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Declines in cigarette smoking among US adolescents and young adults: indications of independence from e-cigarette vaping surge

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ABSTRACT

Objective To compare trends in cigarette smoking and nicotine vaping among US population aged 17–18 years and 18–24 years.

Methods Regression analyses identified trends in ever and current use of cigarettes and e-cigarettes, using three US representative surveys from 1992 to 2022.

Results From 1997 to 2020, cigarette smoking prevalence among those aged 18–24 years decreased from 29.1% (95% CI 27.4% to 30.7%) to 5.4% (95% CI 3.9% to 6.9%). The decline was highly correlated with a decline in past 30-day smoking among those aged 17–18 years (1997: 36.8% (95% CI 35.6% to 37.9%; 2022: 3.0% (95% CI 1.8% to 4.1%). From 2017 to 2019, both ever-vaping and past 30-day nicotine vaping (11.0% to 25.5%) surged among those 17–18 years, however there was no increase among those aged 18–24 years. Regression models demonstrated that the surge in vaping was independent of the decline in cigarette smoking. In the 24 most populous US states, exclusive vaping did increase among those aged 18–24 years, from 1.7% to 4.0% to equivalent to 40% of the decline in cigarette smoking between 2014–15 and 2018–19. Across these US states, the correlation between the changes in vaping and smoking prevalence was low (r=0.11). In the two US states with >US$1/fluid mL tax on e-cigarettes in 2017, cigarette smoking declined faster than the US average.

Conclusions Since 1997, a large decline in cigarette smoking occurred in the US population under age 24 years, that was independent of the 2017–19 adolescent surge in past 30-day e-cigarette vaping. Further research is needed to assess whether the 2014–15 to 2018–19 increase in exclusive vaping in those aged 18–24 years is a cohort effect from earlier dependence on e-cigarette vaping as adolescents.

WHAT IS ALREADY KNOWN ON THIS TOPIC

⇒ Nicotine use in children and adolescents is addictive and harmful. Adolescent cigarette smoking declined in the USA, following interventions funded by legal settlements between US states and the tobacco industry; however, since 2017 e-cigarette vaping has surged among US teens.

WHAT THIS STUDY ADDS

⇒ Between 1997 and 2020, cigarette smoking in US young adults aged 18–24 years declined continuously from 29.1% to 5.4%, closely tracking cigarette smoking among adolescents aged 17–18 years.The surge in e-cigarette vaping occurred only among adolescents, and was independent of smoking trends.Recently, exclusive vaping has increased in young adults.

HOW THIS STUDY MIGHT AFFECT RESEARCH, PRACTICE OR POLICY

⇒ The recent surge in teen vaping was faster, larger and independent of the long-standing decline in cigarette smoking.Without additional intervention, a cohort effect from adolescent vaping will potentially increase nicotine use, including exclusive e-cigarette vaping, among young adults.

INTRODUCTION

Cigarette smoking has been the predominant nicotine delivery system in the USA for over a century,[1] but, among adolescents, it has recently been replaced by e-cigarette vaping.[2] Tobacco use usually begins between the ages of 12 and 24 years,[3] with most people starting between ages 14 and 17 years.[1] After the 1998 Master Settlement Agreement (MSA), a legal settlement to resolve lawsuits filed by US State Attorneys General against the tobacco industry,[4] there was a long-term decline in adolescent cigarette smoking.[1] The MSA resulted in nationwide implementation of three of the six MPOWER tobacco control strategies recommended by WHO to reduce smoking[5]: to warn the population about harms of cigarette smoking, to propose and enforce new advertising restrictions and to raise cigarette prices.[6] The implementation of advertising restrictions had an immediate effect in reducing adolescent receptivity to tobacco advertising, a validated predictor of initiation.[7]

E-cigarettes were introduced in the USA in 2007.[8] From 2013 to 2015, past 30-day e-cigarette vaping increased threefold in national surveys of high school students.[9] Some adolescents who started vaping subsequently switched to cigarette smoking.[10–12] More recently, e-cigarette vaping surged with the introduction of a new generation of high-nicotine e-cigarettes[13] that used fruit and candy flavourings,[14–16] and many adolescents have become dependent on daily vaping.[17 18] From August 2019 until February 2020, there was

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widespread news coverage of Centers for Disease Control and Prevention-reported outbreak of E-cigarette and Vaping Associated Lung Injury (EVALI) and this was associated with changed risk perceptions of e-cigarette vaping in youth and young adults,[19 20] which should be associated with reduced initiation.[21]

Lifelong cigarette smoking harms nearly every organ of the body and reduces life expectancy by ~10 years,[22–24] although there is a long latency period.[25] There are well-established biomarkers for disease from cigarette smoking[26] and a developing list of biomarkers for potential disease from e-cigarettes,[27–29] although none reach the criteria needed to be markers of clinical disease onset,[30] nor considered adequate to be included in screening modalities for lung cancer.[31] Despite this uncertainty, some have used such biomarkers to predict future disease risk, suggesting that e-cigarettes are much safer than cigarettes.[32] This idea has gained some acceptance in the context of adult cigarette smokers who switch from smoking cigarettes to e-cigarette vaping.[8] Recently, Sun *et al*[33] argued that this concept should be extended to adolescent tobacco use, suggesting that, for health policy purposes, the high prevalence of adolescent e-cigarette vaping should be discounted by the presumed lower risk of health consequences compared with cigarette smoking. However, leading public health organisations, noting harm to children and adolescents from nicotine inhalation, have maintained their goal to reduce all types of tobacco use, including e-cigarettes.[34 35]

Adolescents who start vaping e-cigarettes have a similar substance use risk profile as those who start smoking cigarettes, including sensation-seeking and hopelessness,[36] as well as internalising and externalising mental health problem behaviours.[37] Well-known sociodemographic differences in cigarette smoking prevalence across subgroups of age, sex, education and race-ethnicity[38] have been replicated for e-cigarette vaping.[39] Early evidence suggests that there may have been a shift in social norms among adolescents, with cigarettes now being associated with risk and negative affect, while e-cigarettes are not.[40] Some have suggested that adolescents have an equivalent choice between cigarettes and e-cigarettes and that the rise in e-cigarette vaping is associated with a more rapid decline in cigarette smoking[41 42] and further, that preliminary evidence suggests that disincentivising e-cigarettes (eg, with taxes) would encourage youth cigarette smoking.[43]

In this paper, we use three large nationally representative surveys of US residents aged 17–24 years with serial cross-sectional prevalence estimates for cigarettes from 1992 and for e-cigarette vaping from 2014. We assess the strength of associations between rising prevalence of nicotine vaping and falling prevalence of cigarette smoking. For young adults, we investigate state-level changes in prevalence of cigarette smoking and exclusive vaping (defined as of e-cigarette vaping without cigarette smoking) from 2014–15 to 2018–19. To investigate whether taxing e-cigarettes encourages young adult cigarette smoking, we report case studies from two states identified as taxing e-cigarettes at >US$1/fluid mL in 2017,[43] a meaningful level that may encourage behaviour change,[44] and report changes in prevalence of cigarette smoking and exclusive vaping among those aged 18–24 years. Finally, we report changes in the sociodemographic patterns of cigarette smoking and exclusive vaping in this young adult population.

METHODS

Data sources

We describe the three surveys in detail in online supplemental 1 and provide a brief summary below.

