

Flavored Tobacco Sales Restrictions and Teen E-cigarette Use: Quasi-experimental Evidence From California

Melanie S. Dove MPH ScD¹, Kevin Gee EdD², Elisa K. Tong MD³

¹Division of Health Policy and Management, Department of Public Health Sciences, University of California, Davis, USA

²School of Education, University of California, Davis, USA

³Department of Internal Medicine, University of California, Davis, USA

Corresponding Author: Melanie S. Dove, ScD, MPH, University of California Davis Medical Sciences 1-C, One Shields Avenue, Davis, CA 95616, USA.
Telephone: 202-641-5920; Fax: (530) 752-3239; E-mail: mdove@ucdavis.edu

Abstract

Introduction: Flavored tobacco sales restrictions (FTSRs) are implemented to reduce access to flavored tobacco products. We examined the association between seven cities with local FTSRs implemented in 2018/2019 and e-cigarette use among high school students in the California Bay Area.

Aims and Methods: We analyzed data from the California Healthy Kids Survey using a difference-in-differences (D-I-D) strategy. We compared pre- and post-policy changes one year after implementation in current and ever e-cigarette use among students attending school in a city with a FTSR (exposed) ($n = 20\,832$) versus without (unexposed) ($n = 66\,126$). Other outcomes included ever marijuana use in an e-cigarette and ease of access to e-cigarettes.

Results: Pre- to post-policy, the adjusted odds of current and ever e-cigarette use did not significantly change among students exposed and unexposed to a FTSR. In the adjusted D-I-D analysis, the odds of current (aOR: 1.25, 95% CI: 0.95, 1.65) and ever e-cigarette use (aOR: 1.06, 95% CI: 0.89, 1.26) did not significantly change by exposure group. However, one year post-implementation, the odds of ease of access to e-cigarettes significantly increased among exposed (aOR: 1.57, 95% CI: 1.27, 1.95) and unexposed students (aOR: 1.54, 95% CI: 1.39, 1.70). Similarly, the odds of ever using marijuana in an e-cigarette significantly increased among exposed (aOR: 1.35, 95% CI: 1.19, 1.53) and unexposed students (aOR: 1.29, 95% CI: 1.20, 1.39).

Conclusions: Local FTSRs in the California Bay Area were not associated with a change in e-cigarette use one year post-implementation. Increased ease of access and marijuana use may be explanatory factors.

Implications: FTSRs were not associated with a decrease in current or ever e-cigarette use among high school students in the California Bay Area one-year post-implementation. Potential explanatory factors are that ease of access to e-cigarettes and using marijuana in an e-cigarette increased. More research is needed to understand the influence of these factors on youth access and behaviors. To address the youth e-cigarette epidemic, a comprehensive approach is needed, including policies, media campaigns, education programs, and cessation tools targeted to youth.

Introduction

The U.S. Surgeon General reported that youth vaping is an epidemic.¹ Past 30-day e-cigarette use among U.S. high school students nearly doubled in one year from 9.5% in 2017 to 18.3% in 2018 and continued to increase to 22.5% in 2019 and 21.8% in 2020.² This dramatic increase in use was driven by flavors that appeal to youth, a discreet design, social media marketing, and high nicotine levels.³ Indeed, among current users, 97% used a flavored product in the past month.⁴

There is currently no national policy banning all flavors from all tobacco products. Flavors (except for menthol) were banned from cigarettes through the 2009 Family Smoking Prevention and Tobacco Control Act, and the FDA recently announced that it will work towards banning menthol from cigarettes and all flavors from cigars.⁵ Municipalities have passed local flavored tobacco sales restrictions (FTSRs) that are more restrictive than national policies.⁶ As of December 2021, 353 U.S. jurisdictions have some type of restriction on the sale of flavored tobacco products, many of which are in

California.⁶ Most recent estimates (2020) show that 22.1% of the California population was covered by a local FTSR, including those with and without exemptions, such as allowing menthol or sales in adult only stores.⁷

Studies show that local FTSRs decrease the availability and sales of flavored tobacco products in retail stores.^{8–10} However, there is limited evidence examining the impact of FTSRs on change in e-cigarette use and only three studies have included data before policy implementation as a comparison. In addition, no studies have examined using marijuana in an e-cigarette. This may be an important outcome to study as half of current youth e-cigarette users had ever used marijuana in an e-cigarette.¹¹ In Massachusetts, local FTSRs were associated with a decrease in youth e-cigarette use,^{12–14} and the San Francisco FTSR was associated with a decrease in young adult tobacco and flavored cigar use.¹⁵ FTSRs have also been associated with individual users switching sources of flavored tobacco products from retail stores to social sources.¹⁶

The aim of this study is to examine if FTSRs were associated with a change in e-cigarette use among high school students in California. We also examined ease of access to e-cigarettes and use of marijuana in an e-cigarette. This study includes data before and after policy enforcement and a comparison group without a policy. Given prior empirical evidence linking FTSRs to reduced e-cigarette use,^{12–15} we hypothesize that there will be an association between FTSRs and decreased prevalence of e-cigarette use.

