %	95% CI	Sample (n)	Wtd %	95% CI
Age	14–17	8967	18.5	(18.3–18.7)	5603	14.9	(14.6–15.1)
	18–21	5118	19.3	(18.7–19.9)	6025	19.9	(19.3–20.5)
	22–25	4680	19.8	(19.1–20.6)	3508	20.2	(19.6–20.9)
	26–29	2578	18.4	(17.6–19.3)	2769	20.2	(19.3–21.2)
	30–34	3066	24.0	(23.2–24.8)	2256	24.8	(23.9–25.8)
Sex	Male	12 429	50.5	(50.0–51.1)	10 047	51.0	(50.4–51.6)
	Female	11 980	49.5	(48.9–50.0)	10 114	49.0	(48.4–49.6)
Race/ethnicity	Hispanic	5876	20.5	(19.7–21.4)	5351	21.1	(20.3–22.0)
	Non-Hispanic White	12 820	56.5	(55.5–57.4)	9963	55.4	(54.3–56.5)
	Non-Hispanic Black	3459	13.0	(12.5–13.6)	3025	13.3	(12.7–14.0)
	Non-Hispanic Asian American	764	6.5	(5.8–7.2)	571	6.4	(5.7–7.1)
	Other	1490	3.5	(3.3–3.7)	1251	3.8	(3.5–4.0)
Tobacco use ^a status	Never-user	8952	38.9	(37.3–40.4)	7117	34.1	(32.4–35.8)
	Ever, not current daily ^b	10 793	44.5	(43.2–45.9)	9880	50.2	(48.6–51.9)
	Current daily	4664	16.7	(15.9–17.4)	3164	15.7	(15.0–16.5)

Wtd, weighted.

^a Tobacco use includes cigarettes, e-cigarettes, cigars (traditional, filtered, regular), cigarillos, pipes, hookahs, snus, and smokeless tobacco.

^b Ever not current daily includes former users.

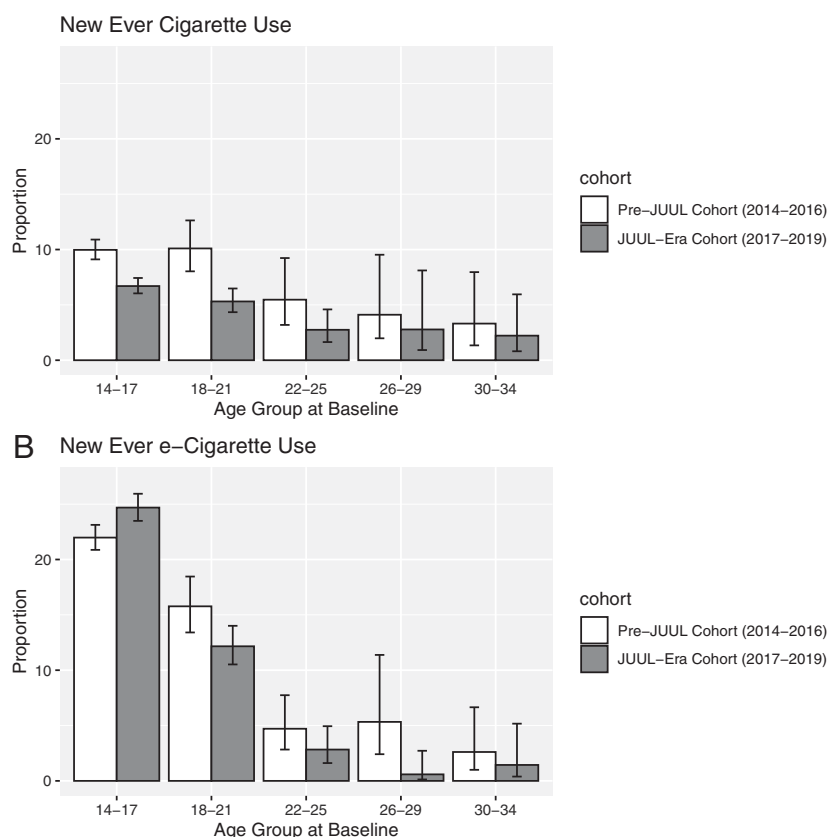


FIGURE 1

New ever-use of cigarettes and e-cigarettes over 2-year follow-up among baseline never-users by JUUL cohorts (2014–2016; 2017–2019). A, cigarette use; B, e-cigarette use. The asterisk marks when estimates from each cohort have nonoverlapping CIs, indicating a significant difference.

the 2014 cohort and even lower still in the 2017 cohort at 12.2% (95% CI: 10.5%–14.0%).