Tobacco Use Supplements to the Current Population Survey (TUS-CPS)[45]: the CPS is a US labour force survey of ~54 000 households/month. Since 1992, the National Cancer Institute has coordinated supplements for independent survey months with 3 monthly samples over a 12-month period, approximately every 3 years. Response rates have varied between 62% and 75%. We limited the sample to self-respondents aged 18–24 years to tobacco use questions. For state-specific data, we limit our analyses to the 24 states with populations >5 million on the 2020 US Census to narrow the confidence limits (CLs). These states contained 82% of the estimated total US population in 2020–22.[46]

National Health Interview Survey (NHIS)[47] is the US annual illness and disability survey of ~35 000 households/year. Cigarette smoking prevalence questions started in 1965, became only self-reported in 1974 and have been part of the annual core questions since 1997. Response rates are ~70%.

Monitoring the Future High School Seniors Surveillance system (MTF-HSS)[16] has conducted annual in-school surveys (since 1975) of national samples of ~16 000 final-year high school students (usually aged 17–18 years) on drug use. Response rates average ~84%. COVID-19 disrupted in-school data collection in 2020, but a sensitivity analysis of previous years supported use of the available data from the first part of that year.[48] We report data from 1991 to 2022.

Cigarette smoking prevalence questions: both TUS-CPS and NHIS asked respondents if they had smoked 100 cigarettes in their lifetime and, if yes, whether they now smoked every day, some days or not at all. MTF-HSS asked both lifetime ever smoking and past 30-day smoking on each survey.

E-cigarette vaping prevalence questions: we report MTF-HSS and TUS-CPS data. While MTF-HSS began asking lifetime ever use and past 30-day vaping in 2014, they divided this category in 2017 (and later surveys) when they asked the same questions for nicotine vaping and we report this variable. In both 2014–15 and 2018–19, TUS-CPS asked "Have you ever used e-cigarettes, even one time?" and "Do you now use e-cigarettes every day, some days or not at all?" We report both ever e-cigarette vaping and exclusive e-cigarette vaping (vaping without cigarette smoking).

Analysis

Weighted estimates with 95% CIs were calculated[49 50] and assessed for statistical significance at a two-sided 5% level. Non-overlapping CLs were used to identify statistically significant differences within and across states between independent surveys at the 0.05 level, a conservative approach. Analyses were conducted using R v.4.1.2,[51] with simple calculations done in Excel. Prevalence estimates for those aged 18–24 years were compared between NHIS and TUS-CPS using correlations paired by survey year, where data were available for both surveys. We analysed time trends for current smoking (NHIS) among those aged 18–24 years, using linear first-degree regression splines with knots at key time points ~5 years apart: 1997 (prior to MSA), 2002, 2008 (prior to Tobacco Control Act), 2013 (early e-cigarette increases). We used a similar model for ever smoking among those aged 17–18 years and past 30-day smoking (MTF-HSS) among those aged 17–18 years, with an additional knot for the 2017 (e-cigarette surge) and we included the e-cigarette

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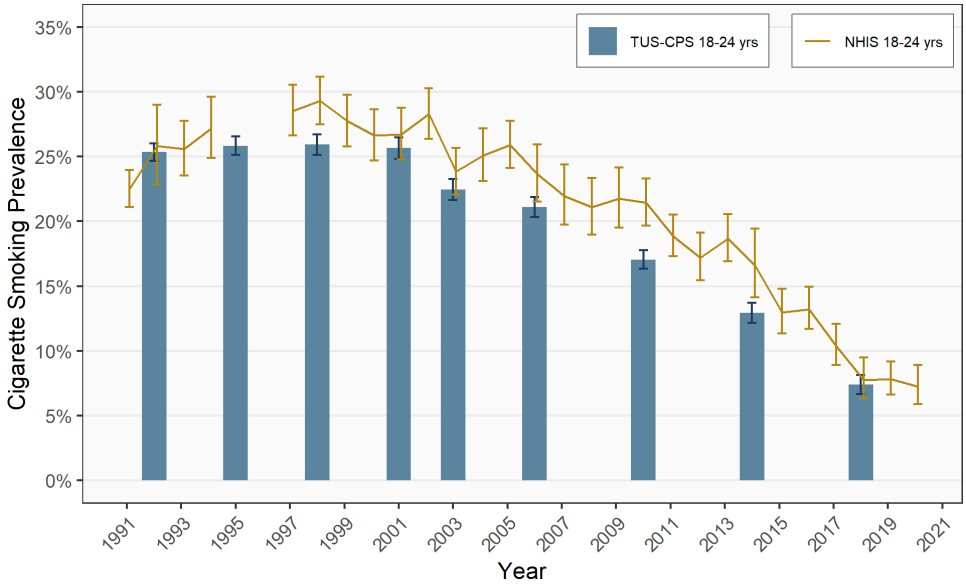

Figure 1 Estimates of current cigarette smoking prevalence among the US population aged 18–24 years from 1991 to 2020 surveys. NHIS, National Health Interview Survey; TUS-CPS, Tobacco Use Supplements to the Current Population Survey. In July 1997, the first state entered into a Settlement Agreement with the tobacco industry that led to a number of tobacco control interventions.

prevalence estimates as predictors in this model. We report the goodness of fit for these models. To describe trends in e-cigarette ever vaping and past 30-day vaping, we used a similar model for the 2017–2022 data with a knot at 2020 (when reporting on EVALI outbreak ended).

We use the TUS-CPS to investigate the sociodemographic characteristics of current smoking and exclusive vaping among those aged 18–24 years, and calculate adjusted ORs for different sociodemographic subgroups in both 2014–15 and 2018–19. We use the ratio of ORs between years to assess whether the odds of smoking across sociodemographic subgroups changed over time, with CIs computed using the delta method.[52]

To investigate if e-cigarette vaping is replacing cigarette smoking as the predominant nicotine delivery system in those aged 18–24 years, we analysed state estimates from the 2014–15 and 2018–19 TUS-CPS for the 24 most populous US states. We report changes in prevalence of cigarette smoking and of exclusive vaping, and combined prevalence of cigarette and/or e-cigarette use. We report the replacement ratio (RepR), which we define as (the percentage point change in prevalence of exclusive vaping)/(percentage point change in cigarette smoking prevalence).

RESULTS

Trends in young adult cigarette smoking prevalence, 1991–2020 and ever vaping between 2014–15 and 2018–19

The TUS-CPS and NHIS data show highly correlated (r=0.987) prevalence of current smoking among those aged 18–24 years (figure 1). Time trends from 1991 to 2020 were estimated using NHIS data, modelled by first-degree regression splines with knots at 1997, 2002, 2008 and 2013 (R^2=0.97). Prevalence increased from 1991 to 1997 and then declined at −1.37 percentage points per year (pp/y) up to 2020. There was no significant change in slope in either 2002 (p=0.5), 2008 (p=0.55) or 2013 (p=0.12) (online supplemental eTable 1). In the TUS-CPS data, between 2014–15 and 2018–19, the proportion of US young adults aged 18–24 years who had ever vaped an e-cigarette did not change (online supplemental eTable 2).