Methods

Data Source

The California Healthy Kids Survey (CHKS) is a comprehensive whole child, school climate, and youth risk behavior data collection service available to all California local education agencies, and is funded by the California Department of Education. Students attending middle and high schools (grades 9 and 11) in California completed an in-person survey during the academic school year from September to June. Although most schools participate once every two years, schools are on different two-year cycles so that data is collected every year. Participation is voluntary, confidential, and passive parental consent was obtained. Student response rate was 75% in 2017–2019.¹⁷ According to the CHKS survey administrators, a majority of completed surveys for the Spring 2020 data were administered in-person before school closures due to COVID-19.

Since all cities with a FTSR that met our inclusion criteria (see below) were in the San Francisco Bay Area (a region of almost 7000 square miles and 7.1 million people), we restricted the analysis to nine counties in the Bay Area (Alameda, Contra Costa, Marin, Napa, San Francisco, San Mateo, Santa Clara, Solano, and Sonoma). We merged the CHKS data from the 2017/2018 and 2019/2020 school years ($n = 277\,449$) with 2020 data from the California Department of Education to determine the city each high school was located in, school size, and the percent of the school eligible for free or reduced-price meals.¹⁸ For additional city characteristics, we also merged population density data from 2015 to 2019 American Community Survey and tobacco retailer data from the 2018 California Department of Tax and Fee Administration, obtained from the California Community Health Assessment Tool.¹⁹ The Public Health Law Center provided a list of all FTSR policies in California, their implementation or enforcement dates, and any exclusions (M. Meany, personal communication, November 16, 2020). This list matched the policy information in the Flavored Tobacco Policy Evaluation Tracking System, a database maintained by the American Non-Smokers Rights Foundation and California Tobacco Control Program.¹⁰ After merging, there were 274 550 students.

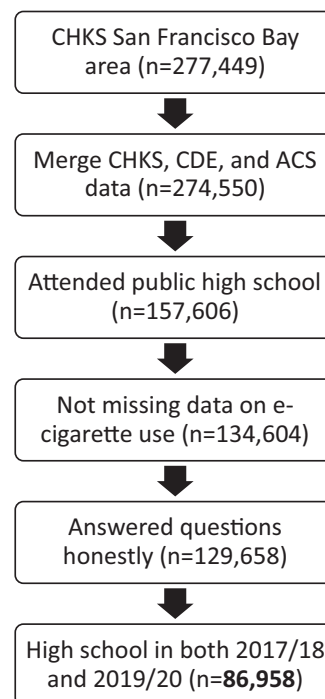
We restricted the data to students attending public high schools or K-12 schools ($n = 157\,606$), who were not missing information on current e-cigarette use ($n = 134\,604$), and reported that they answered all or most of the questions honestly ($n = 129\,658$) (Figure 1). Cities with FTSR policies that were not implemented in 2018/2019 or did not have CHKS data in both 2017/2018 and 2019/2020 were excluded, for a final sample size of 86 958 (46 535 in 2017/2018 and 40 423 in 2019/2020). Table 1 shows a list of included cities and their characteristics. Supplementary table 1 suggests that the

students included in our sample were not substantially different from all students in the Bay Area region of California. The UC Davis Institutional Review Board determined that this study was “exempt”.

Exposure to FTSR

Students were classified as being exposed to a FTSR if their high school was in a city with a FTSR implementation date (enforcement or effective date) during the 2018/2019 school year, or the summer before or after (July 2018–August 2019). Seven cities met these criteria, resulting in 20 832 high school students classified as exposed to FTSR policies (Table 1). The unexposed group included students living in cities in the Bay Area without a FTSR policy adopted before June 2020 ($n = 66\,126$). County FTSR policies only applied to unincorporated areas and were excluded. A timeline of cities with FTSRs included in the analysis is shown in Supplementary figure 1 and a map is shown in Supplementary figure 2.

Among the seven cities with FTSRs, four had comprehensive policies (ie, all flavors from all tobacco products were banned). The three cities with exemptions included two cities that excluded adult-only stores and one city that excluded several products (menthol, premium cigars, large packs of cigars, smokeless tobacco, and pipe tobacco). Two sensitivity analyses were conducted. In the first, students were classified as (1) exposed to comprehensive FTSRs or (2) exposed to a FTSR with an exemption or not exposed to a FTSR. In the second sensitivity analysis, students exposed to FTSRs with exemptions were excluded from the unexposed group.



Footnote: CHKS = California Healthy Kids Survey, CDE = California Department of Education, ACS = American Community Survey

Figure 1. Analysis sample accrual flowchart.

