ADDICTION
SSA SOCIETY FOR THE STUDY OF ADDICTION
RESEARCH REPORT
doi:10.1111/add.15434

Adding vaping restrictions to smoke-free air laws: associations with conventional and electronic cigarette use

Abigail S. Friedman, Jon F. Oliver & Susan H. Busch

Department of Health Policy and Management, Yale School of Public Health, New Haven, CT, USA

ABSTRACT

Background and Aims In the United States, some states and localities have added vaping restrictions to established smoke-free indoor air laws in order to reduce electronic cigarette use. Yet, if smokers use e-cigarettes to quit, such restrictions could have the unintended effect of attenuating the original smoke-free air policy's effects on smoking. This study estimated changes in current smoking, past-year smoking cessation, and recent vaping following the introduction of smoke- and vape-free air laws. **Design** Observational study of nationally representative data from the 2014–2018 National Health Interview Survey. **Setting** United States. **Participants/Cases** 87 334 participants, 18–54 years of age. **Measurements** Multivariable linear regressions estimated the association between increased exposure to smoke- and vape-free worksite and restaurant laws and self-reported current smoking and recent vaping among emerging adults (ages 18–25), as well as past-12-month smoking cessation among prime age adults (ages 26–54). All regressions adjusted for respondent sociodemographic and other tobacco control policies, along with state and year fixed effects. **Findings** Smoke-free worksite laws were associated with significant reductions in the likelihood of current smoking ($\widehat{\beta} = -0.050$, 95% CI: −0.098, −0.002, $P = 0.038$) and recent vaping ($\widehat{\beta} = -0.040$, 95% CI: −0.072, −0.007, $P = 0.013$), as well as increases in the likelihood of smoking cessation ($\widehat{\beta} = 0.026$, 95% CI: 0.000, 0.052, $P = 0.046$). Adding vaping restrictions to smoke-free worksite laws did not yield further reductions in recent vaping ($\widehat{\beta} = 0.008$, 95% CI: −0.021, 0.036, $P = 0.568$) and counteracted over half of the estimated association with current smoking relative to smoke-free policies alone ($\widehat{\beta} = 0.030$, 95% CI: −0.028, 0.088, $P = 0.301$). **Conclusions** From 2014 to 2018, increased adoption of smoke-free worksite laws in the United States was associated with reductions in both current smoking and recent vaping, as well as increases in smoking cessation. Adding vaping restrictions to smoke-free worksite laws, however, was not associated with a reduction in recent vaping among emerging adults and may have attenuated the smoke-free policy's impact on current smoking in this age group.

Keywords Policy, public health, smoking, tobacco control, tobacco use, vaping.

Correspondence to: Abigail S. Friedman, Assistant Professor, Department of Health Policy and Management, Yale School of Public Health, 60 College Street, Rm. 303, New Haven, CT 06520-8034. E-mail: abigail.friedman@yale.edu
Submitted 24 June 2020; initial review completed 8 October 2020; final version accepted 20 January 2021

INTRODUCTION

Tobacco use is the leading cause of preventable mortality in the United States (US), responsible for nearly one in five deaths annually. Two decades of research show that smoke-free indoor air laws lead to reduced conventional cigarette use ("smoking") and increased smoking cessation [1,2]. Since 2014, 10 US states, Washington D.C., and hundreds of localities extended their smoke-free air laws to cover electronic cigarette use ("vaping"). However, these laws' effects on vaping have not been established.

Traditional smoke-free air laws prohibit smoking in certain establishments, without restrictions on vaping. Because quasi-experimental research largely finds that conventional and electronic cigarettes are economic substitutes [3–6], one might expect smokers to respond to smoke-free air laws by substituting toward e-cigarettes. Indeed, 39% of e-cigarette users cite smoke-free air laws as their reason for vaping [7]. Adults often vape as a smoking cessation aid, switching from conventional to electronic cigarettes with the expectation of quitting altogether [8]. These observations suggest that smoke-free air

laws may increase e-cigarette use. However, to the extent that the smoking–vaping relationship is driven by nicotine dependence, these dynamics could differ between addicted adult smokers and tobacco-naïve youths. Therefore, vape-free air laws' effects on initiation of vaping and smoking may differ from their effects on cessation. Limited evidence is available on this issue.

Moreover, research into smoke-free air laws' effects on smoking largely precedes the rise of vaping in the United States. With e-cigarettes widely available, smoke-free air laws may incentivize smokers to switch to vaping in public while continuing to smoke at home, reducing the policy's impact on smoking cessation. Understanding how these laws affect smoking in the context of widespread e-cigarette access is critical to policymaking going forward.

Several states recently added vaping restrictions to existing smoke-free indoor air laws. New Jersey implemented the United States' first comprehensive state-wide vape-free air law—covering worksites, restaurants, and bars—in 2010. In almost all cases, localities implemented a vape-free air law alongside a new or existing smoke-free air law. Conceptually, this might dampen an established smoke-free air law's impact on smoking cessation, as individuals using e-cigarettes to quit smoking could no longer vape nicotine in those venues. Yet, if few smokers successfully use e-cigarettes to quit smoking, the addition of vape-free air laws might reduce e-cigarette use without affecting smoking cessation.