Trends in US population aged 17–18 years regarding prevalence of ever use and past 30-day use, for cigarette smoking and for nicotine vaping, 1991–2020

Using MTF-HSS data and a similar regression spline model as above (R^2=0.99), we observed an increase in ever smoking among those aged 17–18 years through 1997 (figure 2). Subsequently, prevalence declined by −2.4 pp/y, with no significant change in slope in 2002 (p=0.14) or 2008 (p=0.06) (online supplemental eTable 1). However, between 2013 and 2017, the decline in ever smoking accelerated by an additional −1.19 pp/y to −3.59 pp/y (p=0.02). From 2017 to 2022, ever nicotine vaping was added to the model, but this was not associated with any additional change in the decline in ever smoking over this period (p=0.33).

A similar regression spline model of past 30-day smoking (R^2=0.99) also showed an increase from 1991 to 1997. Subsequently, prevalence declined by −3.63 pp/y (p<0.0001) until 2002 after which the rate of decline slowed to −2.67 pp/y (p=0.002). The slope of this decline did not change in 2008 (p=0.96), 2013 (p=0.28) or when past 30-day nicotine vaping was added to the model from 2017 (p=0.95). Between 1997 and 2017, prior to the e-cigarette vaping surge, 30-day cigarette smoking prevalence had already declined to around a quarter of the 1997 level and this rate of change continued through 2022, when only 3.0% (95% CI 1.8% to 4.1%) were past 30-day smokers. From 2002, past 30-day prevalence among those aged 17–18 years using the MTF-HSS data was very highly correlated with current cigarette smoking levels among those aged 18–24 years using the NHIS data (r=0.997) (figure 2), suggesting that there was no late initiation of cigarettes in the young adult years.

A regression spline model of ever nicotine vaping prevalence from 2017 to 2020, with a knot at 2020 (R^2=0.88), showed a rapid increase from 2017 to 2020, at a rate of 6.1 pp/y (p=0.009). In 2020, this slope reversed and started to decline at −9.75 pp/y (p=0.02). The 2022 prevalence of 37.5% (95% CI 30.8% to 44.3%) suggests that this sudden decline may have lasted only 1 year. The regression spline model of past 30-day vaping among those aged 17–18 years was not a good representation of the

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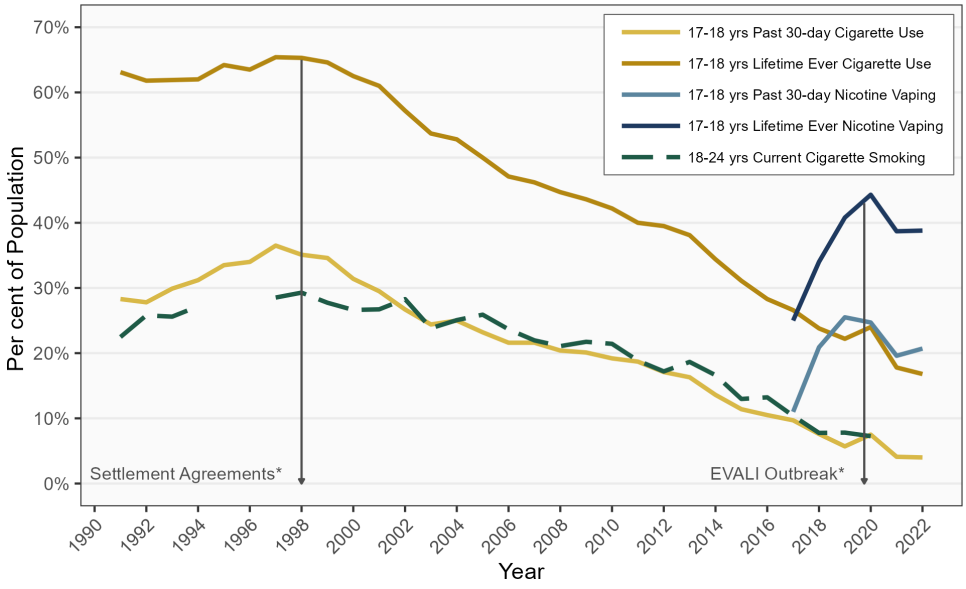

Figure 2 Lifetime ever use and past 30-day use of cigarettes and nicotine vaping among US finalyear high school students from 1991 to 2022 surveys. From figure 1, current smoking prevalence among those aged 18–24 years has been added for comparison purposes. *Settlement Agreements. In July 1997, the first state entered into a Settlement Agreement with the tobacco industry that led to tobacco control interventions; other states quickly followed. †The E-cigarette and Vaping Associated Lung Injury (EVALI) outbreak was first reported in August 2019 and Centers for Disease Control and Prevention stopped reporting on it in February 2020. Source: Monitoring the Future 2022 historical data. Lifetime use and past 30-day use were asked for cigarette smoking throughout the period. Measurement of nicotine vaping started in 2017.

data (R^2=0.47). Between 2017 and 2019, the observed prevalence increased from 11.0% to 25.5%, at an 4.1 pp/y, but then declined to 19.6% in 2021, and was 20.7% in 2022 (figure 2).

Sociodemographic patterns of cigarette smoking among US population aged 18–24 years in 2001–02 and 2018–19

Between 2001–12 and 2018–19, TUS-CPS prevalence of cigarette smoking among those aged 18–24 years declined by 25.9 pp (95% CL 25.2 pp to 26.6 pp) (table 1). In 2001–02, those aged 22–24 years had a higher prevalence than those aged 18–21 years, those who did not attend college had a higher prevalence than those who did, females had a lower prevalence than males, non-Hispanic whites (NHW) had a higher prevalence than non-Hispanic blacks (NHB), Hispanics and Asian/Pacific Islanders. Large declines were observed across all age, sex, education and race-ethnicity subgroups, which increased relative differences between most subgroups, including age, sex, education and between NHW and Asian/Pacific Islanders. The larger decline in NHW reduced the relative difference significantly between NHW and both NHB and Hispanics (table 1).

Sociodemographic patterns of exclusive vaping among US population aged 18–24 years in 2014–15 and 2018–19

Between 2014–15 and 2018–19, exclusive vaping prevalence more than doubled (table 2). Prevalence was higher among those aged 18–21 years than those aged 22–24 years—a gap that increased over time. While prevalence was higher in those with no college education, this did not reach statistical significance in either year. Females had a lower prevalence than males, although the gap declined between survey years. Compared with NHW, there was a much lower prevalence for NHB, Hispanics and Asian/Pacific Islanders, and differences between NHW and Hispanics increased between the two survey years. Similar distributional patterns were observed for exclusive vaping and cigarette smoking (table 1 vs table 2) for sex and race-ethnicities; however, the pattern for age was reversed for exclusive vaping with higher prevalence in those aged 18–21 years than those aged 22–24 years. Notably, although e-cigarette prevalence appeared higher in those who did not attend college, the strong educational difference seen in cigarette smoking was absent in exclusive vaping prevalence.

State-specific prevalence of cigarette and e-cigarette use among those aged 18–24 years

Figure 3 presents the TUS-CPS prevalence of cigarette smoking (blue) and exclusive vaping (gold) for each of the 24 most populous US states (representing 82% of the US population). Stacked bars with CLs on the combined bar height indicate the prevalence of cigarette and/or e-cigarette use (data in online supplemental eTable 3). Comparing 2014–15 with 2018–19, current cigarette smoking prevalence declined across the 24 most populous states, with considerable heterogeneity: the average decline was 5.6 pp (range +1.6 to −12.8 pp) (online supplemental eTable 4). During this same period, current exclusive vaping increased, on average, by 2.3 pp (range –2.4 pp to +8.7 pp) from 1.7% to 4.0%. There was not a high correlation across states between changes in vaping and changes in smoking (r=0.11) as would be expected if one was a simple replacement of the other. The average RepR across states was 0.4 (range −0.96, 2.71), indicating that only 40% of the drop in cigarette smoking prevalence was ‘replaced’ by the increase in nicotine vaping prevalence (online supplemental eTable 3).