Table 1. Characteristics of Cities in the Bay Area Region of California With and Without Flavored Tobacco Sales Restrictions (FTSR)

	Effective/ enforced date	Policy type	Population	Land area (square miles)	Number of tobacco retailers within 1000' of a public school	Number of public high schools
Unexposed cities ^a (median)	NA		69 567	14.4	5	4
Exposed cities (median)			425 097	46.9	20	31
Oakland	7/18/2018	Adult-only stores excluded	425 097	55.8	10	34
Windsor	7/30/2018	Menthol and several to- bacco products excluded ^b	27 447	7.3	2	3
Palo Alto	1/1/2019	Adult-only stores excluded	66 573	23.9	1	2
San Francisco	1/1/2019	Comprehensive	874 961	46.9	101	31
Lafayette	6/26/2019	Comprehensive	26 305	15.2	2	1
Alameda	7/1/2019	Comprehensive	78 522	10.6	7	7
Livermore	8/7/2019	Comprehensive	89 699	25.2	8	7

^aUnexposed cities include: American Canyon, Brentwood, Calistoga, Castro Valley, Concord, Daly City, Dixon, Fairfield, Forestville, Gilroy, Healdsburg, Martinez, Millbrae, Milpitas, Moraga, Mountain View, Napa, Oakley, Orinda, Petaluma, Piedmont, Pleasant Hill, Pleasanton, Rohnert Park, San Bruno, San Lorenzo, San Mateo, Santa Rosa, Sebastopol, St. Helena, Vacaville, Vallejo, Walnut Creek.

^bPremium cigars (priced over \$5), large packs of cigars and smokeless tobacco (5 units or more), and pipe tobacco excluded.

Sources:

Dates—Public Health Law Center.

Population (2015–2019 American Community Survey), number of tobacco retailers within 1000' of a public school (2018 California Department of Tax and Fee Administration), and number of public high schools (2020 California Department of Education) obtained from The California Tobacco Health Assessment Tool (<https://cthat.org>).

Land area—2010 Census.

Outcome Variables: E-cigarette Use

The main outcome variable was current e-cigarette use. The questions for current e-cigarette use changed slightly over time to account for the introduction of JUUL. From 2017 to 2019, the question was “During the past 30 days, on how many days did you use electronic cigarettes, e-cigarettes, or other vaping device such as juul (*added in 2018/2019*), e-hookah, hookah pens, or vape pens.” In 2019/2020, each question was shortened to ask about “vape products”, which were defined at the beginning of the question as “Electronic devices like vape pens, e-cigarettes, e-hookah, hookah pens, e-vaporizers, tanks, pods, or mods used to inhale a vapor.” To capture the prevalence of tobacco use, we coded any respondent who reported ≥ 1 days as having used, 0 otherwise. Among current e-cigarette users, students were classified as using almost daily if they reported using an e-cigarette 20–30 days in the past month (coded as 1 = daily user, 0 otherwise).

Other outcomes included ever e-cigarette use, ever using marijuana in an e-cigarette, and ease of access to e-cigarettes. For the latter, students were asked “How difficult is it for students in your grade to get any of the following if they really want them [E-cigarettes (electronic) or vaping device]?” Students who responded with “very easy” were compared with those who responded with “fairly easy”, “fairly difficult”, “very difficult”, or “don’t know”.

Covariates

Covariates include time-invariant characteristics at the student, school, and city-level. Student level covariates included gender (male, female), grade (9th, or 11th), term (fall or winter), race/ethnicity (Hispanic, Non-Hispanic [NH] Asian, NH Black, NH White, NH other [American Indian/Alaskan

Native and Native Hawaiian/Pacific Islander combined for models], and NH mixed race), sexual orientation (straight, gay/lesbian/bisexual, or not sure/something else), parents' education (did not finish high school, graduated from high school, attended some college, graduated from college, or don't know), type of home (a home with a parent, a relative, or friends home, or a foster home, hotel, shelter, or other), and home language (English, Spanish, or other).

School level covariates were obtained from the 2020 California Department of Education data and included school size (≤ 2000 , >2000) and the percent of the school eligible for free or reduced-priced meals ($>50\%$, $\leq 50\%$). City level covariates included population density (from 2015 to 2019 American Community Survey) and number of tobacco retailers within 1000 feet of schools (from the 2018 California Department of Tax and Fee Administration). Population density was calculated by dividing the population by the land area and categorized into quartiles.

Statistical Analysis

The percent of students in each FTSR exposure category was calculated for each covariate and differences were examined using a chi-square test. In addition, the prevalence of each outcome was calculated before (2017/2018) and after (2019/2020) policy implementation by FTSR category. We estimated difference-in-differences (D-I-D) models using logistic regression to compare how the prevalence of each outcome changed post-policy to pre-policy, and between students exposed to a FTSR relative to unexposed students. To obtain the D-I-D odds ratio, we included an interaction term between year (2019/2020 compared with 2017/2018) and exposure group (FTSR: yes or no). Models were adjusted for covariates previously described. To account for clustering of students within schools, SAS survey procedures were used. All

analysis was conducted using SAS version 9.4 (SAS Institute, Cary, NC).