Establishing how these policies relate to both smoking and vaping is critical to informing health policy, particularly given evidence that vaping nicotine is likely less harmful than conventional cigarette use [9–11]. To address this, we used nationally representative, restricted-use data from the 2014–2018 National Health Interview Survey (NHIS) to estimate changes in smoking and vaping following the adoption of smoke- and vape-free indoor air laws. Specific outcomes include current smoking and recent vaping among 18- to 25-year-olds—proxies for initiation of habitual use, the vast majority of which occurs before age 25—and past-year smoking cessation among 26- to 54-year-olds. Given existing work suggesting that conventional and electronic cigarettes are economic substitutes [3–6], we hypothesized that vape-free air laws would attenuate the impact of smoke-free air laws on smoking, but that this relationship might be stronger for initiation than cessation due to the difficulty of quitting.

METHODS

Data

Respondent-level data came from the nationally representative restricted-use NHIS, an annual repeated cross-section of US households. Because vaping questions were not included until 2014, analyses consider the 2014–2018 waves only. During this period, NHIS sample adult response rates ranged from 53.0% (in 2017) to 58.9% (2014) [12,13]. With surveys fielded throughout each year, interview-quarter indicators facilitate more precise identification of concurrent policies (see Supporting information Data S1 for further details).

Data from the American Nonsmokers' Rights Foundation (ANRF) US Tobacco Control Laws Database [14] provided the effective date of smoke- and vape-free air laws at the local, county, and state level, by venue (e.g. worksites and restaurants). These data were matched to county population estimates from the 2010 Census to calculate the percent of each county's population covered by smoke- and vape-free air laws in each venue, by quarter-year (based on laws in effect on the first day of each quarter-year; e.g. a county-level smoking ban implemented on 1 February 2014 would take on a value of 0 [no coverage] for the first quarter of 2014, and a value of 1 [full coverage] for the second quarter of 2014 and thereafter).

Policy and control variable data were matched to the NHIS respondent data by interview quarter-year and state-county. Such controls included total conventional cigarette taxes (local plus state plus federal) in real 2018 dollars-per-pack (based on data from the Institute for Health Research and Policy at the University of Illinois at Chicago [15], updated by the authors through 2018), minimum legal sales age laws for tobacco products [16–18], median household income in real 2018 $1000 units [19], and binary indicators for county urbanicity [20].

Sample

The analytic sample was restricted to adults under age 55 to reduce the impact of differential mortality by smoking status. As uptake of habitual smoking precedes age 25 for the vast majority of US smokers [21], analyses of current smoking and recent vaping considered 18- to 25-year-olds to best capture initiation of habitual use. To distinguish cessation of an established habit from an experimenter's failure to initiate regular use, cessation analyses limited consideration to respondents ages 26–54.

During our period of analysis, nine counties had a larger share of their population covered by vape-free indoor air laws than smoke-free laws for the same venue. Covering 2.0% of the US population, these counties were dropped for methodological reasons and to avoid drawing non-generalizable conclusions about a rare policy scenario [14]. See Supporting information Data S1 for further details.

Measures

Outcomes include binary current smoking and recent vaping indicators. Current smokers refer to those who have

smoked at least 100 cigarettes in their lifetime and report past-30-day or current use (now using every day or some days), or recent cessation (i.e. self-identified former smokers who report having smoked in the past 3 months). The latter group is included because of high relapse rates generally [22], and because current smoking analyses focus on 18- to 25-year-olds, who are statistically more likely to relapse than older adults [23]. As the standard NHIS only poses recent smoking questions to those who report having smoked at least 100 cigarettes, these data preclude a "recent smoking" variable that captures all past-30-day use regardless of lifetime smoking.

Smoking cessation is captured via a binary indicator for respondents who quit smoking in the previous 12 months, among those who had smoked at any point in the past year.

Vaping indicators could not be defined to match those for smoking; the NHIS does not field a vaping-variable equivalent to "having smoked at least 100 cigarettes." Recent vaping is indicated for individuals who now vape "every day" or "some days," or report any past-30-day e-cigarette use (with no prerequisite level of e-cigarette consumption beyond "ever used").

Likewise, vaping cessation measures could not be defined to match those for smoking, as the NHIS did not ask about time-since-last-vaped or whether past vaping was habitual. Instead, exploratory analyses consider a binary "prior vaping" indicator defined for ever-vapers only, and equal to one among those who do not currently use e-cigarettes, but report having used them in the past. As this indicator groups true quitters with experimenters who never transitioned to regular use, prior vaping analyses are considered exploratory.

Additional variables of interest include indicators for the respondent's age, sex, race (White, Black, Asian, American Indian or Alaska Native, multiple, or other), Hispanic ethnicity, educational attainment, employment status, state of residence, and quarter-year of interview. A binary indicator for being legally prohibited from purchasing tobacco products at interview is coded based on respondent age and the minimum legal sales age for tobacco products in their county of residence.

Statistical analyses

First, summary statistics describe respondent demographics, tobacco use, and policy exposure by age-group, both overall and by exposure to smoke-free worksite and restaurant laws. As smoke-free restaurant and bar laws were often enacted together and therefore are highly correlated, the latter are not considered.