Panel A of figure 3 shows the eight states with significant declines in smoking prevalence from 2014–15 to 2018–19 ordered by 2014–15 prevalence. These states had high cigarette smoking prevalence in 2014–15 (average 16.2%) and substantial and significant declines by 2018–19 (average −10.1 pp, range −6.3 pp, −12.8 pp) (online supplemental eTable 3). In contrast, panel B shows eight states with a similar high 2014–15 prevalence (average 16.1%) but their declines (average −7.2 pp,

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Table 1 Logistic regression models of current cigarette smoking among US population aged 18–24 years, by sociodemographic variables, 2001–02 and 2018–19

	Prevalence of current cigarette smoking								Ratio of adjusted ORs (ROR=AOR 2018–19/AOR 2001–02)	
	2001–02				2018–19					
			Cigarette smoking				Cigarette smoking			
Sociodemographic variables	Sample N	Pop %	%	95% CL	Sample N	Pop %	%	95% CL	ROR	95% CL
Overall	16 707		**25.9**	25.2 to 26.6	7637		**7.4**	6.8 to 8.0		
Age (years)										
18–21	8803	54.6	**24.0**	23.2 to 24.7	3435	52.8	**5.7**	5.1 to 6.3		
22–24	7904	45.4	**27.7**	26.8 to 28.5	4202	47.2	**9.3**	8.6 to 10.0		
AOR			**1.42**	1.33 to 1.50			**2.24**	1.94 to 2.58	1.58	1.35 to 1.84
Education										
College	7610	44.5	**23.4**	22.7 to 24.1	4113	50.6	**6.1**	5.5 to 6.7		
No college	9097	55.5	**28.0**	27.1 to 28.9	3524	49.4	**8.7**	8.0 to 9.5		
AOR			**2.27**	2.12 to 2.44			**2.96**	2.54 to 3.46	1.30	1.10 to 1.55
Sex										
Male	7521	49.1	**30.6**	29.8 to 31.4	3316	45.4	**10.6**	9.8 to 11.4		
Female	9186	50.9	**19.5**	18.8 to 20.3	4321	54.6	**4.8**	4.2 to 5.3		
AOR			**0.83**	0.78 to 0.88			**0.71**	0.61 to 0.82	0.86	0.73 to 1.00
Race-Ethnicity										
NHW	11 583	65.6	**30.8**	30.1 to 31.5	4554	52.8	**9.1**	8.4 to 9.8		
NHB	1791	13.6	**16.8**	15.6 to 18.1	865	13.5	**7.3**	6.1 to 8.7		
Other/Multiple races	308	0.8	**38.0**	32.7 to 43.6	280	3.5	**11.0**	8.7 to 14.0		
A/PI	704	3.5	**17.4**	15.2 to 19.8	426	6.7	**2.4**	1.4 to 4.0		
Hispanic	2321	16.5	**13.6**	12.6 to 14.7	1512	23.4	**4.5**	3.8 to 5.3		
AOR										
NHB			**0.40**	0.36 to 0.44			**0.72**	0.58 to 0.89	1.80	1.42 to 2.28
Hispanic			**0.29**	0.26 to 0.32			**0.42**	0.35 to 0.50	1.45	1.18 to 1.78
A/PI			**0.55**	0.46 to 0.66			**0.30**	0.18 to 0.49	0.55	0.32 to 0.93

Source: tobacco use supplement to the current population survey (https://cancercontrol.cancer.gov/brp/tcrb/tus-cps/questionnaires-data).
*NHW reference group.
AOR, adjusted OR; A/PI, Asian/Pacific Islanders; CL, confidence limits; NHB, non-Hispanic black; NHW, non-Hispanic white; Pop, population of the USA aged 18–24 years; ROR, ratio of OR.

Table 2 Logistic regression models of changes in US population aged 18–24 years in current prevalence of exclusive vaping, by sociodemographic variables before and after the 2017 e-cigarette vaping surge: TUS-CPS 2014–15 and 2018–19

	Prevalence of current exclusive e-cigarette vaping				Ratio of AOR (ROR=AOR 2018–19/AOR 2014–15)	
	2014–15		2018–19			
Sociodemographic variables	%	95% CL	%	95% CL	% ROR	95% CL*
Overall	1.56	1.38 to 2.00	3.96	3.62 to 4.00		
Age (years)						
18–21	1.67	1.43 to 1.96	4.94	4.42 to 5.51		
22–24	1.43	1.21 to 1.70	2.87	2.49 to 3.29		
AOR	0.88	0.70 to 1.11	0.57	0.47 to 0.69	0.65	0.48 to 0.87
Education						
College	1.38	1.17 to 1.62	3.51	3.12 to 3.95		
No college	1.77	1.49 to 2.09	4.50	3.99 to 5.08		
AOR	1.23	0.98 to 1.55	1.15	0.96 to 1.38	0.93	0.70 to 1.25
Sex						
Male	2.24	1.96 to 2.57	4.98	4.44 to 5.58		
Female	0.89	0.72 to 1.09	2.97	2.60 to 3.38		
AOR	0.40	0.32 to 0.50	0.58	0.49 to 0.70	1.45	1.09 to 1.93
Race-Ethnicity						
NHW	1.96	1.69 to 2.27	5.58	5.05 to 6.16		
NHB	0.61	0.37 to 1.01	1.18	0.74 to 1.86		
Other/Multiple races	2.31	1.49 to 3.55	4.89	3.16 to 7.50		
A/PI	0.34	0.12 to 1.00	1.58	1.02 to 2.43		
Hisp	1.42	1.08 to 1.86	2.47	1.97 to 3.08		
NHW versus NHB AOR	0.31	0.18 to 0.52	0.20	0.12 to 0.32	0.65	0.31 to 1.33
NHW versus Hisp AOR	0.69	0.50 to 0.95	0.41	0.32 to 0.53	0.59	0.40 to 0.89
NHW versus A/PI AOR	0.18	0.06 to 0.54	0.27	0.17 to 0.42	1.50	0.46 to 4.92

Source: tobacco use supplement to the current population survey.
*Calculated by delta method.
AOR, adjusted OR; A/PI, Asian/Pacific Islanders; CL, confidence limits; Hisp, Hispanic; NHB, non-Hispanic black; NHW, non-Hispanic white; ROR, ratio of OR; TUS-CPS, Tobacco Use Supplements to the Current Population Survey.