To assess the parallel trends assumption for a D-I-D model, the percent of high school students who had ever or were currently using an e-cigarette was calculated from 2015/2016 to 2019/2020 for exposed and unexposed students (Supplementary figure 3). Data on two variables, marijuana use in an e-cigarette and ease of access to e-cigarettes, was not available until 2017 and was not included in the parallel trends analysis. Before policy implementation (2018/2019), current and ever e-cigarette use appeared to decrease from 2015 to 2016 and then increase in 2017. Therefore, we assessed the parallel trends assumption by including an interaction term (year \times FTSR), using 2016 as the referent category, in logistic regression models. We found no difference in current and ever e-cigarette use over time by FTSR group, suggesting that the parallel trends assumption holds. Results of the logistic regression models are shown in Supplementary tables 2a and 2b.

Results

Among high school students living in the San Francisco Bay Area of California, approximately 20% were in cities with a FTSR. As shown in Table 2, approximately half of the students in the analysis were male, in the 11th grade, and had a parent that graduated from college. Over 1/3 (35.5%) of students were Hispanic, 19.1% were NH Asian, 4.7% NH Black, and almost a quarter (26.8%) were NH White. Almost 10% of students were gay, lesbian, or bisexual. Most (92.9%) students lived in a home with a parent and 2/3 spoke English at home. There were no differences in student variables by exposure status. However, schools in cities with a FTSR had more students eligible for free or reduced-price meals.

As shown in Table 3, there was no significant change in the adjusted odds of current e-cigarette use pre- to post-policy among students exposed to a FTSR (aOR: 1.12, 95% CI: 0.86, 1.45) and unexposed (aOR: 0.90, 95% CI: 0.81, 1.00). Adjusted D-I-D estimates show no pre- to post-policy difference in the odds of current e-cigarette use among students exposed to a FTSR relative to those unexposed to a FTSR (aOR = 1.25, 95% CI: 0.95, 1.65). Among current e-cigarette users, there was a significant increase in the adjusted odds of almost daily e-cigarette use among students unexposed to a FTSR (aOR: 1.25, 95% CI: 1.10, 1.42). However, the increase among exposed students was not significant (aOR: 1.27, 95% CI: 0.91, 1.79).

Consistent with the current e-cigarette results, there was no significant change in the adjusted odds of ever e-cigarette use pre- to post-policy among students exposed (aOR = 1.08, 95% CI: 0.91, 1.27) and unexposed (aOR = 1.02, 95% CI: 0.94, 1.09) to a FTSR. Adjusted D-I-D estimates show no pre- to post-policy change in exposed compared with unexposed students (aOR: 1.06, 95% CI: 0.89, 1.26).

Two factors had significant increases pre- to post-policy among both FTSR exposure groups. The adjusted odds of ease of access to e-cigarettes significantly increased 57% among students exposed (aOR = 1.57, 95% CI: 1.27, 1.95) and 54% among students unexposed (aOR = 1.54, 95% CI: 1.39, 1.70) to a FTSR. Likewise, the odds of ever using marijuana in an e-cigarette significantly increased 35% among students exposed (aOR = 1.35, 95% CI: 1.19, 1.53) and 29% among students unexposed (aOR = 1.29, 95% CI: 1.20,

1.39) to a FTSR. Adjusted D-I-D estimates show that for both outcomes, pre- to post-policy increases were not significantly different for students who were exposed and unexposed to a FTSR.

These findings remained consistent in a set of sensitivity analyses. In the first set of analyses, we compared students who were exposed to a comprehensive FTSR versus a combined group of students who were either exposed to a FTSR with an exemption or unexposed to a FTSR (Supplementary table 3). In the second set, we compared students exposed to a comprehensive FTSR versus those unexposed to a FTSR (Supplementary table 4).

Discussion

Based on the D-I-D estimates, we did not detect a significant association between FTSRs (any or only comprehensive) and current and ever e-cigarette use one-year post-implementation in the California Bay Area. However, when looking at students' outcomes with and without exposure to a FTSR separately, some interesting patterns emerge. Among current e-cigarette users, almost daily use increased pre- to post-policy, but only the increase in unexposed students was statistically significant. In both exposure groups, there was an overall increase in ease of access to e-cigarettes. Marijuana use in an e-cigarette also increased pre- to post-policy among students with and without exposure to a FTSR.

The lack of substantial change in current e-cigarette use in students exposed and unexposed to a FTSR is consistent with overall trends in California youth. Among all 11th graders in the CHKS, e-cigarette use remained stable from 2015–2017 (10%) to 2017–2019 (11%)²⁰ and among high school students in the California Student Tobacco Survey e-cigarette use was 8.6% in 2016, 10.5% in 2018, and 8.2% in 2020.⁷ Tobacco control efforts other than FTSRs targeted toward youth may have contributed to this overall lack of substantial change in e-cigarette use, such as the Tobacco 21 policy (June 2016), the \$2.00 increase in tobacco tax (January 2017), school education programs, or media campaigns, such as California's Flavors Hook Kids.²¹

Our results of no association between FTSRs and e-cigarette use one year post-implementation is not consistent with prior research suggesting that FTSRs reduced retail availability^{8–10} and youth and young adult use of tobacco products.^{12–15} A possible reason for our different results is that the survey questionnaire did not differentiate between flavored and non-flavored e-cigarettes. Among students exposed to a FTSR, it is possible that pre- to post-policy flavored e-cigarette use decreased and non-flavored e-cigarette use increased, resulting in the overall lack of change we observed. Substitution has previously been found after flavor ban policies.^{22,23} Rather than quitting e-cigarettes if flavors are no longer available, youth may turn to replacement products.