Next, sample-weighted multivariable regressions examine how smoking and vaping statuses change before versus after implementation of smoke- and vape-free worksite and restaurant laws, in counties that did versus did not see changes in these policies. Specifically, emerging adult (ages 18–25) analyses estimate how the percent of one's county covered by smoke-free worksite, smoke-free restaurant, vape-free worksite, and vape-free restaurant laws relates to individuals' current smoking and recent vaping status. To adjust for sociodemographics that might vary by county and be correlated with tobacco use, regressions include fixed effects for year of age, female sex, race, Hispanic ethnicity, any college education, employment status, and county urbanicity, as well as a continuous median household income variable (in thousands of real 2018 dollars). To absorb effects of other tobacco policies, additional controls include conventional cigarette taxes per pack (in real 2018 dollars) and an indicator for whether the respondent cannot legally purchase conventional cigarettes at interview. State fixed effects adjust for time-invariant state characteristics, whereas quarter-year fixed effects absorb common time trends.

Separate regressions examine past-year smoking cessation among prime age adults (ages 26–54) who are eligible to quit (i.e. smoked in the past 12 months), as well as prior vaping. Here, the smoke-free air, vape-free air, and conventional cigarette tax controls are lagged to the year before the respondent's interview, to allow for the time it takes to quit these habits and better capture lasting cessation (as opposed to quits with subsequent relapse). This analysis uses the same control variables as the emerging adult specifications, with two exceptions; age fixed effects indicate 5-year age groups (because of the broader age range) and education indicators are more detailed (i.e, completed some college, graduated college, and post-college education, with "high school degree or less" as the reference group), because 26- to 54-year-olds are more likely to have completed their schooling.

With state fixed effects adjusting for time-invariant state characteristics, and quarter-year fixed effects absorbing common time trends, these analyses are similar to a difference-in-differences specification. However, because some policy changes are measured at the county level, a true difference-in-differences analysis would require county fixed effects. The latter are not used here due to potential over-identification and concerns about representativeness. Specifically, as the NHIS covers ~35 000 households annually across more than 3000 US counties, many smaller counties have only a few observations in these data. To reduce concerns that pre-existing differences in county smoking rates might bias results, robustness checks add a control for baseline adult smoking rates by county [24] to absorb time-invariant county-level variation in adult tobacco use. However, this check omits several hundred respondents who lived in the ~429 US counties without baseline smoking rate data, potentially affecting statistical power. Such controls are not available for vaping because of a lack of county-level data on vaping before

2014, although this is less of a concern because most vape-free air variation stems from state policies.

All equations were estimated with sample-weighted linear probability models, both for ease of interpretation and to reduce concerns about bias from the incidental parameters problem (because of the large number of fixed effects) [25]. Given extensive state policy variation related to tobacco control, standard errors were clustered by state (see Supporting information Data S1 for further detail). Analyses were conducted using Stata v.14 (StataCorp, College Station, TX). Yale University's Institutional Review Board (IRB) deemed this study exempt from review (IRB Protocol No. 2000025871). As the analysis was not pre-registered, results should be considered exploratory.

RESULTS

Tables 1 and 2 present summary statistics by the presence of different smoke-free indoor air policies at interview, for emerging and prime age adults, respectively. Respondents subject to smoke-free worksite and restaurant laws tend to be more educated than those with no smoke-free air laws (60% vs 52% for 18- to 25-year-olds; 68% vs 61% for 26- to 54-year-olds) and face higher conventional cigarette taxes: $3.15 versus $1.82 and $3.09 versus $1.78, respectively. Locations with smoke-free laws for both worksites and restaurants have lower current smoking rates among emerging adults (13% vs 18%) and more past-year smoking cessation among prime age adults (13% vs 11%) than locations with neither policy.

Figures 1 and 2 present regression coefficient estimates and 95% confidence intervals (95% CI) for the relationship of smoke-free worksite and restaurant laws to current smoking among 18- to 25-year-olds and past-year smoking-cessation among 26- to 54-year-olds, respectively, controlling for demographics and other tobacco policies. Associations were statistically insignificant for restaurant laws in all specifications. However, adopting a county-wide smoke-free worksite law was associated with a statistically significant 5.0 percentage point reduction (95% CI: −9.8, −0.2, $P = 0.038$) in current smoking among emerging adults and a 2.6 percentage point increase in 26- to 54-year-olds' past-year smoking cessation (95% CI: 0.0, 5.2, $P = 0.046$).