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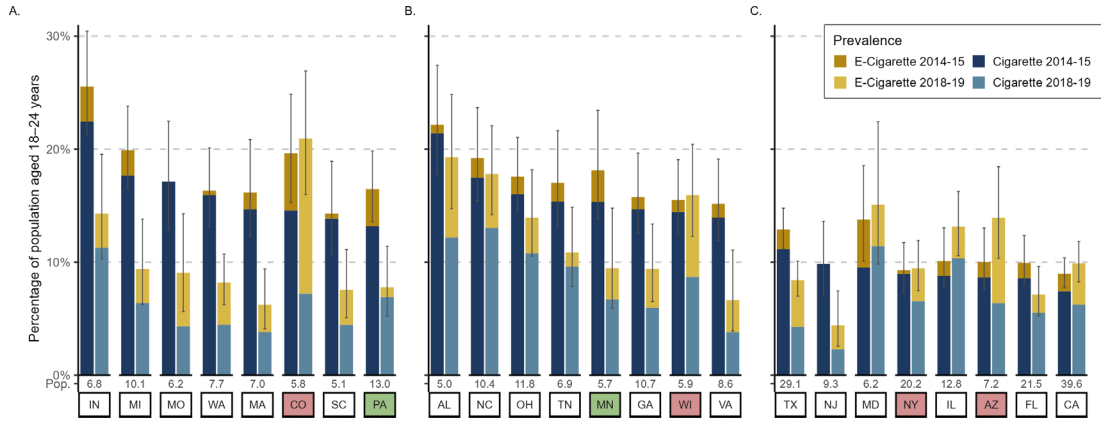

Figure 3 Current prevalence of cigarettes and e-cigarettes use among US young adults aged 18–24 years, 2014–15 and 2018–19, for the 24 most populous US states. (A) Eight states with significant declines in cigarette smoking (non-overlapping CIs between years); (B, C): other 16 states, in order of cigarette smoking prevalence in 2014–15. Source: Tobacco Use Supplement to Current Population Survey. Pop=state population, source: US Bureau of Census estimate of population of state in July 2021 in millions. States logo coloured in pink are those with above average increase in exclusive vaping in which this increase at least matched the decline in cigarette smoking. States logo coloured in green are the only two states with >US$1/fluid mL tax on e-cigarettes.

range −4.4 pp, −10.1 pp) by 2018–19 did not reach statistical significance. Panel C consists of the eight states with the lowest cigarette smoking prevalence in 2014–15 (average 9.1%), where smaller non-significant declines or no changes were observed (average −2.5 pp, range +1.6 pp, −7.6 pp).

Across all three panels, only four states had a greater than median increase (>2.3 pp) in exclusive vaping over this period and had an increase in exclusive vaping that at least matched the decline in cigarette smoking (an RepR of ≥1.0). These states were represented across the panels, highlighting the heterogeneity: panel A (Colorado: RepR=1.2); panel B (Wisconsin: RepR=1.1) and panel C (Arizona: RepR=2.7; New York: RepR=1.1) (online supplemental eTable 3).

Only 2 of the 24 most populous states had high e-cigarette taxes in 2017: Pennsylvania (US$1.05/fluid mL) and Minnesota (US$2.49/fluid mL).[40] Between 2014–15 and 2018–19, the proportion of those aged 18–24 years who vaped e-cigarettes exclusively declined from 3.3% to 0.9% in Pennsylvania, while remaining unchanged at 2.8% in Minnesota. These were both in contrast to the remaining state's average increase (+2.3 pp) over this period (figure 3 and online supplemental eTable 3). During this period, the prevalence of cigarette smoking in Pennsylvania declined by 6.3% pp and, in Minnesota, it declined by 8.6% pp (online supplemental eTable 4). Thus, the cigarette smoking prevalence decline in both states with meaningful e-cigarette taxes was greater than the 5.6% decline for the USA as a whole (2014–15=13.0%, 95% CI 12.2% to 13.7%; 2018–19=7.4%, 95% CI 6.7% to 8.1%).

DISCUSSION

Since 1997, among US young adults aged 18–24 years, current cigarette smoking declined at a rapid, consistent rate of 1.37 pp/y, to attain 5.4% prevalence in 2020—a decline that was highly correlated with the decline seen over the same period in past 30-day cigarette smoking among those aged 17–18 years. However, the surge of increased ever e-cigarette vaping among those aged 17–18 years, from 26.6% to 44.9% between 2017 and 2020, was not observed among those aged 18–24 years, among whom ever e-cigarette vaping was still only 15.3% in 2018–19. Modest increases in young adult exclusive vaping were observed between 2014–15 and 2018–19, which we hypothesise resulted from a cohort effect of adolescents who had already become dependent on vaping[17 18] aging-in to their young adult years.

Large declines in cigarette smoking prevalence were observed among all sociodemographic groups, but differences across subgroups defined by age, sex, education and race-ethnicity remained. We noted similarities in sociodemographic subgroups who were more likely to exclusively vape e-cigarettes, compared with those who smoked cigarettes. Despite consistent declines in national cigarette smoking prevalence, there was considerable heterogeneity across the 24 most populous US states, with differences in state-level changes from 2014–15 to 2018–19 of up to 14 pp. Over this period, increases in the prevalence of exclusive vaping only equated to an average of 40% of the decline in cigarette smoking, and there were only four states in which the increase in vaping matched the decline in cigarette smoking.

Previously, Meza *et al*[41] hypothesised that the rise in e-cigarette vaping in adolescents increased the rate of decline in adolescent cigarette smoking, using as a metric the annual per cent change in prevalence. When we analysed change in prevalence directly for US population aged 17–18 years, rather than as an annual per cent change, we were unable to replicate their result. We went a step further and added cigarette vaping prevalence to the model of cigarette smoking prevalence and found no association between trends in vaping prevalence and smoking prevalence. Using the variance in changes in prevalence across states among those aged 18–24 years, there was a low correlation (r=0.11) between the decline in cigarette smoking prevalence and the increase in exclusive vaping. Abouk *et al*[43] studied 14 jurisdictions with at least some tax on e-cigarettes, but only two of these were large states with taxes large enough to possibly influence behaviour.[44] They concluded that taxing e-cigarettes would push young people to cigarettes; however, in the two states with sizeable e-cigarette taxes, we did not find this to be the case. There was no evidence suggesting the increase in adolescent e-cigarette vaping was associated with a postponed increase or decrease in young adult cigarette smoking. Taken together, these data suggest that the factors leading to an increase in nicotine vaping are largely independent of those associated with the long-term consistent decline observed in cigarette smoking.

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In the 20 years prior to the 2017 surge in e-cigarette vaping among those aged 17–18 years, cigarette smoking prevalence had already declined by almost three-quarters, although the substance use risk profile among adolescents may not have changed.[53] We hypothesise that the rapid increase in e-cigarette vaping between 2017 and 2020 was related to the products' appeal to individuals with the same risk profile for cigarette smoking, but who may have been subject to strong social norms against cigarette smoking.[40] The MSA prohibited cigarette advertising targeting adolescents,[6] but US e-cigarette advertising remains largely unrestricted.[54] In 2013–14, analyses of the Population Assessment of Tobacco and Health Study found that among committed never tobacco users, receptivity to advertising was higher for e-cigarettes than cigarettes,[55] and receptivity was strongly associated with ever e-cigarette vaping at 12-month follow-up.[56] The 2017 surge in adolescent vaping coincided with the launch of effective marketing campaigns for a new generation of flavoured, high nicotine e-cigarettes,[57] which were associated with marked increases in daily and dependent vaping particularly among adolescents.[18] The Food and Drug Administration responded by removing flavourings from some e-cigarette products[58] and this action was associated with a drop in the market share of the leading product, JUUL.[59] Adolescents quickly switched to flavoured, disposable e-cigarettes, suggesting that fruit and candy flavourings are a major attractant for teens. A number of states have introduced bans on flavourings in tobacco products,[60] which could potentially reduce adolescent vaping levels in the future.