Considering incidence of first experimentation with any tobacco product, there was no between-cohort difference among those aged 14 to 17 years: 2014 = 29.8% (95% CI: 28.5%–31.1%); 2017 = 28.7% (95% CI: 27.5%–30.1%). However, a major decline was noted among those aged 18 to 21 years: 2014 = 27.7% (95% CI: 24.4%–31.3%); 2017 = 19.0% (95% CI: 16.8%–21.4%).

Progression to Daily Tobacco Use Among Nondaily Ever Tobacco Users

Over the 2-year follow-up, 4.9% (95% CI: 4.5%–5.4%) of baseline nondaily tobacco users in the 2014 cohort progressed to daily use,

compared with 5.3% (95% CI: 4.9%–5.8%) in the 2017 cohort, with 64.6% of this increase coming from those aged 14 to 17 years (Table 2). Indeed, only those who were aged 14 to 17 years at baseline had a higher progression to daily use in the 2017 cohort compared with the 2014 cohort (2014 cohort = 4.8%, 95% CI: 4.3%–5.5%; 2017 cohort = 6.3%, 95% CI: 5.8%–7.0%); thus, there were 1 030 957 US adolescents aged 14 to 17 years in 2017 who became new daily tobacco users by 2019. In the 2019 survey, there were 1 667 826 new daily tobacco users who were aged <21 years. Assuming an equal distribution across the year, this translates to 2284 new daily tobacco users each day between 2017 and 2019, which is approximating the estimate of

new established smokers in 1989 to 1993 (Supplemental Information).

New Daily Use of Cigarettes And E-Cigarettes Among Nondaily Users at Baseline

In the 2014 cohort, 2.5% (95% CI: 2.1%–3.0%) of baseline ever-users aged 14 to 17 years progressed to new daily cigarette smoking over the 2-year follow-up, and the progression rate was 3.9% (95% CI: 3.1%–4.8%) for those aged 18 to 29 years (Fig 2A). For the 2017 cohort, progression to daily cigarette smoking was 55% lower than the 2014 cohort for both those aged 14 to 17 years (1.1%, 95% CI: 0.9%–1.5%) and for those aged 18 to 21 years (1.7%, 95% CI: 1.54%–2.2%).

Although there was little progression to daily e-cigarette use in the 2014 cohort (all groups <2%), this progression rate was much higher in the 2017 cohort (Fig 2B). Among those aged 14 to 17 years, the rate was 3.6-fold higher at 4.8% (95% CI: 4.4%–5.2%) and among those aged 18 to 21 years, the progression rate was 3.4 times higher at 4.1% (95% CI: 3.5%–4.8%). Among those aged 22 to 25 years, the progression rate was 2.1% (95% CI: 1.5%–2.7%).

New Daily Tobacco Users in the 2017 Cohort By Product Type

Almost half (48.9%) of all the new daily tobacco users in the 2017 cohort were daily e-cigarette vapers (Table 3), with the distribution skewed to the younger age groups. For those aged 14 to 17 years at baseline, 75.4% of all new daily tobacco users were e-cigarette vapers; for those aged 18 to 21 years at baseline, 64.9% were e-cigarette vapers. Both the e-cigarette dependence score (Cronbach's α = 0.89, SE = 0.23) and the cigarette dependence score (Cronbach's α = 0.86, SE = 0.14) had good internal consistency. Among daily vapers, in

TABLE 2 Progression to Daily Tobacco Use among Nondaily Ever Tobacco Users at Baseline in the 2014 and 2017 PATH Cohorts