Table 1 Summary Statistics for 18- to 25-year-olds, means/SD

Sample by county's smoke-free laws	*All counties (1)*	*Smoke-free worksite-only (2)*	*Smoke-free restaurant-only (3)*	*Both (4)*	*Neither (5)*
Current smoker	0.137 (0.296)	0.153 (0.279)	0.161 (0.343)	0.128 (0.287)	0.175 (0.319)
Recent vaper	0.074 (0.225)	0.061 (0.185)	0.100 (0.279)	0.072 (0.222)	0.077 (0.224)
Other tobacco policies					
Conventional cigarette tax ($)	2.909 (1.146)	3.054 (0.474)	2.120 (0.981)	3.150 (1.170)	1.822 (0.341)
Cannot purchase conventional cigarettes	0.043 (0.174)	0.000 (0.006)	0.001 (0.022)	0.056 (0.197)	0.000 (0.007)
Vape-free worksite laws	0.215 (0.326)	0.023 (0.103)	0.014 (0.092)	0.279 (0.353)	0.000 (0.000)
Vape-free restaurant laws	0.238 (0.335)	0.042 (0.116)	0.117 (0.273)	0.297 (0.357)	0.000 (0.000)
Demographics					
Female	0.495 (0.430)	0.492 (0.387)	0.497 (0.466)	0.494 (0.430)	0.503 (0.420)
Education, any college	0.585 (0.424)	0.567 (0.384)	0.569 (0.462)	0.597 (0.422)	0.523 (0.419)
Race					
White	0.762 (0.366)	0.848 (0.278)	0.741 (0.408)	0.760 (0.367)	0.762 (0.357)
Black	0.155 (0.311)	0.094 (0.227)	0.195 (0.369)	0.149 (0.306)	0.184 (0.326)
Asian	0.058 (0.201)	0.044 (0.158)	0.036 (0.173)	0.066 (0.213)	0.027 (0.136)
American Indian/Alaska Native	0.016 (0.107)	0.013 (0.089)	0.023 (0.138)	0.014 (0.102)	0.021 (0.119)
Multiple	0.005 (0.059)	0.000 (0.000)	0.004 (0.060)	0.005 (0.062)	0.003 (0.048)
Other	0.004 (0.057)	0.000 (0.005)	0.002 (0.038)	0.005 (0.062)	0.002 (0.041)
Hispanic	0.218 (0.355)	0.101 (0.233)	0.180 (0.358)	0.241 (0.368)	0.131 (0.283)
Median household income (in $1000s)	61.513 (13.807)	62.426 (9.988)	60.790 (13.385)	62.364 (13.181)	56.162 (17.490)
Observations	15 830	479	1465	12 112	1774

Note: Sample-weighted means—given as proportions for binary variables—are estimated from the 2014–2018 National Health Interview Survey data on 18- to 25-year-olds, with standard deviations in parentheses. Column 1 includes all such respondents, whereas columns 2–5 present subgroups based on the type of smoke-free indoor air policy in the respondent's county at interview. Residents of counties with partial smoke-free air coverage (i.e., from local laws) were assigned to columns 2–5 as follows: "smoke-free worksite only" if >0% of their county's population was covered by smoke-free worksite laws and 0% was covered by smoke-free restaurant laws as of the respondent's interview date, vice versa for the "smoke-free restaurant only" column, "both" for counties with non-zero coverage from both policies, and "neither" for those with no coverage from either policy. All prices are in real 2018 dollars.

Table 2 Summary Statistics for 26- to 54-year-olds, means/SD

Sample by county's smoke-free laws	*All counties* (1)	*Smoke-free worksite only* (2)	*Smoke-free restaurant only* (3)	*Both* (4)	*Neither* (5)
Quit cigarettes, past year	0.124 (0.329)	0.137 (0.305)	0.127 (0.376)	0.126 (0.332)	0.106 (0.302)
Prior e-cigarette use	0.772 (0.411)	0.780 (0.364)	0.790 (0.444)	0.773 (0.409)	0.756 (0.423)
Eligible to quit	0.184 (0.375)	0.224 (0.367)	0.176 (0.400)	0.175 (0.366)	0.232 (0.405)
Other tobacco policies					
Conventional cigarette tax ($), (t-1)	2.846 (1.288)	2.861 (0.494)	2.149 (1.111)	3.089 (1.323)	1.776 (0.377)
Vape-free worksite laws, (t-1)	0.165 (0.330)	0.001 (0.020)	0.003 (0.048)	0.218 (0.363)	0.000 (0.000)
Vape-free restaurant laws, (t-1)	0.182 (0.340)	0.005 (0.038)	0.080 (0.266)	0.231 (0.367)	0.000 (0.000)
Demographics					
Female	0.509 (0.483)	0.488 (0.439)	0.512 (0.524)	0.508 (0.482)	0.519 (0.479)
Education, any college	0.670 (0.455)	0.666 (0.415)	0.672 (0.493)	0.679 (0.450)	0.612 (0.467)
Race					
White	0.770 (0.407)	0.854 (0.310)	0.776 (0.437)	0.766 (0.408)	0.760 (0.410)
Black	0.136 (0.331)	0.103 (0.267)	0.145 (0.369)	0.131 (0.325)	0.174 (0.364)
Asian	0.074 (0.253)	0.040 (0.171)	0.047 (0.222)	0.084 (0.267)	0.041 (0.191)
American Indian/Alaska Native	0.013 (0.111)	0.002 (0.040)	0.028 (0.172)	0.012 (0.103)	0.020 (0.133)
Multiple	0.004 (0.058)	0.001 (0.021)	0.002 (0.047)	0.004 (0.062)	0.002 (0.048)
Other	0.003 (0.055)	0.001 (0.029)	0.002 (0.044)	0.004 (0.058)	0.002 (0.047)
Hispanic	0.188 (0.378)	0.078 (0.235)	0.154 (0.379)	0.209 (0.392)	0.113 (0.303)
Median household income (in $1000s)	62.996 (16.572)	64.228 (12.020)	61.226 (16.218)	63.879 (15.652)	58.178 (21.974)
Observations	71 504	2411	6798	53 869	8426

Note: Sample-weighted means—given as proportions for binary variables—are estimated from the 2014–2018 National Health Interview Survey data on 26- to 54-year-old respondents, with SD in parentheses. Column 1 includes the full dataset of all respondents ages 26–54. Columns 2–5 present various subgroups based on the type of smoke-free indoor air policy in the respondent's county at the time of interview. Residents of counties with partial smoke-free air coverage (i.e., from local laws) were assigned to columns 2–5 as follows: "smoke-free worksite only" if >0% of their county's population was covered by smoke-free worksite laws and 0% was covered by smoke-free restaurant laws as of the respondent's interview date, vice versa for the "smoke-free restaurant only" column, "both" for counties with non-zero coverage from both policies, and "neither" for those with no coverage from either policy. "Quit cigarettes, past year" is only defined for respondents who smoked at some point in the past 12 months, while "Prior e-cigarette use" is only defined for those who reported ever vaping. "Eligible to quit" refers to respondents who either smoked in the past 12 months or ever-vaped, and therefore can be included in smoking cessation or prior-e-cigarette use analyses. All prices are in real 2018 dollars.