Strengths and limitations

A strength of this study is its use of multiple national surveillance systems, each with serial cross-sectional surveys, that demonstrate a consistent and similar pattern of decline in youth and young adult cigarette smoking. The TUS-CPS and NHIS provided very similar estimates of smoking prevalence, strengthening confidence in the observed decline. However, the study is limited as it is largely descriptive and aims to identify trends and suggest hypotheses for further research, rather than testing causal inferences.[8] Additionally, other potential influences on the major decline in cigarette smoking need to be acknowledged. These include state-level differences in cigarette prices,[41] expenditures on tobacco control programmes[61] and changes in social norms.[62]

CONCLUSIONS

Cigarette smoking has declined precipitously among both adolescents and young adults since 1997. Starting in 2017, adolescent e-cigarette vaping surged, concomitant with the popularity of flavoured, high nicotine e-cigarettes that have been shown previously to lead to dependence. Our findings do not support the previously suggested evidence that this increase in e-cigarette vaping was associated with a more rapid decline in adolescent cigarette smoking. Among US population aged 18–24 years, there was no similar surge in ever vaping. However, further research is needed to investigate a potential cohort effect of adolescents ageing into adulthood that may be leading to increased prevalence of exclusive vaping among these young adults. Despite the consistent, decades long national decline in cigarette smoking, there is considerable heterogeneity across US states in both rates of decline of cigarette smoking and in increases of exclusive vaping, which offers opportunity to identify potential public health interventions for both of these trends.

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Contributors JPP is responsible for the overall content and is the guarantor of the paper. JPP and KM conceptualised and designed the study, drafted the initial manuscript and reviewed and revised the manuscript. SBM and JPP acquired funding for the study. ML undertook the analyses for this study under the supervision of KM. MS, ML, ECL, DS, YS, SK and TB had input into the study conceptualisation and critically reviewed the manuscript for important intellectual content. All authors approved the final manuscript as submitted and agreed to be accountable for all aspects of the work.

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Competing interests None declared.

Patient consent for publication Not applicable.

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Supplement to Pierce et al. **A major 1998-2020 decline in US cigarette smoking initiation could be replaced by a cohort effect from adolescent dependent e-cigarette vaping.**

Table of Contents

1. Surveillance Systems used in this Study

The following three US representative Surveillance systems on tobacco use are used in this study.

Tobacco Control Supplement to the Current Population Survey (TUS-CPS

The Current Population Survey is sponsored jointly by the US Census Bureau and the US Bureau of Labor Statistics and is the primary source of labor force statistics in the US since the 1930s. From 1942 to 1948 it was known as the Monthly Report on the Labor Force, after which the name was changed to the CPS. Detailed information on the methodology used in this survey are available at https://www2.census.gov/programs-surveys/cps/methodology/CPS-Tech-Paper-77.pdf. The following are the surveys design requirements: a) it is a probability survey, b)primary design is to produce national and state estimates of labor force characteristics of the civilian noninstitutionalized population aged 16+, c) independent samples are drawn for each state and the District of Columbia, with both California and New York divided into two areas one including the major population city and the other the rest of the state. Sample sizes are determined by reliability requirements (using coefficient of variation) with a goal that a difference of 0.2 percentage points in unemployment rate between 2 consecutive months be statistically significant at the 0.10 level.

Since 1953, each housing unit is rotated within the sample in a 4-8-4 pattern. It is interviewed for 4 consecutive months, then not-interviewed for the next 8 months and then interviewed again for the same 4 months in the following year. Each month a new rotation comes into the sample for the first time and another returns to the sample after an 8 month rest. Approximately 54,000 households are interviewed each month and within each household the CPS seeks information about every eligible person in the household. An eligible household unit that does not yield any interviews in called a type A non-response – between December 2014 and December 2017, this ranged from 11.7% to 15.1%

In addition to being the primary source of monthly labor force statistics, the CPS is used to collect data for a variety of other studies that keep the nation informed of the economic and social well-being of its people. This is done by adding a set of supplemental questions to one or more months of the CPS. The first Tobacco Use Supplement, which was the first US national smoking survey, was undertaken by the National Cancer Institute in 1955.(see Surgeon General's report 2001 below) Starting in 1992, the National Cancer Institute coordinated a series of Tobacco Use Supplements to add to the CPS and added additional money to maximize the self-reported tobacco use behavior (to ~80% which is much higher than the usual 50% on CPS).(28) Each NCI coordinated TUS consists of three independent monthly samples spaced 4 months apart to account for the study design and ensure a maximum representative cross-sectional sample. and so the 3 survey months typically spans 2 calendar years. The current study analyzed the harmonized datafile that included surveys conducted in 1992/1993, 1995/1996, 1998/1999, 2001/2002, 2003, 2006/2007, 2010/2011, 2014/2015, and 2018/2019. Response rates ranged from a low of 62% in 2006/2007 to 75% in 2018/2019.

National Health Interview Survey (NHIS)

The NHIS interviews ~35,000 households containing ~87,000 US noninstitutionalized civilians each year using field staff employed and trained by the US Census Bureau. The survey has been conducted annually since 1957 and is redesigned statistically to be representative of the US population every 10 years. Detailed methods for each statistical design are available at https://www.cdc.gov/nchs/nhis/methods.htm. The NHIS design has an annual core questionnaire (smoking was added to the core in 1997 and it was not asked in 1994-6) and a rotating core (included in the NHIS with a fixed periodicity). NHIS data are used widely throughout the Department of Health and Human Services (HHS) to monitor national trends in illness and disability and to track progress toward achieving national health objectives (e.g., Pierce et al. Trends in cigarette smoking in the United States: Projections to the year 2000. *JAMA,* 261:61-65, 1989). Prior to 1974, smoking data could be

reported by another adult member of the household. Since 1974, only self-reported data are collected. The total household response rate is usually around 70%.

Monitoring the Future High School Seniors Survey (MTF-HSS)

Monitoring the Future, conducted out of the University of Michigan under a series of grants from the National Institute on Drug Abuse, started annual surveys of US high school students on drug use and lifestyles in 1975. It has become one of the nation's most relied upon sources of information on emerging trends in illicit drug, alcohol, and tobacco use among American adolescents. Each year, a multi-staged sampling procedure is used to obtain a nationally representative sample of high schools (from the 48 contiguous US states) are invited to participate in surveys of 8th, 10th and 12th grade (high school seniors) students. A detailed description of the multistage sampling design is available (see Bachman ref below) Personnel from the University of Michigan administered MTF surveys in classrooms, and students self-completed questionnaires during a normal class period. Typically, ~16,000 students from ~420 public and private high schools each year for each grade are surveyed in the Spring quarter. Student response rates average about 84% for 12th graders, with absence on the day of data collection the primary reason for non-completion.