In addition to switching products, youth may be switching sources of flavored e-cigarette products. For example, among current flavored e-cigarette users in California (age 15–29 years), those in cities with a policy were less likely to obtain them from a retail store and more likely to obtain them from social sources, compared with their peers in the rest of the state without a policy.¹⁶ Another possible reason for the lack of change in the exposed group is that cities with FTSRs may have already had strong tobacco control efforts and a lower prevalence of youth e-cigarette use. Indeed, students exposed

Table 2. Characteristics of High School Students in California by Flavored Tobacco Sales Restriction Category, CHKS 2017/2018 and 2019/2020 (*n* = 86 958)

	2017/2018 and 2019/2020	Pre-policy 2017/2018		Post-policy 2019/2020	
		Unexposed (<i>n</i> = 35 070)	Exposed (<i>n</i> = 11 465)	Unexposed (<i>n</i> = 31 056)	Exposed (<i>n</i> = 9367)
Number of cities	40	33	7	33	7
Number of schools	79	53	26	53	26
Student variables					
Male	49.9	49.9	50.1	49.7	50.4
11th grade	45.5	46.0	45.2	45.3	44.5
Race/ethnicity					
Hispanic	35.5	35.2	33.7	36.9	34.6
NH American Indian/Alaskan Native	0.53	0.54	0.42	0.57	0.49
NH Asian	19.1	18.3	22.0	17.8	23.1
NH Black	4.7	3.7	8.6	3.5	7.5
NH Native Hawaiian/Pacific Islander	2.2	2.6	1.7	2.3	1.4
NH White	26.8	28.1	23.6	27.8	22.3
NH Mixed	11.2	11.5	10.1	11.2	10.8
Sexual orientation					
Straight	84.7	85.4	84.8	84.4	82.8
Gay, lesbian, or bisexual	9.0	8.1	8.7	9.6	10.4
Not sure or something else	6.3	6.5	6.5	5.9	6.8
Parents education					
<High school	11.9	10.4	16.0	11.1	15.2
High school	13.5	13.5	14.3	13.2	13.5
Some college	11.9	13.2	10.2	11.9	9.2
College graduate	51.9	50.1	46.7	53.5	48.5
Don't know	10.8	9.9	12.7	10.3	13.6
Type of home					
Home with a parent	92.9	93.2	91.4	93.6	91.8
Relative/friend's home	5.0	4.7	6.3	4.5	5.9
Foster, hotel, shelter, other	2.1	2.1	2.3	2.0	2.3
Home language					
English	68.8	69.3	61.3	72.1	65.0
Spanish	19.2	17.8	21.0	19.5	21.8
Other	12.0	12.9	17.7	8.3	13.2
School level variables					
>2000 students	25.8	30.1	15.2	28.0	15.7
≥50% of school eligible for FRPM	18.6	11.4	39.4*	13.4	37.6*
City level variables					
Population density (population/land area)					
<3520	28.5	31.4	17.9	31.8	20.2
3520–4226	22.8	24.0	20.6	24.9	14.4
4226–7620	21.1	25.3	9.7	23.8	10.9
>7620	27.5	19.4	51.9	19.5	54.5
Number of tobacco retailers within 1000 feet of a school (mean)	9.2	5.9	12.5	6.0	12.7

Abbreviations: CHKS, California Healthy Kids Survey; FRPM, Free or Reduced Price Meal; FTSR, Flavored Tobacco Sales Restriction; NH, Non-Hispanic.
**p*-value from chi-square test <.05 comparing unexposed (no FTSR) to exposed (FTSR) students by year.

Sources:

School level variables (school size and percent eligible for FRPMs) from the 2020 California Department of Education.

Population (2015–2019 American Community Survey) and number of tobacco retailers within 1000' of a public school (2018 California Department of Tax and Fee Administration) obtained from The California Tobacco Health Assessment Tool (<https://cthat.org>).

Land area—2010 Census.