Estimates of the combined effect of smoke- and vape-free worksite laws on current smoking and past-year cessation were both statistically insignificant ($\widehat{\beta} = -0.020$, 95% CI: −0.061, 0.021, $P = 0.331$; and $\widehat{\beta} = -0.027$, 95% CI: −0.004, 0.058, $P = 0.09$, respectively). Although the differences between these point estimates and the corresponding smoke-free worksite coefficients are not significant, their relative magnitudes do not rule out the possibility that adding vaping restrictions to existing smoke-free worksite laws may reduce the latter's impact on current smoking.

The robustness check—adding a control for baseline county smoking rates to absorb between-county differences in tobacco use and attitudes—yields statistically insignificant coefficient estimates for worksite policies in both current smoking and past-year cessation analyses (see Tables A1 and A2 in Supporting information Data S1). Although this implies less evidence against the corresponding null hypotheses, the smoke-free worksite coefficient rises in the cessation robustness check, suggesting that reduced statistical significance may stem from reduced sample size (baseline county smoking rates were unavailable for 429 counties).

For recent vaping, analyses show no statistically significant effects of smoke- and vape-free restaurant laws, but a significant 4.0 percentage point reduction in recent vaping (95% CI: −7.2, −0.7, $P = 0.013$) subsequent to smoke-free worksite policies' implementation (see Figure 3). The combined smoke-and-vape-free worksite effect estimate is smaller but still significant: a 3.2 percentage point reduction in recent vaping (95% CI: −5.9, −0.5, $P = 0.020$). Both of these estimates are robust to the inclusion of controls for baseline county smoking rates (Table A3 in Supporting information Data S1). Thus, the reduction in recent vaping associated with smoke-free worksite laws does not appear to be amplified by adding vape-free worksite restrictions.

All policy effects are insignificant for prior-vaping (Table A4 in Supporting information Data S1). However, that variable's limitations preclude strong conclusions from this result.

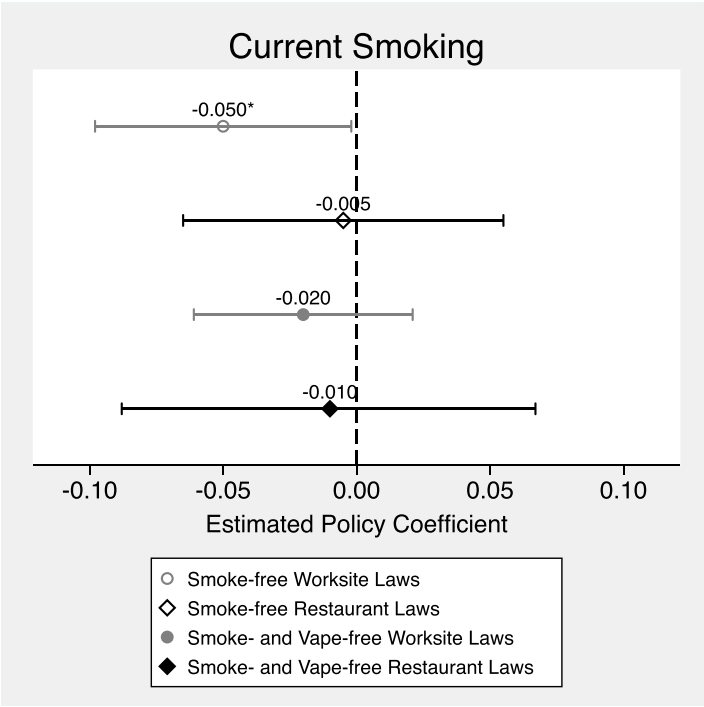

Figure 1 Relationship of smoke-free indoor air laws to current smoking among 18- to 25-year-olds from 2014 to 2018, coefficients and 95% CI. Note: coefficient estimates and 95% CI come from sample-weighted linear regressions using 2014–2018 National Health Interview Survey data on 18- to 25-year-old respondents. Controls not shown include the conventional cigarette tax rate, median household income, and fixed effects for year of age, sex, race, ethnicity, education, urban status, employed status, and whether the respondent can legally purchase conventional cigarettes. Analyses exclude counties where vape-free law coverage exceeds smoke-free law coverage for a given venue at any point between 2014 and 2018. Standard errors are clustered at the state level (see Table A1in the Supporting information Data S1 for regression results). *$P < 0.05$

DISCUSSION

This research provides new insight into the relationship of smoke- and vape-free air laws to the use of both conventional and electronic cigarettes. Among emerging adults, our work confirms earlier studies' findings that smoke-free worksite laws have a sizable and significant negative relationship to current smoking. Moreover, these laws also showed a sizable and significant negative effect on vaping. Yet adding vaping restrictions to smoke-free air laws did not have the intended effect; results showed no further decline in recent vaping in response to these policy changes.