In 2020, MTF collected 4627 surveys from 12th-grade students in 74 schools before MTF stopped data collection prematurely on March 14, 2020, due to coronavirus disease 2019 (COVID-19) concerns. (see Miech ref below) This was 30% the size of a typical annual MTF data collection. At the time of the 2020 halt, MTF had collected data from a wide geographic range and had surveyed schools in each of the 9 US Census geographic divisions (with weighting each division has influence on the analysis per its size nationally). The 2020 response rates within schools were 81% for 12th-grade students. The 2020 sample matches closely the 2019 sample in terms of demographics and key levels of substance use. Sensitivity analyses that restricted MTF data in all years to surveys collected on or before March 14 document prevalence levels markedly similar to results calculated with the full samples.

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eTable 1: Spline Regression Models of Trends in Prevalence of Various Cigarette-E-cigarette Measures

Model Variable	17-18 years old Ever Smoking			17-18 years old 30 day smoking			18-24 years old Current Smoking			17-18 years old ever Vaping			17-19 years old 30-day vaping		
	Est	**SE**	**P-value**	**Est**	**SE**	**P-value**	**Est**	**SE**	**P-value**	**Est**	**SE**	**P-value**	**Est**	**SE**	**P-value**
Model R-sq	**0.99**			**0.99**			**0.97**			**0.88**			**0.47**		
Intercept	**60.50**	1.14	**<0.0001**	**25.30**	0.79	**<0.0001**	**22.90**	0.99	**<0.0001**	-138	28.8	0.017	-96.8	46.2	0.13
1991-1997 Slope	**0.77**	0.23	**0.003**	**1.64**	0.17	**<0.0001**	**0.87**	0.21	**<0.0001**						
1997 Slope Change	**-2.40**	0.43	**<0.0001**	**-3.63**	0.31	**<0.0001**	**-1.37**	0.41	**0.003**						
2002 Slope Change	**-0.63**	0.41	0.14	**0.96**	0.29	**0.002**	**-0.26**	0.37	0.50						
2008 Slope Change	**0.84**	0.40	0.06	**-0.01**	0.28	0.96	**0.21**	0.35	0.55						
2013 Slope Change	**-1.19**	0.34	0.02	**-0.35**	0.32	0.28	**-0.51**	0.31	0.12						
Addition of E-cigarettes	**0.06**	0.06	0.33	**0.004**	0.06	0.95				**6.10**	1.01	**0.009**	**4.10**	1.62	0.08
2020 Slope Change										**-9.75**	2.25	**0.023**	**-7.68**	3.61	0.12

eTable 2: Ever e-cigarette Vaping by 18 to 24-year-olds in the 24 US most populous states: 2014/15 & 2018/19, ranked by difference in ever vaping between survey years

State	2014/5 % Ever	95% C.I.			2018/9 % Ever	95% C.I.		Diff in % Ever
Colorado	**15.8**	10.4	21.2		**27.8**	17.8	37.8	**12.0**
Minnesota	**18.4**	10.5	26.3		**25.9**	14.6	37.2	**7.5**
Ohio	**17.2**	11.8	22.7		**22.0**	14.0	29.9	**4.7**
Illinois	**11.9**	8.4	15.3		**16.5**	10.9	22.1	**4.6**
Wisconsin	**17.4**	11.8	23.0		**22.0**	14.1	29.9	**4.6**
Maryland	**12.1**	6.8	17.4		**16.1**	8.0	24.3	**4.0**
New Jersey	**8.2**	3.5	12.9		**11.8**	5.4	18.2	**3.5**
California	**11.3**	8.9	13.6		**13.8**	10.8	16.8	**2.5**
Alabama	**18.8**	11.9	25.7		**20.4**	13.7	27.1	**1.6**
Arizona	**18.6**	13.3	24.0		**20.1**	13.6	26.6	**1.4**
Texas	**13.1**	10.2	16.0		**14.4**	10.4	18.4	**1.3**
Tennessee	**13.7**	8.6	18.9		**14.8**	9.2	20.4	**1.0**
Florida	**7.1**	4.6	9.6		**7.6**	4.2	10.9	**0.5**
Virginia	**14.5**	8.8	20.2		**14.1**	8.6	19.6	**-0.4**
Washington	**17.5**	12.5	22.6		**16.7**	10.9	22.4	**-0.9**
Missouri	**16.4**	9.2	23.6		**14.9**	7.7	22.0	**-1.5**
Massachusetts	**14.1**	7.1	21.0		**12.1**	6.4	17.9	**-1.9**
New York	**14.5**	9.9	19.2		**12.2**	8.7	15.8	**-2.3**
Pennsylvania	**16.9**	11.9	22.0		**14.6**	8.8	20.4	**-2.3**
South Carolina	**11.5**	6.7	16.2		**8.6**	2.7	14.5	**-2.9**
Georgia	**14.0**	8.6	19.4		**10.2**	5.5	14.9	**-3.8**
North Carolina	**18.3**	12.2	24.4		**13.5**	8.7	18.3	**-4.8**
Michigan	**22.0**	17.0	27.0		**15.0**	9.0	21.1	**-7.0**
Indiana	**20.8**	11.9	29.6		**13.7**	8.3	19.1	**-7.0**
Overall US States	**14.5**	13.7	15.3		**15.3**	14.3	16.3	**+0.8**

Source: Tobacco Use Supplement to the Current Population Survey

Grey shaded cells are the 11 states in which experimentation with e-cigarettes decreased between 2014/15 and 2018/19

eTable 3: Current prevalence of cigarettes and exclusive vaping* in 2014/15 and 2018/19 in TUS-CPS