Table 3. Association Between Exposure to Any Flavored Tobacco Sales Restrictions and Student E-cigarette Use, CHKS 2017/2018 and 2019/2020

	Pre-policy 2017/2018	Post-policy 2019/2020	Post compared with pre-policy					
			Unadjusted (<i>n</i> = 86 958)			Adjusted ^a (<i>n</i> = 77 760)		
			OR (95% CI)	D-I-D OR (95% CI)	<i>p</i> ^b	OR (95% CI)	D-I-D OR (95% CI)	<i>p</i> ^b
Current e-cigarette use								
Exposed	10.5	11.1	1.06 (0.84, 1.36)	1.22 (0.94, 1.58)	.14	1.12 (0.86, 1.45)	1.25 (0.95, 1.65)	.11
Unexposed	12.8	11.4	0.88 (0.79, 0.98)	ref		0.90 (0.81, 1.00)	ref	
Almost daily e-cigarette use^c								
Exposed	20.8	22.7	1.12 (0.81, 1.55)	0.94 (0.66, 1.33)	.71	1.27 (0.91, 1.79)	1.01 (0.71, 1.46)	.94
Unexposed	21.2	24.3	1.19 (1.06, 1.34)			1.25 (1.10, 1.42)		
Ever e-cigarette use								
Exposed	20.8	21.5	1.04 (0.91, 1.18)	1.05 (0.90, 1.22)	.51	1.08 (0.91, 1.27)	1.06 (0.89, 1.26)	.52
Unexposed	24.0	23.8	0.99 (0.91, 1.07)			1.02 (0.94, 1.09)	ref	
Ever used marijuana in an e-cigarette								
Exposed	16.9	20.6	1.27 (1.14, 1.42)	1.04 (0.91, 1.18)	.59	1.35 (1.19, 1.53)	1.05 (0.91, 1.21)	.53
Unexposed	17.6	20.8	1.23 (1.14, 1.32)	ref		1.29 (1.20, 1.39)	ref	
Access to e-cigarettes								
Easy to obtain								
Exposed	30.6	39.2	1.46 (1.17, 1.84)	1.01 (0.78, 1.29)	.96	1.57 (1.27, 1.95)	1.02 (0.81, 1.29)	.85
Unexposed	34.6	43.5	1.46 (1.30, 1.62)	ref		1.54 (1.39, 1.70)	ref	

Abbreviations: CHKS, California Healthy Kids Survey; D-I-D, Differences in differences analysis; OR, odds ratio.

Bold values indicate statistically significant odds ratios comparing pre- to post-policy change in each outcome ($p < .05$).

^aAdjusted for gender, grade, race/ethnicity, sexual orientation, parent education, type of home, home language, term, school size, percent of school eligible for Free or Reduced Price Meals, population density, and the number of tobacco retailers within 1000' of a school.

^b*p*-value for interaction term between year and FTSR exposure status.

^c20–30 times/month among current users ($n = 10\ 304$).

to a FTSR had a lower pre-policy e-cigarette prevalence, but the post-policy e-cigarette prevalence was similar for students unexposed (11.4%) and exposed (11.1%) to a FTSR.

Our finding of an increase in ease of access to e-cigarettes among all groups, irrespective of whether they were exposed or unexposed to a FTSR, is consistent with research showing that non-flavored e-cigarettes are still available in stores, and a lack of complete compliance of retail stores to FTSRs and minimum age policies. Flavored e-cigarettes were still available to purchase in approximately 20% of retail stores one year after San Francisco's FTSR.¹⁵ In addition, nearly half (45%) of vape shops and tobacco stores in California still sold e-cigarettes to underage youth in 2018.^{24,25} Likewise, youth and young adults exposed to a FTSR in California were more likely to report difficulty in accessing flavored vaping products, but the percentages reporting difficulty were low in those exposed (17.5%) and unexposed to a FTSR (14.8%).²⁶ National studies also show that youth are still able to purchase tobacco products.^{27,28}

An increase in ease of access to e-cigarettes may also result from students traveling to nearby cities without a FTSR to obtain flavored e-cigarettes. As shown in [Supplementary figure 2](#), all exposed cities were adjacent to at least one city without a FTSR. A state level policy may help prevent cross city border purchasing. In 2020, California passed a FTSR at the state level, but the tobacco companies filed a referendum, and the FTSR will not be implemented until January 2023, if approved by voters.²⁹ More research is needed to examine other sources for the increase in access, such as online sales or peer access.

Our finding of an increase in ever using marijuana in an e-cigarette among students exposed and unexposed to a FTSR

is consistent with national data on ever using marijuana in an e-cigarette³⁰ and California data on marijuana use.^{31,32} Research showed an increase in marijuana use among youth³¹ and young adults³² in California following the November 2016 legalization of recreational marijuana, which passed one school year before our pre-policy period. Students may switch to flavored marijuana products in an e-cigarette if flavored e-cigarettes are no longer available. Among high school students in Northern and Central California, 58% of those who smoked marijuana in an e-cigarette used a flavored product.³³ Future policies may consider restricting youth access to retail sales of marijuana. In 2019 the Surgeon General issued an advisory statement about marijuana being harmful to the developing adolescent brain.³⁴