There is some concern that if conventional and electronic cigarettes are substitutes, adding vaping restrictions may have the unintended consequence of reducing the impact of smoke-free air laws on smoking. Our point estimates do not rule out such effects; when combined with vaping restrictions, smoke-free worksite laws no longer yielded statistically significant declines in current smoking ($\beta = -0.020$, 95% CI: -0.061, 0.021, $P = 0.331$).

Interestingly, findings suggest potential effects from smoke-free worksite but not smoke-free restaurant laws. This could stem from exposure: most people spend far more hours per day at their worksite than in restaurants. However, the result might also relate to peer effects if not being able to smoke at work reduces smoking's value as a social lubricant with colleagues.

These findings have important policy implications. First, even with e-cigarettes widely available in the period of analysis, smoke-free worksite laws were associated with sizable reductions in emerging adults' current smoking and increases in prime age smoking cessation. These findings provide reassurance that the rise of e-cigarettes has not made smoke-free laws moot, both reductions in current smoking and increases in smoking cessation occurred in response to these policies between 2014 and 2018. Smokers did not merely switch to vaping in public while continuing to smoke at home. As 18 states did not have smoke-free worksite laws as of 1 January 2020, such evidence is particularly important and delays in enacting these policies may have long-term effects as more emerging adults become habitual smokers or vapers in the interim.

Second, whereas smoke-free worksite laws were associated with reduced recent vaping among emerging adults, adding vaping restrictions to these laws did not amplify the policy's effect on recent vaping. In fact, we could not rule out a reduction in the current smoking effect associated with this policy change. If adding vaping restrictions does not reduce vaping and attenuates the smoke-free

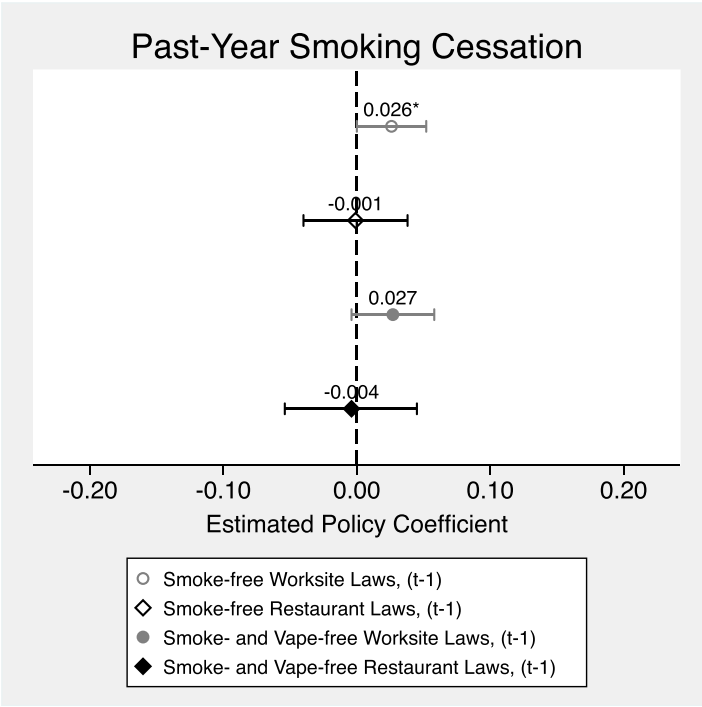

Figure 2 Relationship of smoke-free indoor air laws to past-year smoking cessation among 26- to 54-year-olds from 2014 to 2018, coefficients and 95% CI. Note: coefficient estimates and 95% CI come from sample-weighted linear regressions using 2014–2018 National Health Interview Survey data on 26- to 54-year-old respondents. Smoking cessation is defined as having quit smoking conventional cigarettes in the past year, with that analysis restricted to respondents who reported smoking at some point in the prior 12 months. Controls not shown include the conventional cigarette tax rate, median household income, and binary indicators for 5-year age group, sex, race, ethnicity, education, urban status, and employed status. Analyses exclude counties where vape-free law coverage exceeds smoke-free law coverage for a given venue at any point between 2014 and 2018. Standard errors are clustered at the state level (see Table A2 in the Supporting information Data S1 for regression results). *$P < 0.05$

worksite policy's effect on current smoking among emerging adults, introducing vape-free air laws may not be a net benefit for public health. This finding warrants caution among policymakers, and further study.

Strengths and limitations

This research engages with a pressing issue in tobacco policy: given the apparent relationship between consumers' use of conventional and electronic cigarettes, how do policies targeted to reduce smoking or vaping impact use of the other product? Analyses indicate an ongoing benefit from smoke-free worksite laws through reductions in current smoking and increased smoking cessation, even with the rise of e-cigarettes. Indeed these policies were also associated with reductions in recent vaping. In contrast, we could not rule out that adding vape-free requirements to these laws may reduce their impact on current smoking among emerging adults. Although unmeasured confounders might drive these results, the inclusion of quarter-year and state fixed effects as well as controls for baseline county-level smoking rates mean that an unobserved confounder would have to vary over time within states in a manner correlated with the timing of counties' smoke- or vape-free air laws in a specific venue (worksite or restaurants), as well as the outcome variable. Therefore, these findings provide compelling evidence to guide policymakers when considering such regulations.