Age at Baseline ^a	2014 PATH Cohort				2017 PATH Cohort				Increase in New Daily Tobacco Use in 2017 Cohort	
	Progression from Nondaily to Daily Tobacco Use, 2016				Progression from Nondaily to Daily Tobacco Use, 2019					
	Nondaily Tobacco Users in 2014 (n)	% ^c	95% CI	US Population Estimate (N)	Nondaily Tobacco Users in 2017 (n)	% ^b	95% CI	US Population Estimate (N)		
14–17	7051	4.8	4.3–5.5	775 504	8585	6.3	5.8–7.0	1 030 957	255 453	64.60
18–21	2938	5.8	4.8–6.8	840 154	5587	6.3	5.6–7.1	971 496	131 342	33.20
22–25	2369	5.2	4.4–6.1	721 298	2987	5.3	4.5–6.1	726 049	4751	1.20
26–29	1181	5.6	4.4–7.1	681 767	1878	5.4	4.3–6.8	717 815	36 048	9.10
30–34	1437	3.7	2.9–4.6	617 338	1563	3.5	2.6–4.6	585 341	−31 997	−8.10
Total	14 976	4.9	4.5–5.4	3 636 060	20 600	5.3	4.9–5.8	4 031 657	395 597	100

Tobacco use means any cigarettes, e-cigarettes, cigars (traditional, filtered, regular), cigarillos, pipes, hookahs, snus, and smokeless tobacco.

^a Baseline for pre-JUUL cohort is 2014; baseline for JUUL-era cohort is 2017.

^b Percentage of nondaily tobacco users who progressed to daily use over a 2-year follow-up.

2019, the mean e-cigarette dependence score for those aged 14 to 17 years in 2017 was 17.4 (95% CI:16.5–18.3), with the lower-bound confidence limit more than double the score, indicating no dependence. The mean dependence score in this youngest age group was similar to adult scores in all under age 35 years age groups, and these scores were similar to the dependence scores for those of the same age who became daily smokers (Supplemental Information).

E-Cigarette Brand of Daily Vapers in 2017 Cohort By Tobacco Use Status at Baseline

In 2019, there were >1 million daily vapers among US residents under the age of 21 years. The majority (56.3%, 95% CI: 50.4%–62.0%) used JUUL products, which translates to 600 000 daily JUUL users (Table 4). The proportion of daily e-cigarette vapers using JUUL was lower among those aged 21 to 24 years (42.9%, 95% CI: 36.0%–50.1%) and those who were aged >25 years (22.6%, 95% CI: 17.5%–28.7%). In 2019, daily e-cigarette vapers aged <21 years were 2.5 times more likely to be JUUL users than young adults aged 25-plus years.

DISCUSSION

We identified 2 PATH Study cohorts aged <35 years, before and after the surge in US e-cigarette sales that started in 2017. There were no new daily JUUL e-cigarette vapers in the 2-year follow-up of our comparison group: the 2014 cohort. There were an additional 395 597 new daily tobacco users in the 2-year follow-up of the 2017 cohort compared with the 2014 cohort, two-thirds of whom were in the youngest age group (14–17 years at baseline). Indeed, it was only this youngest age group that had a significant increase in progression to daily tobacco use between the 2 cohorts.