State	Current use in 2014/5					Current use in 2018/9						Percentage Point Change			
	cigarette (%)	Exclusive vaping %	either cig or ecig %	95% CI		cigarette %	Exclusive vaping %	either cig or ecig %	95% CI		Cigs as % of combined prevalence	Cigarette	Exclusive vaping %	Cigs or E-cigs	Replacement Ratio*
Group A															
Indiana	22.4	3.1	**25.5**	21.2	30.4	11.3	3.0	**14.3**	10.3	19.6	79%	**-11.2**	**-0.1**	**-11.2**	**0.0**
Michigan	17.7	2.3	**19.9**	16.5	23.8	6.4	3.0	**9.4**	6.3	13.8	68%	**-11.3**	**0.8**	**-10.5**	**0.1**
Missouri	17.1	0.0	**17.1**	12.9	22.5	4.3	4.7	**9.1**	5.6	14.3	48%	**-12.8**	**4.7**	**-8.1**	**0.4**
Washington	15.9	0.4	**16.3**	13.1	20.1	4.5	3.7	**8.2**	6.2	10.7	55%	**-11.5**	**3.3**	**-8.1**	**0.3**
Massachusetts	14.7	1.5	**16.2**	12.4	20.9	3.8	2.4	**6.2**	4.1	9.4	61%	**-10.9**	**1.0**	**-9.9**	**0.1**
Colorado	14.6	5.1	**19.6**	15.3	24.9	7.2	13.7	**20.9**	16.0	26.9	34%	**-7.4**	**8.7**	**1.3**	**1.2**
South Carolina	13.9	0.5	**14.3**	10.7	18.9	4.5	3.1	**7.6**	5.1	11.1	59%	**-9.4**	**2.7**	**-6.8**	**0.3**
Pennsylvania	13.2	3.3	**16.5**	13.6	19.8	6.9	0.9	**7.8**	5.2	11.4	89%	**-6.3**	**-2.4**	**-8.7**	**-0.4**
State Average	16.2	2.0	**18.2**			6.1	4.3	**10.4**			59%	**-10.1**	**2.3**	**-7.7**	**0.2**
Group B															
Alabama	21.4	0.7	**22.2**	17.6	27.4	12.2	7.1	**19.3**	14.7	24.8	63%	-9.2	**6.4**	**-2.9**	**0.7**
North Carolina	17.5	1.7	**19.2**	15.4	23.7	13.0	4.8	**17.8**	14.2	22.1	73%	-4.4	**3.0**	**-1.4**	**0.7**
Ohio	16.0	1.6	**17.6**	14.6	21.0	10.8	3.1	**13.9**	10.5	18.2	78%	-5.2	**1.6**	**-3.7**	**0.3**
Tennessee	15.4	1.7	**17.0**	13.2	21.6	9.6	1.3	**10.9**	7.8	14.9	88%	-5.8	**-0.4**	**-6.1**	**-0.1**
Minnesota	15.3	2.8	**18.1**	13.8	23.4	6.7	2.8	**9.5**	5.9	14.8	71%	-8.6	**0.0**	**-8.7**	**0.0**
Georgia	14.7	1.1	**15.8**	12.5	19.7	6.0	3.4	**9.4**	6.5	13.4	64%	-8.7	**2.4**	**-6.4**	**0.3**
Wisconsin	14.4	1.1	**15.5**	12.5	19.1	8.7	7.2	**15.9**	12.3	20.4	55%	-5.7	**6.2**	**0.4**	**1.1**
Virginia	13.9	1.2	**15.2**	11.9	19.1	3.8	2.8	**6.6**	3.9	11.1	57%	-10.1	**1.6**	**-8.5**	**0.2**
State Average	16.1	1.5	**17.6**			8.8	4.1	**12.9**			69%	**-7.2**	**2.6**	**-4.7**	**0.4**
Group C															
Texas	11.1	1.8	**12.9**	11.2	14.8	4.3	4.1	**8.4**	7.0	10.1	51%	**-6.9**	**2.4**	**-4.5**	**0.3**
New Jersey	9.8	0.0	**9.8**	7.0	13.6	2.3	2.1	**4.4**	2.6	7.5	52%	**-7.6**	**2.1**	**-5.4**	**0.3**
Maryland	9.5	4.2	**13.8**	10.1	18.6	11.4	3.7	**15.1**	9.8	22.4	76%	**1.9**	**-0.6**	**1.3**	**0.3**
New York	9.0	0.4	**9.3**	7.3	11.7	6.5	2.9	**9.5**	7.5	11.9	69%	**-2.4**	**2.6**	**0.2**	**1.1**
Illinois	8.8	1.3	**10.1**	7.8	13.0	10.4	2.8	**13.2**	10.6	16.3	79%	**1.6**	**1.5**	**3.1**	**-1.0**
Arizona	8.7	1.4	**10.0**	7.6	13.0	6.4	7.5	**13.9**	10.4	18.4	46%	**-2.3**	**6.2**	**3.9**	**2.7**
Florida	8.6	1.4	**9.9**	7.9	12.4	5.5	1.6	**7.1**	5.3	9.6	77%	**-3.1**	**0.3**	**-2.8**	**0.1**
California	7.4	1.6	**9.0**	7.7	10.4	6.3	3.6	**9.9**	8.2	11.8	63%	**-1.2**	**2.1**	**0.9**	**1.8**
State Average	9.1	1.5	**10.6**			6.6	3.6	**10.2**			65%	**-2.5**	**2.1**	**-0.4**	**0.7**

*Exclusive vaping is defined as e-cigarette vaping without cigarette smoking.

Highlighted states met criteria for high replacement ratio and increase in cigarettes with cigarette prevalence.

eTable 4: Decline in cigarette smoking prevalence among 18- to 24-year-olds between 2014/15 and 2018/19 in the 24 most populous US States

Pop* in 2021	State	2014/5 (%)	95% CI		2018/9 (%)	95% CI		Percentage Point Change in Estimate (2014/5-2018/9)	Confidence Limit Difference (UCI 2018/9 - LCI 2014/5)
5.0	**Alabama**	**21.4**	16.5	26.3	**12.2**	6.7	17.6	**-9.2**	1.1
7.2	**Arizona**	**8.7**	3.8	13.5	**6.4**	3.8	8.9	**-2.3**	5.1
39.6	**California**	**7.4**	0.2	14.6	**6.2**	-0.2	12.7	**-1.2**	12.4
5.8	**Colorado**	**14.6**	11.9	17.3	**7.2**	5.5	8.9	**-7.4**	-3.0
21.5	**Florida**	**8.6**	6.6	10.5	**5.5**	3.4	7.6	**-3.1**	1.0
10.7	**Georgia**	**14.7**	8.5	20.8	**6.0**	-0.5	12.5	**-8.7**	3.9
12.8	**Illinois**	**8.8**	3.8	13.8	**10.3**	7.3	13.4	**1.6**	9.6
6.8	**Indiana**	**22.4**	18.0	26.9	**11.3**	6.5	16.0	**-11.2**	-2.0
6.2	**Maryland**	**9.5**	5.4	13.7	**11.4**	7.1	15.8	**1.9**	10.4
7.0	**Massachusetts**	**14.7**	11.6	17.7	**3.8**	0.7	7.0	**-10.9**	-4.7
10.1	**Michigan**	**17.7**	11.6	23.7	**6.4**	3.4	9.3	**-11.3**	-2.3
5.7	**Minnesota**	**15.3**	10.2	20.5	**6.7**	2.7	10.8	**-8.6**	0.6
6.2	**Missouri**	**17.1**	11.3	23.0	**4.3**	0.7	8.0	**-12.8**	-3.3
9.3	**New Jersey**	**9.8**	4.6	15.1	**2.3**	-1.8	6.4	**-7.6**	1.8
20.2	**New York**	**8.9**	2.4	15.5	**6.5**	1.5	11.6	**-2.4**	9.2
10.4	**North Carolina**	**17.5**	12.5	22.5	**13.0**	4.9	21.2	**-4.4**	8.7
11.8	**Ohio**	**16.0**	12.4	19.6	**10.8**	7.1	14.4	**-5.2**	2.0
13.0	**Pennsylvania**	**13.2**	10.0	16.3	**6.9**	4.2	9.6	**-6.3**	0.4
5.1	**South Carolina**	**13.9**	8.5	19.2	**4.4**	1.8	7.1	**-9.4**	-1.4
6.9	**Tennessee**	**15.4**	9.4	21.3	**9.6**	4.5	14.7	**-5.8**	5.4
29.2	**Texas**	**11.1**	7.8	14.5	**4.3**	0.3	8.3	**-6.9**	0.5
8.6	**Virginia**	**13.9**	7.0	20.9	**3.8**	-1.2	8.8	**-10.1**	1.8
7.7	**Washington**	**15.9**	8.9	22.9	**4.5**	0.5	8.4	**-11.5**	-0.5
5.9	**Wisconsin**	**14.4**	8.5	20.3	**8.7**	3.6	13.8	**-5.7**	5.2
	Overall US	**12.9**	12.2	13.7	**7.4**	6.7	8.1	**-5.6**	-4.1

Pop – US Bureau of Census estimate of population of state in July 2021 in millions

UCI = upper confidence interval, LCI= lower confidence interval

Source: Tobacco Use Supplement to the Current Population Survey