This study has several limitations. First, because tobacco use is self-reported in the NHIS, both social desirability and recall bias could affect results. If respondents under-report their true smoking or vaping status, estimates may be biased toward zero. Second, because the survey did not ask about vaping before 2014, analyses are limited to the 2014–2018 waves, and specification checks controlling for county-level baseline vaping rates are not possible. Third, although time since smoking cessation can be identified in the NHIS, the same is not true for vaping. Therefore, we cannot assess past year vaping cessation. Prior vaping analyses—indicating an individual who ever-vaped but does not currently use e-cigarettes—are considered, but may be biased toward the null if some ex-vapers quit before a particular policy was adopted. More detailed data on past vaping patterns and time since last vaped are needed to assess policies' effects on vaping cessation.

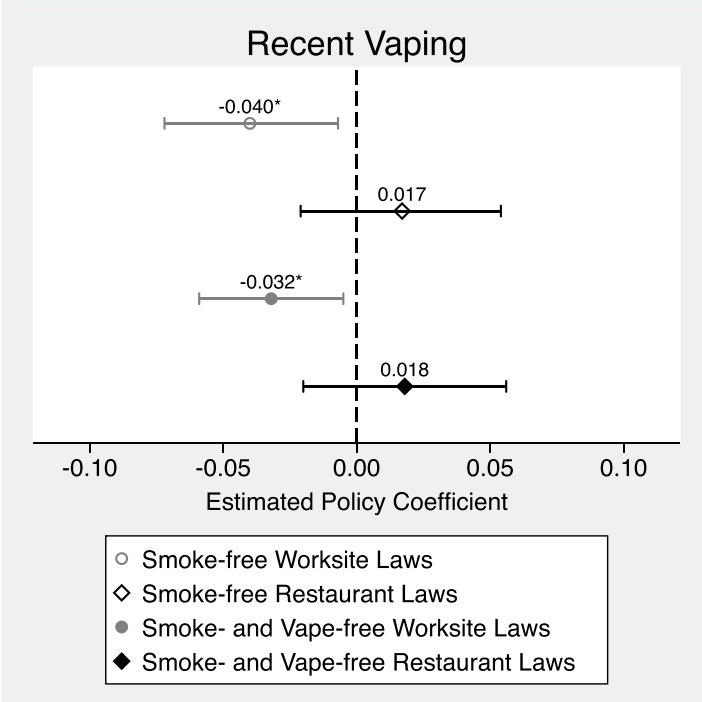

Figure 3 FigureRelationship of smoke- and vape-free indoor air laws to recent vaping among 18- to 25-year-olds from 2014 to 2018, coefficients and 95% CI. Note: coefficient estimates and 95% CI come from sample-weighted linear regressions using 2014–2018 National Health Interview Survey data on 18- to 25-year-old respondents. Controls not shown include the conventional cigarette tax rate, median household income, and fixed effects for year of age, sex, race, ethnicity, education, urban status, employed status, and whether the respondent can legally purchase conventional cigarettes. Analyses exclude counties where vape-free law coverage exceeds smoke-free law coverage for a given venue at any point between 2014 and 2018. Standard errors are clustered at the state level (see Table A3 in the Supporting information Data S1 for regression results). *$P < 0.05$

Separate from data limitations, this analysis did not consider qualified smoke-free air laws (i.e. those with workplace or restaurant size exemptions, or that allows smoking in separately ventilated rooms). If these "qualified" laws impacted smoking or vaping, the difference between outcomes in areas with and without full smoke-free policies would be reduced, biasing coefficient estimates toward zero. Similarly, e-cigarette taxes were not considered for both conceptual and practical reasons (see Supporting information Data S1 for further detail).

Finally, regressions considered 18- to 25-year-olds separately from 26- to 54-year-olds, a choice that might exclude some late initiators and early quitters from the corresponding analyses. Still, with 98% of US smoking initiation occurring before age 26 [26], this is unlikely to substantively alter the initiation sample size and helps distinguish established smokers' cessation from a temporary experimenter's decision not to progress to habitual use, facilitating a clearer interpretation of regression results.

CONCLUSIONS

Evidence that consumer demand for conventional and electronic cigarettes is inter-related calls for careful analysis of how laws targeting one of these products impact use of the other. This study finds that smoke-free worksite laws continue to be an effective mechanism to reduce smoking, even with the advent of widespread e-cigarette use. Indeed, these laws were also associated with reductions in recent e-cigarette use. Localities that have not introduced smoke-free worksite laws should consider adopting them as a means to reduce smoking and vaping uptake, and increase smoking cessation. In contrast, localities and states considering adding vaping restrictions to their smoke-free air laws should note that these may not have their intended effect– we found no further reduction in vaping from these restrictions. Policymakers should also consider potential effects on smoking as well as vaping, such amendments may have the unintended consequence of increasing smoking among emerging adults relative to smoke-free laws that do not restrict e-cigarette use.

Declaration of interests

None of the authors have any conflicts of interest with this research.

Acknowledgements

This research was supported by an Evidence for Action grant from the Robert Wood Johnson Foundation (grant

74869). The Robert Wood Johnson Foundation had no role in the study's design or conduct; the data's collection, analysis, or interpretation, or the manuscript's preparation. The content is solely the responsibility of the authors and does not necessarily represent the official views of the Robert Wood Johnson Foundation. Data on smoke- and vape-free air laws were provided by the American Nonsmokers' Rights Foundation US Tobacco Control Laws Database.