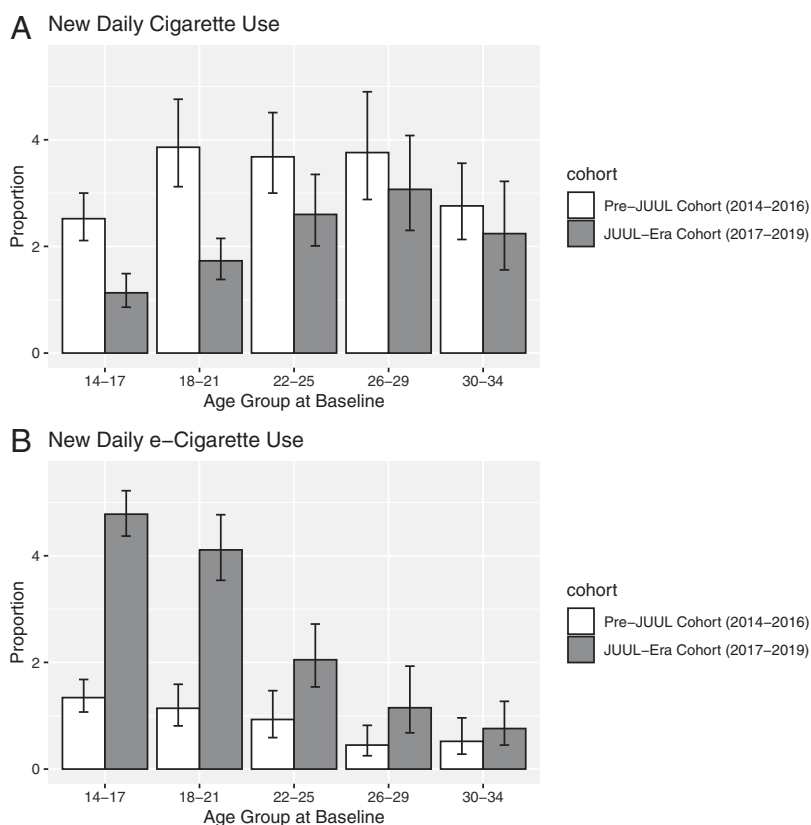


FIGURE 2 New daily use of cigarettes and e-cigarettes over 2-year follow-up among nondaily users at baseline by JUUL cohorts (2014–2016; 2017–2019). A, cigarette use; B, e-cigarette use. The asterisk marks when estimates from each cohort have nonoverlapping confidence intervals, indicating a significant difference.

In the 2 years to 2019, there were 2284 per day, <21-year-old new daily tobacco users, a rate that approaches the levels observed in the 1990s before the 1998 additional restrictions on cigarette advertising and promotions.¹⁷ However, the vast majority of young new daily tobacco users were daily

vapers, a clear difference from the 2014 cohort. In 2019, there were 600 000 daily JUUL vapers aged <21 years.

Previously, adolescent JUUL users have been reported to have some symptoms of nicotine dependence.^{18,19} The PATH Study

used the Wisconsin Inventory of Smoking Dependence Motives framework³ and questioned 7 dependence domains for each tobacco product. We report that <21-year-old, recent daily e-cigarette vapers in 2019 had similar dependence scores to older recent daily vapers. Additionally, they had dependence scores that were similar to those for new daily cigarette smokers.

There are at least 3 major influencers on this substantial increase in daily e-cigarette vaping seen between our 2 cohorts:

1. there was an ongoing innovative social media marketing campaign that was attractive to youth;²⁰
2. the new normal e-cigarettes used nicotine salt technology that made higher nicotine concentration aerosols less aversive, thus allowing users to self-administer larger nicotine doses with each puff;²¹ and
3. experimentation with e-cigarettes typically occurred with products with fruit/candy flavors.²²

Data collection for our study was completed in 2019. In October 2019, JUUL voluntarily suspended sales of all e-cigarette flavors except for menthol and tobacco,²³ just before the Food and Drug Administration's (FDA's) announcement on its

TABLE 3 E-Cigarettes as a Proportion of All New Daily Tobacco Use in the 2017 Cohort

Age Group in 2017	Sample Size <i>n</i>	US Population Estimate <i>N</i>	Progression to New Daily Tobacco Use in 2017 Cohort			2019 E-Cigarette Dependence Score ^a Among New Daily Users		Percentage of New Daily Users Vaping E-Cigarettes
			Any Daily Use %	Daily E-Cigarette Use		Score	95% CI	
				%	95% CI			
14–17	8585	16 252 616	6.3	4.8	4.4–5.2	17.4	16.5–18.3	75.4
18–21	5587	15 350 099	6.3	4.1	3.5–4.8	16.9	15.9–18.8	64.9
22–25	2987	13 800 964	5.3	2.1	1.5–2.7	16.4	14.8–17.9	39.0
26–29	1878	13 232 687	5.4	1.2	0.7–1.9	13.9	11.2–16.2	21.2
30–34	1563	16 876 203	3.5	0.8	0.5–1.3	15.4	11.8–18.9	21.9
Total	20 600	75 512 569	5.3	2.6	2.4–2.8	16.7	16.0–17.3	48.9

^a E-cigarette dependence score derived from 7 items based on Wisconsin Inventory of Smoking Dependence Motives framework³ that assesses craving, tolerance, and loss of control symptoms of dependence. Scores range from 7 to 35, with 7 indicating no dependence.