Limitations

Exposure to FTSRs was determined based on the city where each student attended high school, not where they lived, resulting in potential non-differential exposure misclassification, biasing the results towards the null. In addition, in order to have pre- and post-policy data, we only included seven cities with FTSRs out of the 76 municipalities that prohibit all flavors including menthol.⁶ The cities with FTSRs in our sample may be different than cities with FTSRs outside of our sample. We did not have information on all tobacco products, such as flavored cigar use (which decreased after the San Francisco FTSR)¹⁵ or quit attempts. In California, the percent of high school students who tried to quit e-cigarettes in the past 12 months increased from 27.0% in 2018 to 54.6% in 2020.⁷ We did not consider FTSR implementation time, which ranged between one month and one

year. Students from cities with longer FTSR implementation time may have had more time for behavior change. This is an opportunity for future research, as it may even take longer than one year post-implementation to see a change in youth e-cigarette behavior. Last, our estimates of tobacco use are not representative of all high school students in the San Francisco Bay Area, as the data are not weighted. However, estimates for current e-cigarette use from the 2017–2019 CHKS (11.0%) were similar to those from the 2017–2018 California Student Tobacco Survey (10.9%), a weighted survey that is representative of all high school students in California.⁷

Conclusions

Using a D-I-D analysis with a large sample, results suggest that local FTSRs in the California Bay Area were not associated with a change in e-cigarette use one-year post-implementation. Increased ease of access and marijuana use may be explanatory factors. The steep increase in e-cigarette use among U.S. youth in 2018 will need a comprehensive approach to counteract, including policies (FTSRs, e-cigarette inclusive smoke-free policies, etc.), media campaigns, education programs, and cessation tools targeted to youth.

Supplementary Material

A Contributorship Form detailing each author's specific involvement with this content, as well as any supplementary data, are available online at <https://academic.oup.com/ntr>.

Funding

Melanie Dove was supported by the National Center for Advancing Translational Sciences, National Institutes of Health, through grant number UL1 TR001860 and linked award KL2 TR001859. Elisa Tong was supported by the National Cancer Institute Award Number P30CA093373-15S and UC Davis Health System.

Declaration of Interests

None declared.

Acknowledgments

The authors would like to acknowledge Mark Meany from the Public Health Law Center for providing detailed information on Flavored Tobacco Sales Restrictions in California. We would also like to acknowledge Ben Trigg from WestEd for his help with the California Healthy Kids Survey data.

Data Availability

The California Healthy Kids Survey data is available by request: <https://calschls.org/reports-data/>.

References

1. Surgeon General's Advisory on E-cigarette Use Among Youth. <https://e-cigarettes.surgeongeneral.gov/documents/surgeon-generals-advisory-on-e-cigarette-use-among-youth-2018.pdf>. Accessed June 24, 2021.
2. Miech R, Leventhal A, Johnston L. Trends in use and perceptions of nicotine vaping among US youth from 2017 to 2020. *JAMA Pediatr.* 2021;175(2):185–190.
3. Institute for Global Tobacco Control. *State of the Evidence: Flavored Tobacco Product Bans or Restrictions*. 2020. https://www.drugsandalcohol.ie/32662/1/state_of_the_evidence_-_flavor_ban_or_restriction.pdf. Accessed September 7, 2021.
4. *E-cigarettes: Facts, Stats, and Regulations*. 2021. <https://truthinitiative.org/research-resources/emerging-tobacco-products/e-cigarettes-facts-stats-and-regulations#flavors>. Accessed on September 7, 2021.
5. FDA News Release - FDA Commits to Evidence-Based Actions Aimed at Saving Lives and Preventing Future Generations of Smokers. 2021. <https://www.fda.gov/news-events/press-announcements/fda-commits-evidence-based-actions-aimed-saving-lives-and-preventing-future-generations-smokers>. Accessed September 7, 2021.
6. *Flavored Tobacco Policy Restrictions as of December 31, 2021, Truth Initiative*. https://truthinitiative.org/sites/default/files/media/files/2022/04/Q4%202021_FINAL.pdf. Accessed May 6, 2022.
7. California Department of Public Health, California Tobacco Control Program. *California Tobacco Facts and Figures 2021*. Sacramento, CA: California Department of Public Health; 2021.
8. Rogers T, Brown EM, Siegel-Reamer L, et al. A comprehensive qualitative review of studies evaluating the impact of local US laws restricting the sale of flavored and menthol tobacco products. *Nicotine Tob Res.* 2022;24(4):433–443.
9. *Healthy Stores for a Healthy Community. San Francisco County Results*. <https://healthystoreshealthycommunity.com/counties/san-francisco/>. Accessed September 7, 2021.
10. Anderson-Rogers E, Zhang X, Vuong TD, et al. Flavored tobacco sales restrictions effective in reducing the retail availability of flavored tobacco products? A multicomponent evaluation. *Eval Rev.* 2021;45(3-4):134–165.
11. Farsalinos K, Barbouni A, Niaura R. Changes from 2017 to 2018 in e-cigarette use and in ever marijuana use with e-cigarettes among US adolescents: Analysis of the National Youth Tobacco Survey. *Addiction.* 2021;116(1):139–149.
12. Kingsley M, Setodji CM, Pane JD, et al. Short-term impact of a flavored tobacco restriction: Changes in youth tobacco use in a Massachusetts community. *Am J Prev Med.* 2019;57(6):741–748.
13. Hawkins SS, Kruzik C, O'Brien M, Coley RL. Flavored tobacco product restrictions in Massachusetts associated with reductions in adolescent cigarette and e-cigarette use [published online ahead of print]. *Tob Control.* 2022;31(4):576–579. doi:10.1136/tobaccocontrol-2020-056159.
14. Kingsley M, Setodji CM, Pane JD, et al. Longer-term impact of the flavored tobacco restriction in two Massachusetts communities: a mixed-methods study. *Nicotine Tob Res.* 2021;23(11):1928–1935.
15. Yang Y, Lindblom EN, Salloum RG, Ward KD. The impact of a comprehensive tobacco product flavor ban in San Francisco among young adults. *Addict Behav Rep.* 2020;11:100273. doi:10.1016/j.abrep.2020.100273.
16. Gaiha SM, Henriksen L, Halpern-Felsher B, et al. Sources of flavoured e-cigarettes among California youth and young adults: associations with local flavoured tobacco sales restriction [published online ahead of print]. *Tob Control.* 2021. doi:10.1136/tobaccocontrol-2020-056455.
17. Austin G, Hanson T, Zhang G, Zheng C. School climate and student engagement and well-being in California, 2017/19. In: *Results of the Seventeenth Biennial State California Healthy Kids Survey, Grades 7, 9, and 11*. WestEd; 2020.
18. California Department of Education. *Public Schools and Districts Data Files*. <https://www.cde.ca.gov/ds/si/ds/pubschls.asp>. Accessed September 8, 2021.
19. *The California Tobacco Health Assessment Tool (CTHAT) was developed by the Stanford Prevention Research Center and GreenInfo Network, with funding from the Tobacco-Related Disease Research Program grant #22RT-0142, PI: Lisa Henriksen, PhD*. <https://cthat.org>. Last updated September 2020.
20. *California Healthy Kids Survey Data Dashboard*. <https://calschls.org/reports-data/public-dashboards/secondary-student/>. Accessed August 17, 2021.