Author contributions

Abigail Friedman: Conceptualization; formal analysis; funding acquisition; methodology; supervision. **Jon Oliver:** Data curation; formal analysis; visualization. **Susan Busch:** Methodology; supervision.

References

1. Fichtenberg C. M., Glantz S. A. Effect of smoke-free workplaces on smoking behaviour: systematic review. *BMJ* 2002; **325**: 188.
2. Callinan J. E., Clarke A., Doherty K., Kelleher C. Legislative smoking bans for reducing secondhand smoke exposure, smoking prevalence and tobacco consumption. *Cochrane Database Syst Rev* 2010; **4**: CD005992.
3. Friedman A. S. How does electronic cigarette access affect adolescent smoking? *J Health Econ* 2015 Dec 1; **44**: 300–8.
4. Stoklosa M., Drope J., Chaloupka F. J. Prices and e-cigarette demand: evidence from the European Union. *Nicotine Tob Res* 2016; **18**: 1973–80.
5. Pesko M. F., Warman C. The effect of prices on youth cigarette and E-cigarette use: economic substitutes or complements. *SSRN* 2017.
6. Dave D., Feng B., Pesko M. F. The effects of e-cigarette minimum legal sale age laws on youth substance use. *Health Econ* 2019; **28**: 419–36.
7. Etter J. F., Bullen C. Electronic cigarette: users profile, utilization, satisfaction and perceived efficacy. *Addiction* 2011; **106**: 2017–28.
8. Dawkins L., Turner J., Roberts A., Soar K. 'Vaping' profiles and preferences: an online survey of electronic cigarette users. *Addiction* 2013; **108**: 1115–25.
9. Glasser A. M., Collins L., Pearson J. L., Abudayyeh H., Niaura R. S., Abrams D. B., *et al*. Overview of electronic nicotine delivery systems: a systematic review. *Am J Prev Med* 2017; **52**: e33–e66.
10. Goniewicz M. L., Smith D. M., Edwards K. C., Blount B. C., Caldwell K. L., Feng J., *et al*. Comparison of nicotine and toxicant exposure in users of electronic cigarettes and combustible cigarettes. *JAMA Netw Open* 2018; **1**: e185937.
11. Czoli C. D., Fong G. T., Goniewicz M. L., Hammond D. Biomarkers of exposure among "dual users" of tobacco cigarettes and electronic cigarettes in Canada. *Nicotine Tob Res* 2019; **21**: 1259–66.
12. National Center for Health Statistics. Survey Description, National Health Interview Survey, 2017. Hyattsville, Maryland 2018.
13. National Center for Health Statistics. Survey Description, National Health Interview Survey, 2014. Hyattsville, Maryland. 2015.
14. American Nonsmokers' Rights Foundation. 2019. U.S. Tobacco Control Laws Database.
15. Liu Y. The Effect of County-level Smoke-free Air (SFA) Policies on Smoking and Drinking (Doctoral dissertation). Available at: https://hdl.handle.net/10027/21561 (accessed May 2020).
16. Preventing Tobacco Addiction Foundation. 2019. Available at: https://tobacco21.org/ (accessed May 2020).
17. Office on Smoking and Health (OSH). State Tobacco Activities Tracking and Evaluation (STATE) System: Custom Reports, 2019. Available at: https://nccd.cdc.gov/STATESystem/rdPage.aspx?rdReport=OSH_State.CustomReports (accessed May 2020).
18. Institute of Medicine Appendix A: State and Local Laws on the Minimum Age of Legal Access to Tobacco Products. In: Bonnie R. J., Kwan L. Y., Stratton K. R., editors. *Public health implications of raising the minimum age of legal access to tobacco products*. Washington, DC: National Academies Press; 2015: 265–86.
19. US Census Bureau, American Community Survey, using American FactFinder. Available at: http://factfinder.census.gov (accessed 12 August 2018).
20. Economic Research Service, US Department of Agriculture, 2013. Available at: https://www.ers.usda.gov/data-products/rural-urban-continuum-codes/ (accessed 12 August 2018).
21. Lillard D. R., Molloy E., Sfekas A. Smoking initiation and the iron law of demand. *J Health Econ* 2013; **32**: 114–27.
22. Herd N., Borland R., Hyland A. Predictors of smoking relapse by duration of abstinence: findings from the international tobacco control (ITC) four country survey. *Addiction* 2009; **104**: 2088–99.
23. García-Rodríguez O., Secades-Villa R., Flórez-Salamanca L., Okuda M., Liu S. M., Blanco C. Probability and predictors of relapse to smoking: results of the National Epidemiologic Survey on alcohol and related conditions (NESARC). *Drug Alcohol Depend* 2013; **132**: 479–85.
24. University of Wisconsin Population Health Institute. County Health Rankings, Adult Smoking, 2019.
25. Wooldridge J. *Econometric analysis of cross section and panel data*. Cambridge, Mass: MIT Press; 2002, pp. 543–7.
26. US National Institutes of Health. National Cancer Institute. Cancer trends progress report March 2020 update. Available at: https://progressreport.cancer.gov/prevention/smoking_initiation#field_additional_information (accessed June 2020).

Supporting Information

Additional supporting information may be found online in the Supporting Information section at the end of the article.

Data S1 Supporting information.