TABLE 4 Brand of E-Cigarette Used By Daily E-Cigarette Vapers Aged 14–34 Years in 2019: the PATH Study

Age in 2019	Sample Size, No.	US Population Estimate of Daily E-Cigarette Vapers (N)	JUUL Brand		SMOK Brand		Other Brand	
			%	95% CI	%	95% CI	%	95% CI
<21 y	470	1 065 565	56.3	50.4–62.0	17.4	14.3–21.0	25.4	20.7–30.8
21–24 y	276	934 052	42.9	36.0–50.1	26.6	21.6–32.3	28.1	22.3–34.8
≥25 y	295	1 385 665	22.6	17.5–28.7	33.4	27.3–40.1	42.4	36.2–48.8

enforcement policies for unauthorized flavored, cartridge-based e-cigarettes.¹³ However, the FDA's announcement did not include disposable e-cigarettes,²⁴ e-liquids, or refillable devices.²⁵ As a result, there was another major market shift to e-cigarettes that had these flavored options. In 2021, there were an estimated 1.7 million high school vapers, with 85% using flavored products. Over half these vapers used disposable devices and JUUL was no longer the market leader.²⁶

Our data suggest that there may be a new generation of daily tobacco users who did not become dependent on combustible tobacco. Hopefully, they may never switch to cigarette smoking, thus avoiding many of the health consequences, although e-cigarettes themselves are not harmless.²⁷ However, tobacco industry giants have copied the JUUL social media model, going further to invest large sums on social media influencers who can produce their own viral videos that market tobacco.²⁸ Further, there are recent reports that smoking is making a comeback among trendy youth²⁹ and, in 2020, annual cigarette sales increased for the first time in 2 decades.³⁰ All this suggests the possibility that dependent e-cigarette users could switch to cigarette smoking as young adults. Further follow-up of the PATH Study is needed to document whether dependent e-cigarette vaping becomes a stable adult behavior.

We confirmed results from earlier reports of the cross-sectional

National Youth Tobacco Survey,^{26,31} that the follow-up in 2019 showed evidence of a considerable decline in experimentation with e-cigarettes for those aged 18 to 21 years at baseline, possibly linked to concerns relating to the 2019 E-cigarette or Vaping Use-Associated Lung Injury epidemic.³² However, there was no such decline seen among those aged 14 to 17 years in 2017. Compared with the 2014 cohort, the 2 youngest age groups in the 2017 cohort had much lower experimentation rates with cigarettes. However, only the 14- to 17-year-olds increased their experimentation with e-cigarettes.

A strength of this paper is the use of 2 cohorts from the PATH Study that allows nationally representative estimates of tobacco use. We targeted daily tobacco use and demonstrated that this daily e-cigarette use was associated with significant dependence levels. We identified 2 cohorts and validated 1 as occurring before the JUUL-related surge in e-cigarette sales. Each cohort had large samples who were in the age window for initiation of tobacco use.³³ The PATH Study includes state-of-the-art measurement of product use on each survey, as well as a theory-driven, psychometrically validated dependence scale for each product used. It also collects and analyzes biological samples on a large subsample that have been used previously to demonstrate the validity of self-reported smoking behavior,³⁴ as well as the PATH-dependence scales.³⁵ A limitation is that these cohorts were not

contemporaneous but were followed in sequential time periods, thus, we were unable to rule out the influence of other time-based variables. Additionally, other unmeasured confounders could have influenced the population estimates.

CONCLUSIONS

The surge in sales of JUUL e-cigarette from 2017 to 2019 was accompanied by increased daily e-cigarette use that was most marked among adolescents aged 14 to 17 years at baseline. Members of this youngest age group who became daily e-cigarette users had dependence scores that were not different to older adults nor different from adult daily cigarette smokers. This recent upswing in tobacco use in the young has resulted in initiation levels that are somewhat similar to those seen in the early 1990s, before the introduction of many effective tobacco control measures. In 2019, an estimated 600 000 Americans aged <21 years used high-nicotine JUUL products daily and these would now be below the legal age to purchase tobacco in the United States.³⁶ The FDA has responded to this e-cigarette epidemic by reducing the availability of flavored additives to e-cigarettes, presumably focused on reducing experimentation. It has not limited the amount of nicotine allowed in e-cigarettes, as other countries have done.³⁷ The large increase in daily use among US adolescents could presage future health consequences and needs urgent additional action from the regulatory body.

ABBREVIATIONS

CI: confidence interval

FDA: Food and Drug Administration

PATH: Population Assessment of Tobacco and Health

FUNDING: Supported by the National Institutes of Health (grant R01CA234539) and by the Tobacco-Related Disease Research Program of the University of California, Office of the President (grants 28IR-0066, T31IR-1584, T30IP-0965). The funding sources did not have any role in the design, analysis, or presentation of this secondary data analysis of public use data. Funded by the National Institutes of Health (NIH).