21. California Tobacco Control Program's Flavors Hook Kids Campaign. <https://www.flavorhookkids.org/#top>. Accessed on August 17, 2021.
22. Carpenter C, Nguyen HV. *Intended and Unintended Effects of Banning Menthol Cigarettes*. NBER Working Paper No. 26811. February 2020, JEL No. 11. https://www.nber.org/system/files/working_papers/w26811/w26811.pdf. Accessed June 10, 2021.
23. Ali FRM, Diaz MC, Vallone D, et al. E-cigarette unit sales, by product and flavor type- United States, 2014-2020. *MMWR*. 2020;69(37):1313–1318.
24. Schiff S, Liu F, Cruz TB. E-cigarette and cigarette purchasing among young adults before and after implementation of California's tobacco 21 policy. *Tob Control*. 2021;30(2):206–211.
25. Roeseler A, Vuong TD, Henriksen L, Zhang X. Assessment of underage sales violations in tobacco stores and vape shops. *JAMA Pediatr*. 2019;173(8):795–797.
26. Feld AL, Rogers T, Gaber J, et al. Impact of local flavored tobacco sales restrictions on policy-related attitudes and tobacco product access [published online ahead of print]. *Health Educ Behav*. 2021. doi:10.1177/10901981211027520.
27. Berg C, Barker DC, Meyers C, et al. Exploring the point-of-sale among vape shops across the United States: audits integrating a mystery shopper approach. *Nicotine Tob Res*. 2021;23(3):495–504.
28. Liu ST, Snyder K, Tynan MA, Want TW. Youth access to tobacco products in the United States 2016-2018. *Tob Regul Sci*. 2019;5(6):491–501.
29. Public Health Law Center-What the Referendum on California's Flavored Tobacco Sales Ban Means. 2021. <https://www.publichealthlawcenter.org/commentary/200904/what-referendum-californias-flavored-tobacco-sales-ban-means>. Accessed August 23, 2021.
30. Watson CV, Puvanesarajah S, Trivers KF. Racial and ethnic differences in marijuana use in e-cigarettes among US youth in 2017, 2018, and 2020. *JAMA Pediatr*. 2021;175(7):746–748.
31. Paschall MJ, Garcia-Ramirez G, Grube JW. Recreational marijuana legalization and use among California adolescents: findings from a statewide survey. *J Stud Alcohol Drugs*. 2021;82:103–111.
32. Meng YY, Ponce NA. *The Changing Landscape: Tobacco and Marijuana Use Among Young Adults in California*. Los Angeles, Calif.: UCLA Center for Health Policy Research; 2020.
33. Werts M, Urata J, Watkins SL, Chaffee BW. Flavored cannabis product use among adolescents in California. *Prev Chronic Dis*. 2021;18:E54. doi:10.5888/pcd18.210026.
34. U.S. Surgeon General's Advisory: Marijuana Use and the Developing Brain. 2019. <https://www.hhs.gov/surgeongeneral/reports-and-publications/addiction-and-substance-misuse/advisory-on-marijuana-use-and-developing-brain/index.html>. Accessed September 14, 2021.