CONFLICT OF INTEREST DISCLOSURES: The authors have indicated that there are no potential conflicts of interest to disclose.

REFERENCES

1. Pierce JP, Sargent JD, White MM, et al. Receptivity to tobacco advertising and susceptibility to tobacco products. *Pediatrics*. 2017;139(6):e20163353
2. Arrazola RA, Singh T, Corey CG, et al. Centers for Disease Control and Prevention. Tobacco use among middle and high school students – United States, 2011–2014. *MMWR Morb Mortal Wkly Rep*. 2015;64(14):381–385
3. Smith SS, Piper ME, Bolt DM, et al. Development of the Brief Wisconsin Inventory of Smoking Dependence Motives. *Nicotine Tob Res*. 2010;12(5):489–499
4. Owotomo O, Stritzel H, McCabe SE, Boyd CJ, Maslowsky J. Smoking intention and progression from e-cigarette use to cigarette smoking. *Pediatrics*. 2020;146(6):e2020002881
5. Pierce JP, Chen R, Leas EC, et al. Use of e-cigarettes and other tobacco products and progression to daily cigarette smoking. *Pediatrics*. 2021;147(2):e2020025122
6. Jackler RK, Ramamurthi D. Nicotine arms race: JUUL and the high-nicotine product market. *Tob Control*. 2019;28(6):623–628
7. Leventhal AM, Madden DR, Peraza N, et al. Effect of exposure to e-cigarettes with salt versus free-base nicotine on the appeal and sensory experience of vaping: a randomized clinical trial. *JAMA Netw Open*. 2021;4(1):e2032757
8. Romberg AR, Miller Lo EJ, Cuccia AF, et al. Patterns of nicotine concentrations in electronic cigarettes sold in the United States, 2013–2018. *Drug Alcohol Depend*. 2019;203:1–7
9. King BA, Gammon DG, Marynak KL, Rogers T. Electronic cigarette sales in the United States, 2013–2017. *JAMA*. 2018;320(13):1379–1380
10. Cullen KA, Ambrose BK, Gentzke AS, Appelberg BJ, Jamal A, King BA. Notes from the field: use of electronic cigarettes and any tobacco product among middle and high school students – United States, 2011–2018. *MMWR Morb Mortal Wkly Rep*. 2018;67(45):1276–1277
11. Miech R, Johnston L, O'Malley PM, Bachman JG, Patrick ME. Trends in adolescent vaping, 2017–2019. *N Engl J Med*. 2019;381(15):1490–1491
12. Creamer MR, Dutra LM, Sharapova SR, et al. Effects of e-cigarette use on cigarette smoking among US youth, 2004–2018. *Prev Med*. 2021;142:106316
13. U.S. Food & Drug Administration. FDA finalizes enforcement policy on unauthorized flavored cartridge-based e-cigarettes that appeal to children, including fruit and mint. Available at: <https://www.fda.gov/news-events/press-announcements/fda-finalizes-enforcement-policy-unauthorized-flavored-cartridge-based-e-cigarettes-appeal-children>. Accessed November 2, 2021
14. US Department of Health and Human Services; National Institutes of Health; National Institute on Drug Abuse; US Department of Health and Human Services; Food and Drug Administration; Center for Tobacco Products. Population Assessment of Tobacco and Health (PATH) Study [United States] restricted-use files. Available at: 10.3886/ICPSR36231.v18 Accessed November 1, 2021
15. National Addiction & HIV Data Archive Program. Population Assessment of Tobacco and Health (PATH) Study [United States] restricted-use files (ICPSR 36231). Available at: <https://www.icpsr.umich.edu/icpsrweb/NAHDAP/studies/36231>. Accessed October, 2021
16. Hyland A, Ambrose BK, Conway KP, et al. Design and methods of the Population Assessment of Tobacco and Health (PATH) Study. *Tob Control*. 2017;26(4):371–378
17. Pierce JP, Gilpin EA. How did the master settlement agreement change tobacco industry expenditures for cigarette advertising and promotions? *Health Promot Pract*. 2004;5(3 Suppl):84S–90S
18. Kechter A, Cho J, Miech RA, Barrington-Trimis JL, Leventhal AM. Nicotine dependence symptoms in US youth who use JUUL E-cigarettes. *Drug Alcohol Depend*. 2021;227:108941
19. Tackett AP, Hébert ET, Smith CE, et al. Youth use of e-cigarettes: does dependence vary by device type? *Addict Behav*. 2021;119:106918
20. Huang J, Duan Z, Kwok J, et al. Vaping versus JUULing: how the extraordinary growth and marketing of JUUL transformed the US retail e-cigarette market. *Tob Control*. 2019;28(2):146–151
21. Prochaska JJ, Vogel EA, Benowitz N. Nicotine delivery and cigarette equivalents from nt vaping a JUULpod [Published

- online ahead of print March 24, 2021]. *Tob Control*. doi: 10.1136/tobacco-control-2020-056367
22. Leventhal AM, Goldenson NI, Cho J, et al. Flavored e-cigarette use and progression of vaping in adolescents. *Pediatrics*. 2019;144(5):e20190789
23. Labs JUUL. Discontinued JUULpods flavors. Available at: <https://www.juul.com/discontinued-flavors>. Accessed January 26 2022
24. Kaplan S. Juul suspends online sales of flavored e-cigarettes. *New York Times*. Available at: <https://www.nytimes.com/2019/10/17/health/vaping-juul-e-cigarettes.html>. Accessed October 28, 2021
25. Campaign for Tobacco Free Kids. E-cigarettes: flavored products fuel a youth epidemic. Available at: <https://www.tobaccofreekids.org/what-we-do/industry-watch/e-cigarettes>. Accessed January 26, 2022
26. Park-Lee E, Ren C, Sawdey MD, et al. 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*. 2021;70(39):1387–1389
27. Eltorai AE, Choi AR, Eltorai AS. Impact of electronic cigarettes on various organ systems. *Respir Care*. 2019;64(3):328–336
28. Rob Davies and Matthew Chapman. Tobacco giant bets £1bn on influencers to boost 'more lung-friendly' sales. The Guardian. Available at: <https://www.theguardian.com/business/2021/feb/20/tobacco-giant-bets-1bn-on-social-media-influencers-to-boost-lung-friendlier-sales>. Accessed January 26, 2022
29. Ortved J. That cloud of smoke is not a mirage. Cigarettes, once shunned, have made a comeback with a younger crowd who knows better. The New York Times. Available at: <https://www.nytimes.com/2022/01/12/style/smoking-cigarettes-comeback.html>. Accessed January 26, 2022
30. Federal Trade Commission. FTC report finds annual cigarette sales increased for the first time in 20 years. Available at: <https://www.ftc.gov/news-events/press-releases/2021/10/ftc-report-finds-annual-cigarette-sales-increased-first-time-20>. Accessed January 26, 2022
31. Wang TW, Gentzke AS, Neff LJ, et al. Characteristics of e-cigarette use behaviors among us youth, 2020. *JAMA Netw Open*. 2021;4(6):e2111336
32. Wiens T, Taylor J, Cole C, et al. Lessons learned from the e-cigarette, or vaping, product use-associated lung injury (EVALI) outbreak response, Minnesota, 2019–2020 [Published online ahead of print October 25, 2021]. *Public Health Rep*. doi: 10.1177/00333549211051394
33. US Department of Health and Human Services. *The Health Consequences of Smoking-50 Years of Progress: A Report of the Surgeon General*. Atlanta, GA: 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; 2014
34. Rostron BL, Corey CG, Chang JT, van Bommel DM, Miller ME, Chang CM. Associations of cigarettes smoked per day with biomarkers of exposure among U.S. adult cigarette smokers in the population assessment of tobacco and health (PATH) study wave 1 (2013–2014). *Cancer Epidemiol Biomarkers Prev*. 2019;28(9):1443–1453
35. Strong DR, Leas E, Noble M, et al. Predictive validity of the adult tobacco dependence index: findings from waves 1 and 2 of the population assessment of tobacco and health (PATH) study. *Drug Alcohol Depend*. 2020;214:108134
36. US Food & Drug Administration. Tobacco 21. Available at: <https://www.fda.gov/tobacco-products/retail-sales-tobacco-products/tobacco-21>. Accessed November 2, 2021
37. GOV.UK. E-cigarettes: regulations for consumer products. Available at: <https://www.gov.uk/guidance/e-cigarettes-regulations-for-consumer-products>. Accessed November 4, 2021